Universidad de Valladolid

ESCUELA DE INGENIERÍAS INDUSTRIALES

UNIVERSIDAD DE VALLADOLID

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Grado en Ingeniería Mecanica

Design of a windmill for a Romanian Countriside Home

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Valladolid, 11/2018.

TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

TÍTULO: Design of a windmill for a Romanian Countriside Home

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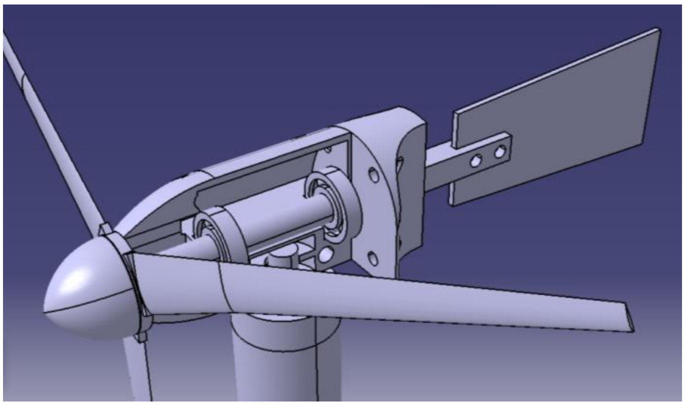

Design of a windmill for a romanian countryside home

ALVARO BARINAGA RODRIGUEZ

FINAL PROJECT DEGREE

MECHANICAL ENGINEER

2018

MAIN SUMMARY

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Rezumat

Principalul obieciv al acestui proiect este de a crea o mică turbină eoliană care să furnizeze suficientă electricitate pentru o familie. Proiectul este dezvoltat în România (Iași), mai precis pentru o zonă rurală a acestui județ unde locuiesc persoane în vârstă care au problemă cu alimentarea de energie electrică sau cu dezvoltarea acestui domeniu, oferind accesul persoanelor fără resurse la ceva atât de esențial precum energia electrică. Se pot găsi în această zonă probleme cu furnizarea de energie electrică, așa cum menționează și Uniunea Europeană într-un raport despre infrastructura acestei țări, asigurând că aceasta nu a intrat încă la nivelul mediu al Europei.

Vorbim aici despre o zonă foarte vântoasă care ne oferă posibilitatea să instalăm o mică turbină eoliană conectată în afara rețelei publice, care ar putea rezolva problemele de aprovizionare, permițându-ne astfel să dezvoltăm alte activități, sau în cazul de față să ne permină pur și simplu să trăim, acest lucru rezolvându-ne problema energiei electrice.

În zilele de astăzi, costul aceste turbine eoliene nu este foarte scump și fiecare familie și-ar putea permite una, după cum urmează să fie demostrat în acest proiect.

Pentru a asigura funcționalitatea și structura turbinei eoliene, a fost efectuată o analiză exhaustivă ANSYS a axei, structurii, scărilor și mecanismului turbinelor eoliene, asigurând că acestea pot rezista chiar și în celor mai grave condiții de vânt din Iași, urmărind datele din harta vântului furnizate în timp real de către Uniunea Europeană.

Toate modelele 3D ale acestei turbine eoliene, precum și desenele, au fost realizate cu ajutorul CATIA V5 R20, oferind posibilitatea ca în viitor să se poată îmbunătăți componente, materiale etc. În general, toată proiectarea ar putea fi îmbunătățită și chiar s-ar putea realiza un proiect mai rentabil pentru dezvoltarea societății.

După cum o să puteți vedea, în dezvoltarea proiectului se găsesc foarte multe probleme pentru care se vor căuta soluții prin alegerea a diverse materiale pentru fiecare parte a proiectului. În orice caz, se asigură măcar o durabilitate de aproximativ 18 ani.

La sfârșitul proiectului este prezentată o secțiune economică foarte importantă în zilele noastre și câteva concluzii care ar trebui luate în considerare.

Resumen

El principal objetivo de este proyecto es diseñar un pequeño aerogenerador que proporcione suficiente suministro eléctrico para una familia. El proyecto está desarrollado en Rumania (Iasi) concretamente para una zona de población rural dentro de esta provincia, donde se puede encontrar a personas de avanzada edad con problemas en el suministro eléctrico o para favorecer el desarrollo de esta zona, dando acceso a personas sin recursos a algo tan básico como la electricidad. Incluso se puede encontrar en esta zona problemas con el suministro eléctrico, así lo asegura la unión europea, en un informe sobre las infraestructuras de este país, en el que asegura que no ha entrado aun en el nivel de la media Europa.

Nos encontramos en una zona con mucho viento para instalar un pequeño aerogenerador conectado fuera de la red pública, que nos pueda solventar los problemas de suministro para poder desarrollar otras actividades, o en este caso vivir, lo cual nos haría resolver el problema energético.

Hoy en día el coste de este aerogenerador no es muy caro y podría ser asumido por cualquier familia, como se demostrará en este proyecto.

Para asegurarnos el funcionamiento y la estructura del aerogenerador, se ha realizado un exhaustivo análisis con ANSYS del eje, estructura, escaleras, y mecanismo del aerogenerador, asegurando que pueden resistir incluso en las peores condiciones de viento en Iasi, siguiendo datos del mapa de viento que proporciona en tiempo real la Unión Europea.
Todo el modelo 3D de este aerogenerador así como los planos se ha realizado con CATIA V5 R20 dando la posibilidad, para que en el futuro se puedan mejorar componentes, materiales, en general el diseño, y incluso hacer un proyecto más rentable para el desarrollo de la sociedad.

Como se podrá ver en el desarrollo del trabajo se encuentran multitud de problemas que se intentan solucionar eligiendo diversos materiales para cada parte del proyecto.En cualquier caso se asegura al menos una vida estimada de 18 años.

Al final del proyecto se presenta un apartado económico muy importante hoy en dia, y unas conclusiones a tomar en cuenta.

Summary

The main objective of this project is to design a small wind turbine that provides enough electricity for a family. The project is developed in Romania (Iasi) specifically for an area of rural population within this province, where you can find elderly people with problems in the electricity supply or to promote the development of this area, giving access to people without resources to something as basic as electricity. You can even find in this area problems with the electricity supply, as the European Union says, in a report on the infrastructure of this country, which ensures that it has not yet entered the level of the average Europe.

We are in a windy area to install a small wind turbine connected outside the public network, which can solve the problems of supply to develop other activities, or in this case live, which would solve the energy problem.

Nowadays the cost of this wind turbine is not very expensive and could be assumed by any family, as will be demonstrated in this project.

To ensure the operation and structure of the wind turbine, an exhaustive analysis has been made with ANSYS of the axis, structure, stairs, and mechanism of the wind turbine, ensuring that they can withstand even the worst wind conditions in Iasi, following wind map data provided in real time by the European Union.

All the 3D model of this wind turbine as well as the drawings has been made with CATIA V5 R20 giving the possibility, so that in the future components, materials, in general the design can be improved, and even make a more profitable project for the development of the society.

As you can see in the development of the work are many problems that are trying to solve by choosing various materials for each part of the project. In any case it ensures at least an estimated life of 18 years.

At the end of the project a very important economic section nowadays is presented, and some conclusions to be taken into account.

1.-Introduction

1.1.- Abstract

The world is running out of conventional energy sources and there is a pressing need of utilizing non-traditional energy sources to endure the ever escalating energy needs. Wind turbines provide an alternative way of generating energy from the power of wind. At windy places, wind speeds can achieve scintillating values of 10-12 m/s. Such high speeds of wind can be utilized to harness energy by installing a wind turbine usually having 3 blades. The geometry of the blades is made as such that it generates lift from the wind and thus rotates. The lift force generates a moment around the hub and thus the combined torque effort of 3 blades rotates the turbine and generates electricity.

1.2.-Motivation

The main objective of the project is to design a small wind generator, which mission will be to supply electricity to a home that is of grid connected, knowing the energy that is needed and estimating if the turbine is competitive economical and energetically speaking.

The region studied in Romania.Is characterized for constant and strong wind during all the year and due to most of the population is distributed in houses in the countryside along the region an ideal solution is an off-grid system that could assure a minimum of energy each day. Due to the economical problema that most the population lives in this country.

As Europe development is a must to invest this kind of new energy forms,to be self-sufficient and be able to pose challenges for the future, especially today with problems and competition with nations such as Russia and China and the number of emerging countries.

The main obt¡jectives of the project are:

- Determinate if it is interesting for a family use a small wind power system to provide themselves of energy
- Once it can be assured that it is possible and interesting, economical and physically speaking it will be designed a small wind system that will supply energy a family.
- At the last part of the work there is an exhausted economical study in order to give and exact price for the wind system.

2.-Wind energy among renovable energies

Wind was the largest destination for power sector investments in 2016. Most of this investment represents financing for greenfield assets. This suggests that wind energy is seen as a major driver to exit from fossil fuels. Cost competitiveness and reduced risk perceptions have brought in market players who are looking to diversify their oil and gas portfolios.

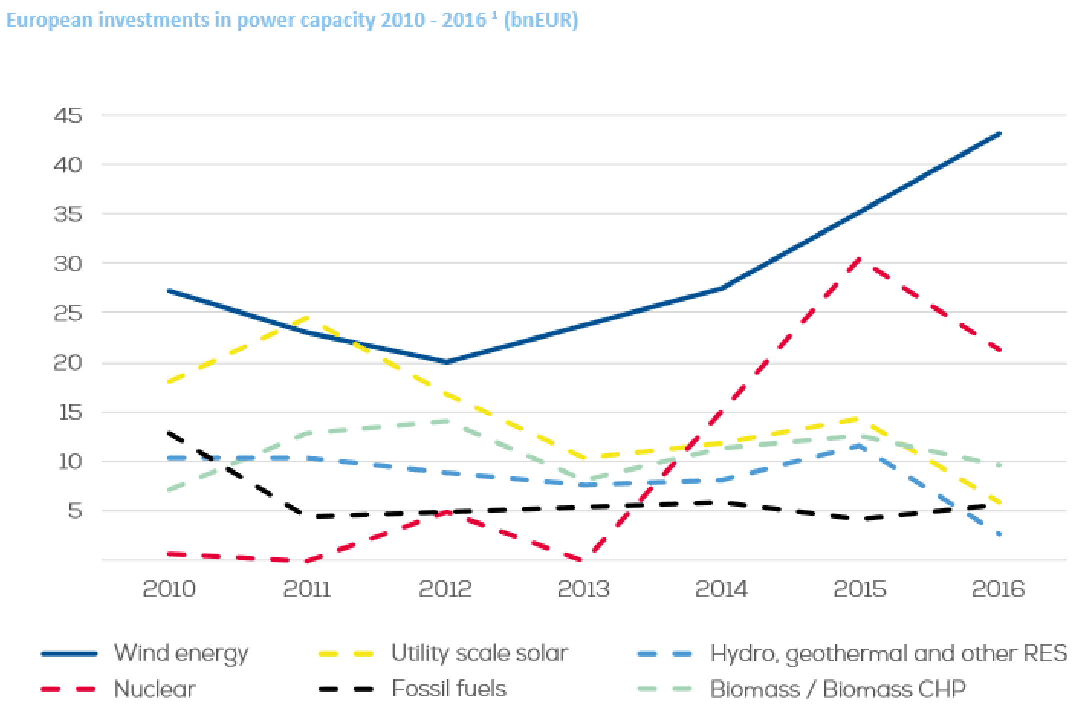


Figure .2.1.-European investments 2010-2016[1]

2.1.-Invesments in wind power

In the past Europe we can see that was a great deal to invest in wind energy specially countries like Spain and Germany did it.

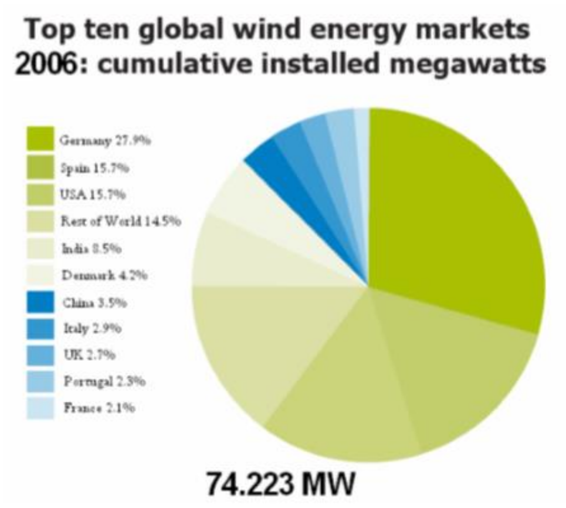


Figure .2.2.- Top ten global wind energy markets[1]

The deployment of wind energy in Europe is a remarkable industrial success for Europe. Between 2006 and 2016, 106 GW of power capacity were installed, supporting 262,000 jobs. In the same period the US installed 71 GW, China 156 GW and the rest of the world 80 GW. 31% of the global installed capacity is in Europe and 46% was manufactured by European companies.

Onshore wind energy is today the cheapest source of new power capacity in many places in Europe. Offshore, auction prices over the last year have exceeded the industry's selfimposed cost reduction targets of €100/MWh with projects delivering bids significantly below that level.

So wind energy could become the leading element of the power system with sustained progress on system integration and the acceleration of electrification. In 2016 wind energy overtook coal in terms of installed capacity, and for the sixth consecutive year wind energy topped investments in new power capacity.

However, the development of wind energy in Europe is more uncertain in the decade after 2020 than it was in the 10 years after it took off from being a niche technology.

European Commission President JeanClaude Juncker committed in his July 2014 inaugural speech to the European Parliament to making Europe the world's number one in renewables. However, Europe is dealing with increasingly intense competition from mature and emerging markets. This trend was highlighted in the run up to the 2015 Paris Agreement, when more than 70 countries mentioned wind energy in their Intended Nationally Determined Contributions (INDC) as a key mitigation measure against climate change.

In the next 12 to 15 months, EU Member States and the European Parliament are expected to adopt the Clean Energy for All Europeans legislative package which will in large part determine the future of renewables in the decade after 2020. With this report WindEurope informs this process by providing updated potential deployment scenarios for wind energy to 2030. The report also highlights the role of wind in delivering the energy transition in Europe, in securing Europe's leadership in renewables and its role in supporting Europe's wider social and economic development.

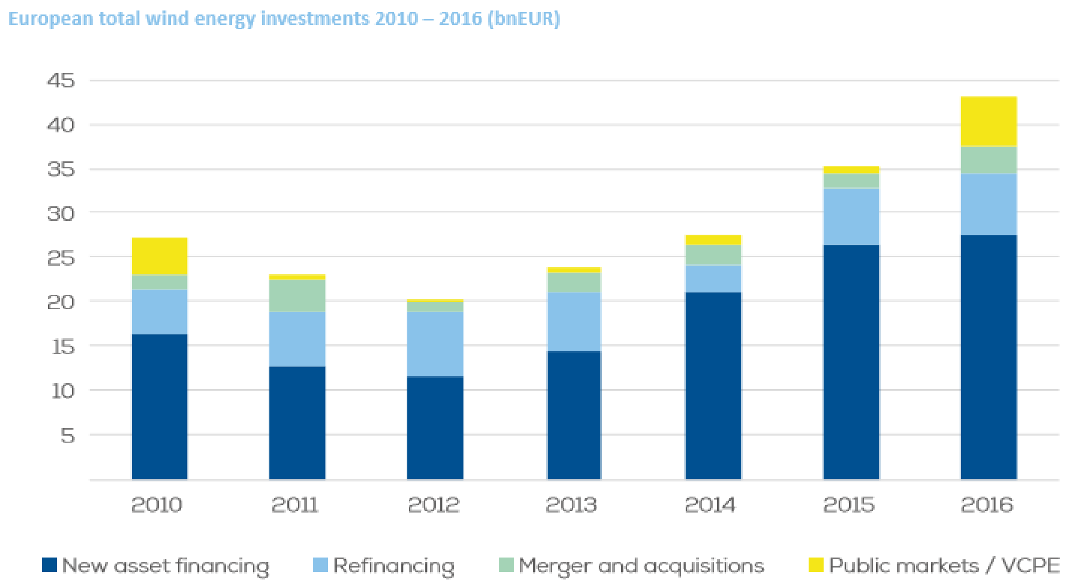


Figure .2.3.-European total wind investments[1]

Europe invested a total of €43bn in the wind power sector during 2016. This includes investments in new assets, refinancing transactions, mergers and acquisition activity for wind power projects, public market transactions, venture capital and private equity raised.

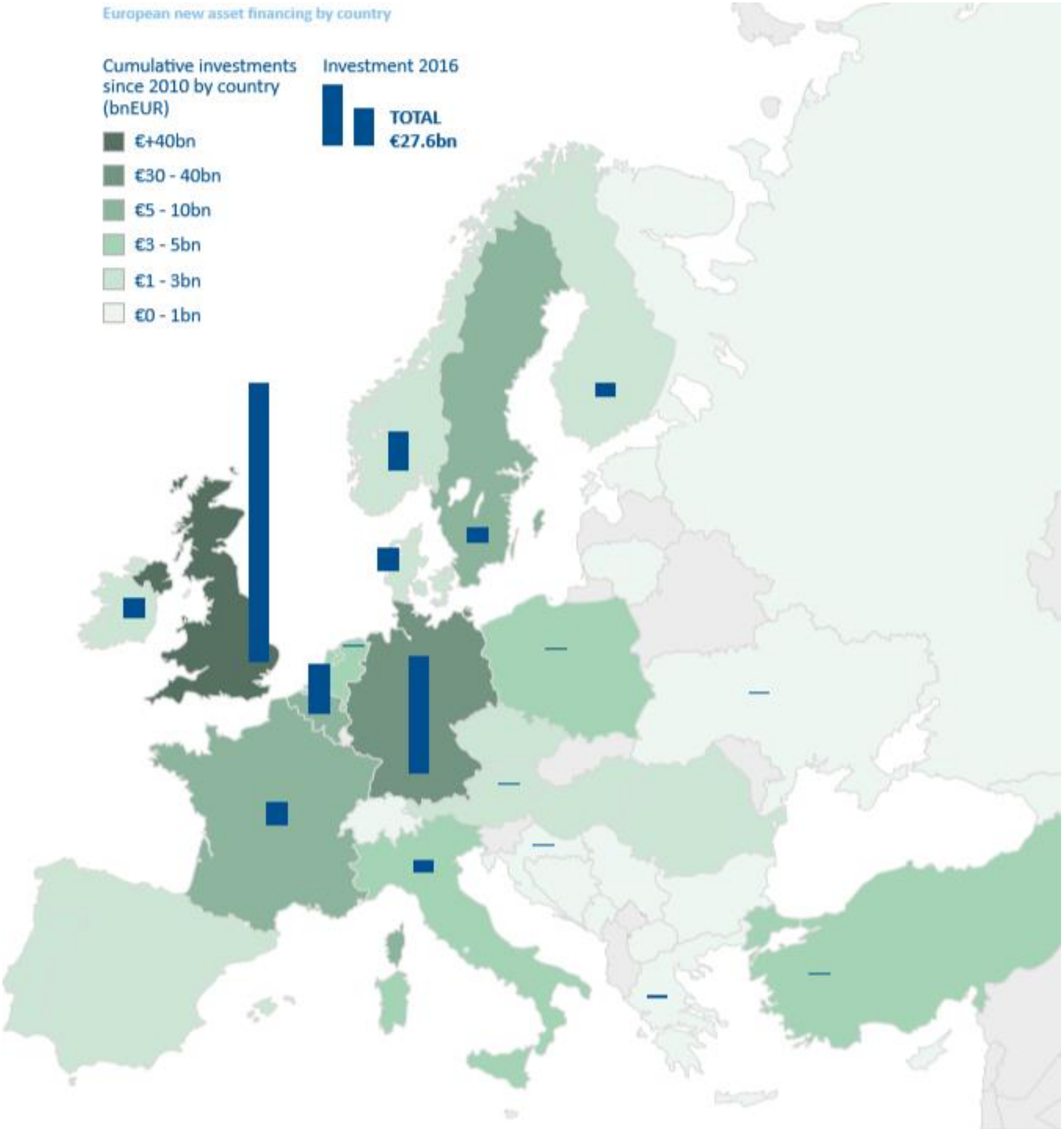


Figure .2.4.- Cumulative investments. [1]

European new asset financing by country

EU-28 (MW)	INVEST-MENT 2015 (€bn)	NEW CAPACITY FINANCED 2015 (MW)	INVEST-MENT 2016 (€bn)	NEW CAPACITY FINANCED 2016 (MW)
Austria	0.49	272	0.11	-
Belgium	0.92	297	2.3	688
Bulgaria	-	-	-	-
Croatia	-	-	0.06	44
Cyprus	0.03	10	-	-
Czech Republic	-		-	
Denmark	0.2	76	1.08	445
Estonia	-	-	-	-
Finland	0.95	501	0.66	363
France	1.36	600	1.07	583
Germany	5.32	1,735	5.33	1,790
Greece	0.08	40	0.15	73
Hungary	-	-	-	-
Ireland	0.52	280	0.89	520
Italy	0.92	504	0.54	327
Latvia	-	-	-	-
Lithuania	0.12	60	-	-
Luxembourg	-		-	
Malta	-		-	
Netherlands	0.11	62	0.07	22
Poland	0.65	355	0.1	56
Portugal	0.16	67	-	
Romania	-	-	-	-
Slovakia	-	-	-	-
Slovenia	-	-	-	-
Spain	0.01	5	-	-
Sweden	0.56	276	0.68	415
UK	12.64	3,800	12.68	3,535
TOTAL EU-28	25.04	8940	25.72	8861

CANDIDATE COUNTRIES (MW)	INVEST-MENT 2015 (€bn)	NEW CAPACITY FINANCED 2015 (MW)	INVEST-MENT 2016 (€bn)	NEW CAPACITY FINANCED 2016 (MW)
Bosnia	0.07	48	-	-
FYROM	-	-	-	-
Montenegro	0.15	72	-	-
Serbia	0.25	129	-	
Turkey	0.82	418	0.09	50
TOTAL	1.29	667	0.09	50

EFTA (MW)	INVEST-MENT 2015 (€bn)	NEW CAPACITY FINANCED 2015 (MW)	INVEST-MENT 2016 (€bn)	NEW CAPACITY FINANCED 2016 (MW)
Iceland	-		-	
Liechtenstein	-		-	
Norway	-		1.77	1,436
Switzerland	0.05	24	-	
TOTAL	0.05	24	1.77	1436

OTHER (MW)	INVEST-MENT 2015 (€bn)	NEW CAPACITY FINANCED 2015 (MW)	INVEST-MENT 2016 (€bn)	NEW CAPACITY FINANCED 2016 (MW)
Belarus	-	-	-	
Faroe Islands	-	-	-	
Russia	-	-	-	-
Ukraine	-	-	0.05	41
TOTAL	0	0	0.05	41

	INVEST-MENT 2015 (€bn)	NEW CAPACITY FINANCED 2015 (MW)	INVEST-MENT 2016 (€bn)	NEW CAPACITY FINANCED 2016 (MW)
TOTAL EUROPE	26.38	9,631	27.63	10,388

Source: WindEurope

Table .2.1.-Eurpean new assents[1]

Wind energy markets in 2016 were very concentrated in Northern and Western Europeand were driven mainly by offshore wind.

Investments in Southern and Eastern Europe (SEE) remain very low. Regulatory concerns and macroeconomic stability have reduced investments in some of the SEE markets over the last years.

For the second consecutive year, the UK saw the highest level of funding for new projects. In total, €12.7bn were raised for the construction of new onshore and offshore wind farms. This accounts for 46% of new assets financed in Europe.

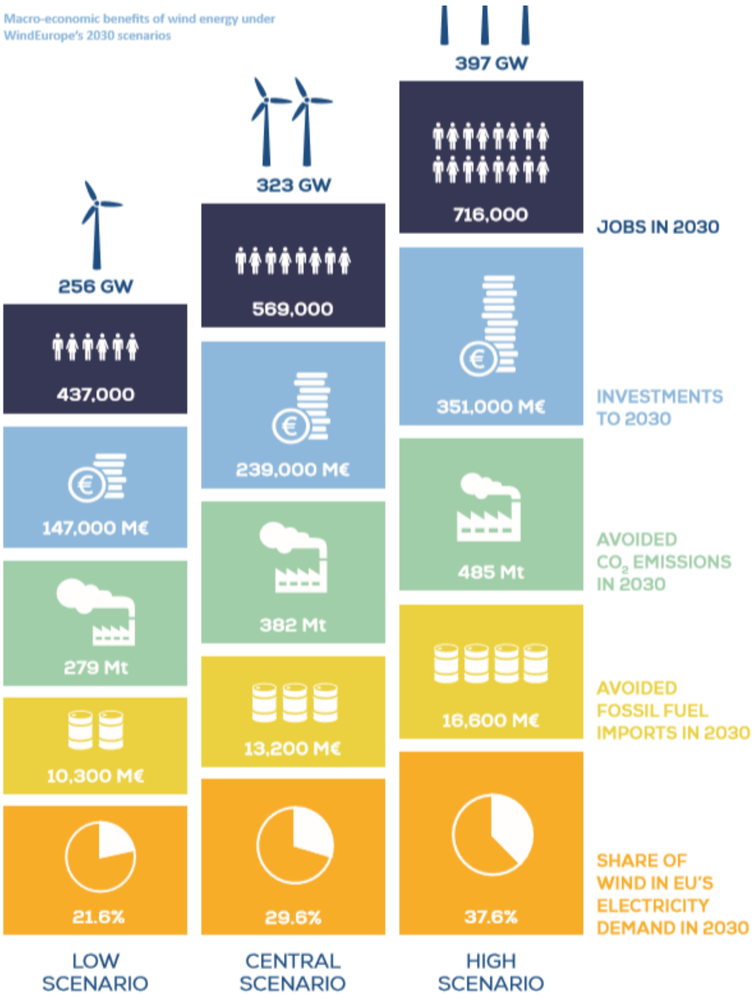
Germany represented the second biggest market in 2016: the €5.3bn raised accounted for 19% of new assets financed in Europe.

Two landmark projects reached FID in 2016. The largest offshore wind farm to date, Hornsea 1, adds 1.2 GW of new capacity to projects awaiting construction in the UK.

2.2.-Plans for 2030 in Europe

Policy recommendations

The EU should raise its 2030 renewable energy target to at least 35% of final energy demand by 2030 with a clear breakdown per Member State
Member States should adopt early National Energy and Climate Action Plans based on a binding template providing clarity to investors on the post2020 market volumes including repowering
The post2020 Renewable Energy Directive should mandate Member States to set a schedule for renewable energy support providing investors at least three years of visibility
The post2020 Renewable Energy Directive should set clear design rules for renewable energy support mechanisms, including technology specific tenders, to manage the energy transition
Market design rules should maintain priority dispatch for existing wind power plants and ensure new wind plants are dispatched down last and properly compensated in that occurrence
Member States should stop capacity payments to polluting power plants through the adoption of an Emissions Perfor mance Standard of 550 g CO2/kWh
EU rules on Guarantees of Origin should facilitate corporate renewable PPAs and drive renewables based electrification



Figre .2.5.-Macro economic benefits[2]

2.3.-DESCRIPTION OF THE 2030 WIND ENERGY CAPACITY SCENARIOS

2.3.1.-Central Scenario

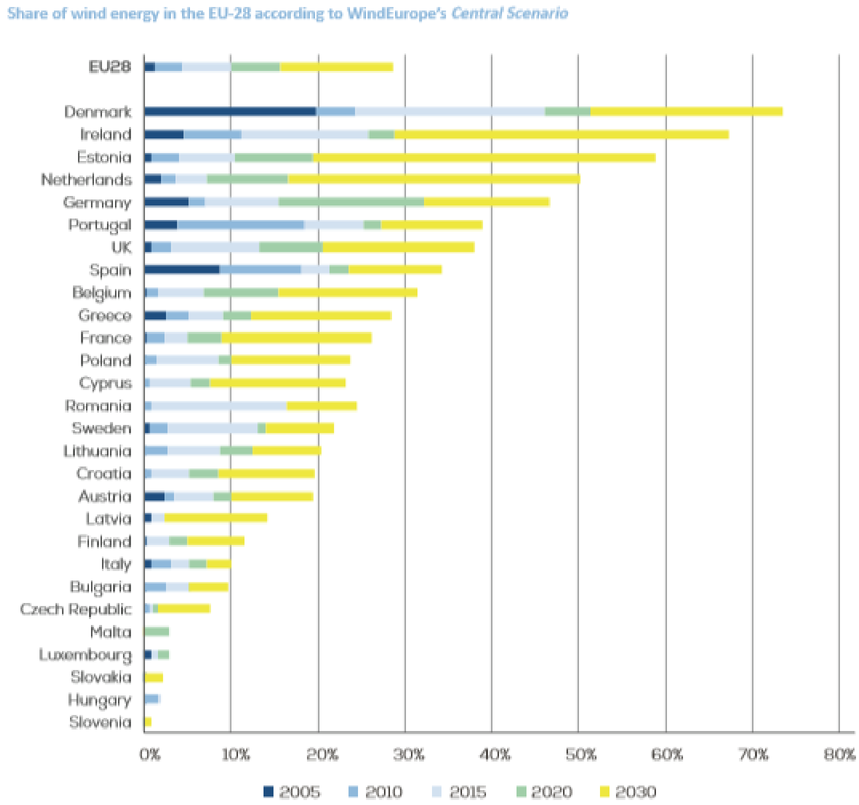


Figure .2.6.- Share of wind energy[2]

In the Central Scenario , the EU would be able to power 10ateo f10 30% of its electricity. Denmark would remain the country with the highest share of wind energy in its power mix followed by Ireland and Estonia. Germany, the UK, Spain and France would power respectively 47%, 38%, 34% and 26% of their electricity demand with wind energy.

In WindEurope's Central Scenario , a clear 2030 governance structure with reporting mechanisms on Member States' progress to 2030 is implemented, and effective regional cooperation mechanisms are established. Member States implement detailed National Energy and Climate Plans in line with the EU's binding targets. The Re newable Energy Directive is implemented as proposed by the European Commission, and national policies for wind energy are streamlined, including repowering. As a result, the EU achieves a 27% renewable energy target

2.3.2.-Low Scenario

No binding templates are agreed for National Energy and Climate Plans leading to weak governance, a challenging implementation of the post2020 Renewable Energy Directive and failure to deliver the EUwide 27% renewable energy target.

Persistent overcapacity continues to 2030. The new market design is 10ateo f10 to guarantee increased renewable energy penetration, and system costs are therefore not reduced.

No significant progress is made in electricity interconnections between Member States. Grid congestion issues continue to slow down new installations. The offshore wind energy pipeline of projects is below 4 GW/year, and cost reductions do not materialise.

Unfavourable national policies for permitting and planning in highpotential markets persist, resulting in the slowdown of new and repowered installations.

2.3.3.-High Scenario

The EUwide RES target for 2030 is increased to 35%. Binding templates for National Energy and Climate Plans are adopted, leading to an efficient governance system and full implementation of the recast Renewable Energy Directive.

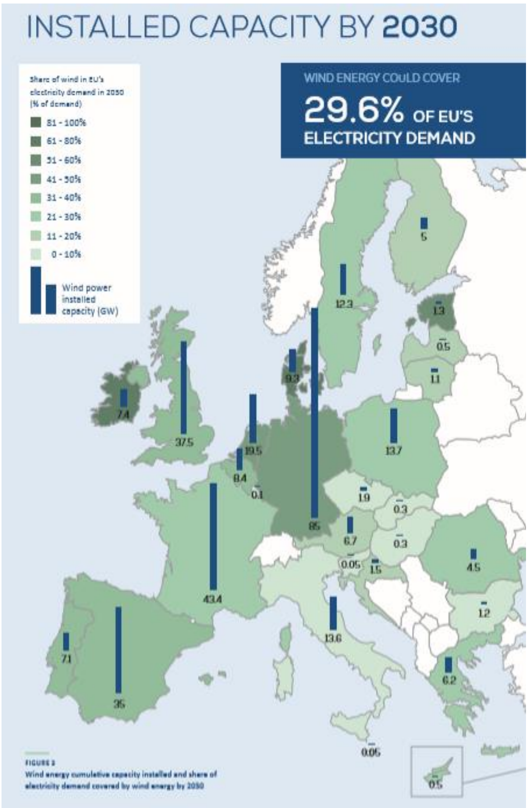
The EUwide power transmission network is further developed beyond the European Commission's 15% target.

Both the new market design and a reformed ETS contribute to the phasing out of inefficient and uneconomical fossil fuels power plants and pave the way for a sustained development of renewable energy.

With a deployment 11ateo f 7 GW/year, the offshore wind industry becomes fully competitive with new fossil fuel generation.

Favourable national policies for permitting and planning are in place, resulting in the acceleration of new and repowered installations.

Europe accelerates electrification of heating, cooling and transport, bolstering demand for renewable power



Onshore wind power cumulative capacity to 2030

	LOW	CENTRAL	HIGH
Germany	60,000	70,000	71,000
France	31,320	36,360	41,400
Spain	30,000	35,000	40,000
United Kingdom	13,000	15,000	20,000
Italy	10,700	13,600	16,700
Sweden	9,000	12,000	13,000
Poland	7,000	10,500	12,000
Netherlands	8,000	8,000	15,000
Portugal	6,750	7,000	7,250
Austria	5,000	6,700	8,000
Greece	3,400	6,200	7,000
Ireland	5,000	5,600	6,700
Denmark	3,650	5,000	6,500
Finland	3,000	5,000	10,000
Romania	3,025	4,500	6,000
Belgium	3,400	4,400	4,400
Bulgaria	691	1,200	3,000
Lithuania	750	1,100	1,500
Czech Republic	1,450	1,900	2,450
Estonia	600	744	1,000
Cyprus	158	483	600
Hungary	300	300	1,500
Luxembourg	100	100	200
Malta	50	50	100
Slovenia	3	50	100
Slovakia	3	300	500
Croatia	500	1,500	2,000
Latvia	63	500	648
TOTAL EU-28	206,913	253,087	298,548
Switzerland	300	600	1,200
Turkey	16,000	24,000	28,000
Norway	4,000	10,000	11,000
TOTAL EUROPE	227,213	287,687	337,748

Figure 2.7.-Installed capacity[2]

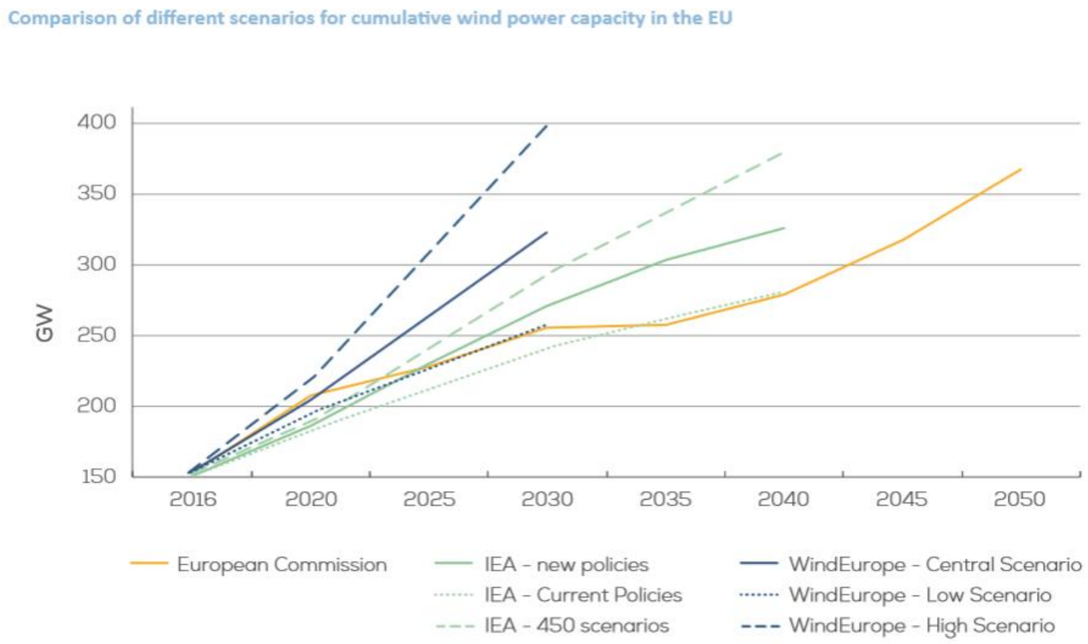


Figure 2.8.- GW politics[2]

2.4.-MACROECONOMIC AND SOCIAL IMPACTS OF THE SCENARIOS

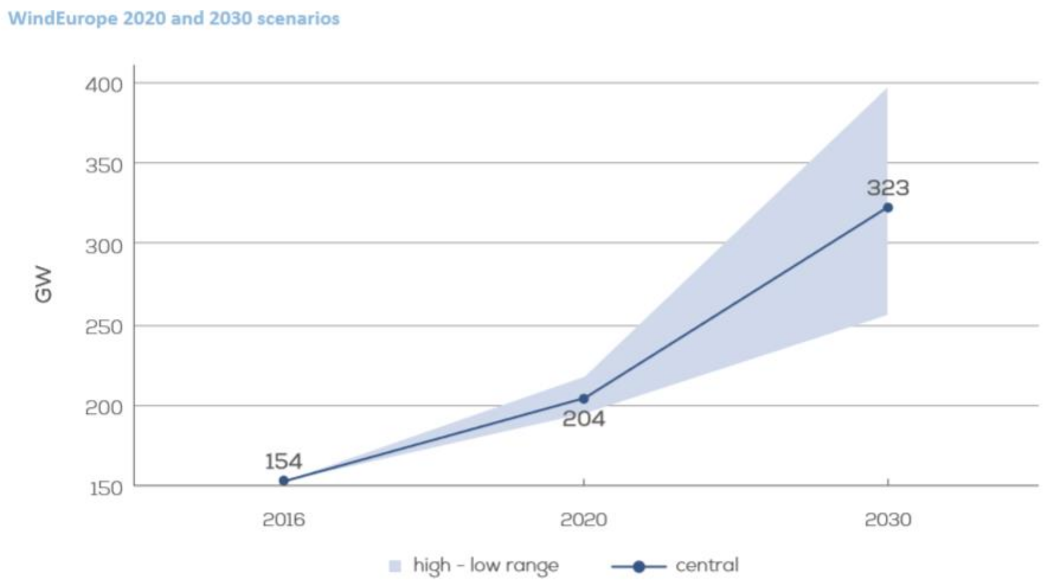


Figure 2.9..-Windeurope 2020-2030[2]

WindEurope's Central Scenario of 323 GW would generate investment of €263 bn by 2030. The industry could provide 569,000 jobs by 2030. The increase in jobs assumes that the EU supply chain remains competitive thanks to a robust market a doubling of onshore wind capacity and a fivefold increase in offshore wind capacity and to sustained European leadership in Research and Innovation. Wind energy would save 382 million tCO2 emissions and €13 bn in fossil fuel imports to the EU in 2030.

The Low Scenario has 20% less capacity than the Cen tral Scenario in 2030. As a consequence, the amount of investment would be reduced to €147 bn. The industry would generate 132,000 fewer jobs and would save 103 million tCO2 less than in the Central Scenario . Likewise, there would be a drop of 22% in savings on the imports of fossil fuels to the EU.

However, the realisation of the High Scenario would mean 23% more wind power capacity in 2030, which would yield 47% more investments, amounting to €351 bn. The industry would be able to create 147,000 more jobs for a total of 716,000. Wind energy would save 103 million tCO2 more than in the Central Scenario for a total of 485 million tCO2. Finally, it would avoid 26% more fossil fuel imports for a total of €17 bn.

	LOW SCENARIO	CENTRAL SCENARIO	HIGH SCENARIO
Installed capacity [GW]	256	323	397
Investments [M€]	147,000	239,000	351,000
Jobs	437,000	569,000	716,000
CO_2 emissions savings [$MtCO_2$]	279	382	485
Avoided fossil fuel imports [M€]	10,300	13,200	16,600

Table 2.2.-Possible scenarios[2]

2.5.-Developments

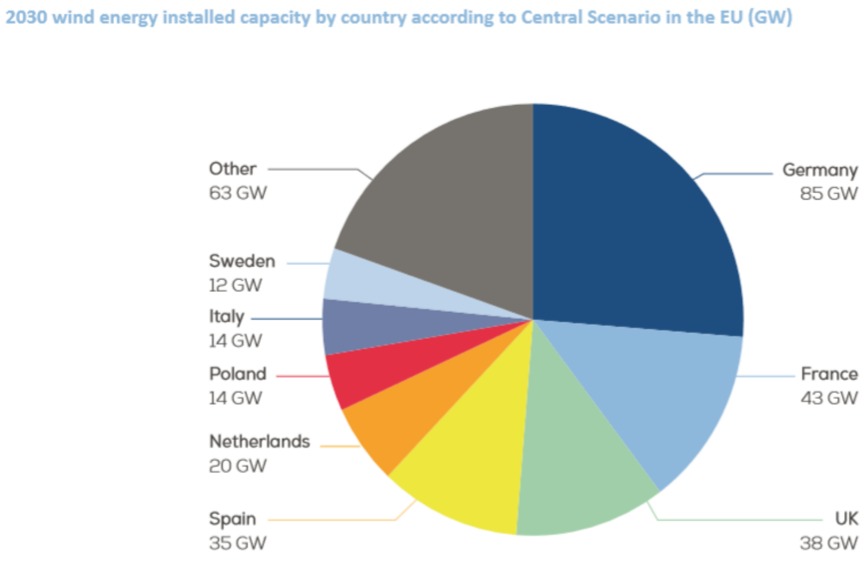


Figure 2.10.- Countries situation[2]

With 85 GW and more than a quarter of Europe's cumulative capacity, Germany would be the country with the largest wind energy fleet in the Central Scenario . France would follow with 43 GW, close to half of the German installations. The UK would be the third country in wind installations with 37.5 GW, 60% of which would be offshore. These three countries would account for more than half of the EU's total installations. Outside of the EU, Turkey (28 GW) and Norway (11 GW) would also constitute significant wind energy fleets.
Central And Eastern Europe, which is composed by all the countries that joined the European Union after 2004, would represent a small proportion of the European installed capacity with 27 GW isntalled. This corresponds to only slightly more than half of the total installed capacity in Germany at the end of 2016.

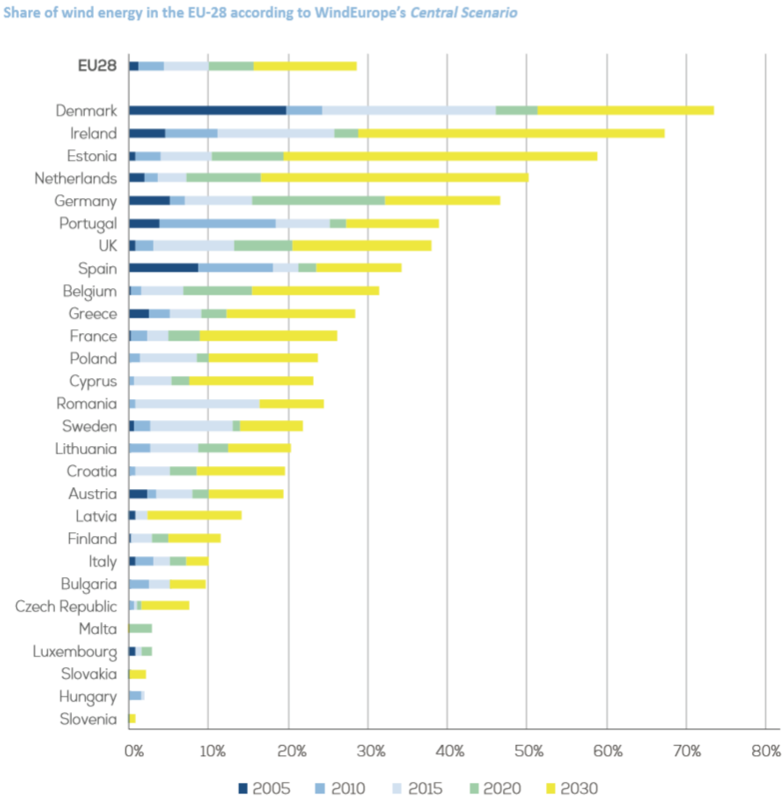


Figure 2.11.Countries develpment[2]

In the Central Scenario , the EU would be able to power close to 30% of its electricity. Denmark would remain the country with the highest share of wind energy in its power mix followed by Ireland and Estonia. Germany, the UK, Spain and France would power respectively 47%, 38%, 34% and 26% of their electricity demand with wind energy.

2.6.-Repoweting potential to 2030

Considering a lifetime between 20 and 25 years, 40 to 80 GW of the installed onshore wind capacity in the EU could reach endof life by 2030. The potential annual repowering volumes should grow significantly to reach the 47 GW/year range by 2025. This volume represents more than half of the annual onshore market, but will be highly dependent on the implementation of fasttrack administrative procedures and Member States properly factoring repowering volumes as part of the National Energy and Climate Action Plans.

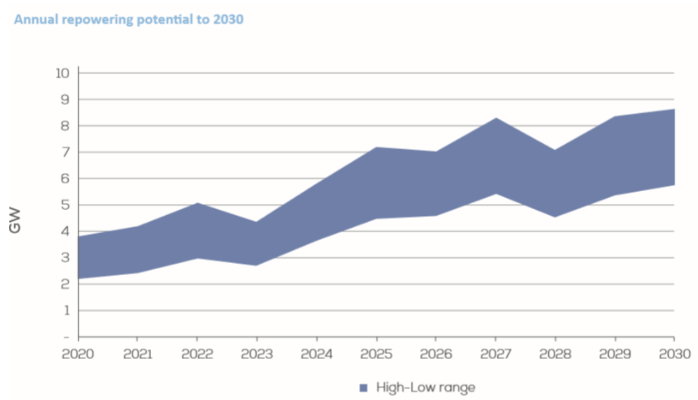


Figure 2.12.Potencial in 2030[2]

3.-Physical principles

3.1.-Wind generation

Wind is an atmospheric phenomenon due to the heating of the sun. The sun radiates on the Earth a power of 1.74 x 1017 Watts: about 2% of it is converted into wind energy. The Earth releases the heat received from the Sun, but this is hardly homogeneous. In those areas where less heat is released, the pressure of atmospheric gases increases, while in those areas where more heat is released, the air becomes hot and the gas pressure is reduced. As a consequence, high-pressure areas and low-pressure areas are formed, which are also influenced by the Earth's rotation. When different masses of air get in contact, the area with a higher pressure tends to transfer air towards the area with lower pressure. Therefore wind is a more or less rapid air transfer between different pressure areas. The higher is the pressure difference, the faster is the air displacement and the stronger is the wind.

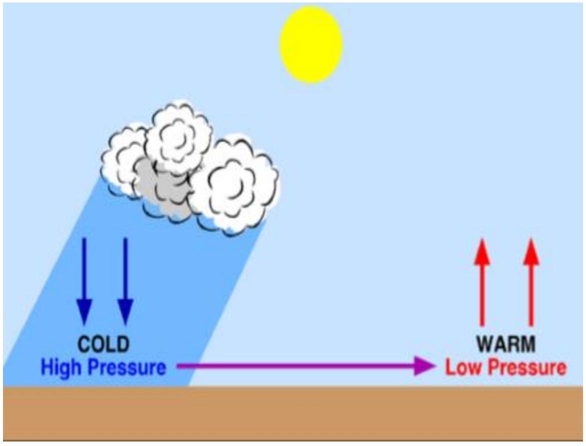


Figure 3.1 Wind generation[3]

3.2.-Sea and land breezes

In coastal regions, sea breezes and land breezes can be important factors in a location's prevailing winds. The sea is warmed by the sun more slowly because of water's greater specific heat compared 15ill1515a. As the 15ill1515atura of the 15ill1515a of the land rises, the land heats the air above it by conduction. The warm air is less dense than the surrounding environment and so 15ill1515at. This causes a pressure gradient of about 2 millibars from the ocean to the land. The cooler air above the sea, now with higher sea level pressure, flows inland into the lower pressure, creating a cooler breeze near the coast. When large-scale winds are calm, the strength of the sea breeze is directly proportional to the 15ill1515atura difference between the land mass and the sea. 15ill15 offshore wind of 8 knots (15 km/h) exists, the sea breeze is not likely to develop.

At night, the land cools off more quickly than the ocean because of differences in their specific heat values. This 15ill1515atura change causes the daytime sea breeze to dissipate. When the 15ill1515atura onshore cools below the 15ill1515atura offshore, the pressure over the 15ill15 15ill be lower than that of the land, establishing a land breeze, as long as an onshore wind is not strong enough to oppose it.

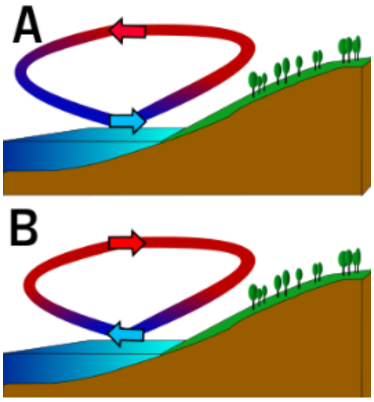


Figure 3.2.-sea and land frezees[3]

3.3.-Near mountains

Over elevated surfaces, heating of the ground exceeds the heating of the surrounding air at the same altitude above sea level, creating an associated thermal low over the terrain and enhancing any thermal lows that would have otherwise existed, and changing the wind circulation of the region. In areas where there is rugged topography that significantly interrupts the environmental wind flow, the wind circulation between mountains and valleys is the most important contributor to the prevailing winds. Hills and valleys substantially distort the airflow by increasing friction between the atmosphere and landmass by acting as a physical block to the flow, deflecting the wind parallel to the range just upstream of the topography, which is known as a barrier jet. This barrier jet can increase the low level wind by 45%. Wind direction also changes because of the contour of the land.

If there is a pass in the mountain range, winds will rush through the pass with considerable speed because of the Bernoulli principle that describes an inverse relationship between speed and pressure. The airflow can remain turbulent and erratic for some distance downwind into the flatter countryside. These conditions are dangerous to ascending and descending airplanes. Cool winds accelerating through mountain gaps have been given regional names. When these winds blow over open waters, they increase mixing of the upper layers of the ocean that elevates cool, nutrient rich waters to the surface, which leads to increased marine life.

In mountainous areas, local distortion of the airflow becomes severe. Jagged terrain combines to produce unpredictable flow patterns and turbulence, such as rotors, which can be topped by lenticular clouds. Strong updrafts, downdrafts and eddies develop as the air flows over hills and down valleys. Orographic precipitation occurs on the windward side of mountains and is caused by the rising air motion of a large-scale flow of moist air across the mountain ridge, also known as upslope flow, resulting in adiabatic cooling and condensation. In mountainous parts of the world subjected to relatively consistent winds (for example, the trade winds), a more moist climate usually prevails on the windward side of a mountain than on the leeward or downwind side. Moisture is removed by orographic lift, leaving drier air on the descending and generally warming, leeward side where a rain shadow is observed. Winds that flow over mountains down into lower elevations are known as downslope winds. These winds are warm and dry.

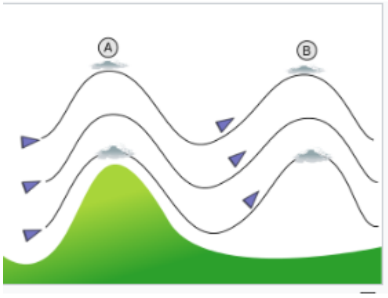


Figure 3.3.-Wind near mountains[3]

3.4.-Venturi effect

The Venturi effect consists of a phenomenon in which a moving fluid inside a closed conduit decreases its pressure when the velocidadal increases passing through a zone of smaller section. Under certain conditions, when the speed increase is very large, negative pressures are produced and then, if at this point of the duct the end of another duct is introduced, an aspiration of the fluid from this duct takes place, which will be mixed with the one that circulates through the first conduit.

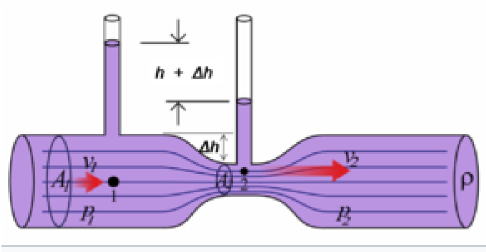


Figure 3.4.-Venturi effect[4]

The Venturi effect is explained by the Bernoulli Principle and the principle of mass continuity. If the flow of a fluid is constant but the section decreases, the velocity necessarily increases after crossing this section. By the theorem of the conservation of mechanical energy, if the kinetic energy increases, the energy determined by the value of the pressure decreases forcibly.

3.5.-Coandă effect

The Coandă effect is the tendency of a fluidjet to stay attached to a convex surface. As described by the eponymous Henri Coandă in different patents: "the tendency of a jet of fluid emerging from an orifice to follow an adjacent flat or curved surface and to entrain fluid from the surroundings so that a region of lower pressure develops." The pressure effect, which is usually not indicated, is fundamental for the comprehension of the Coandă effect.

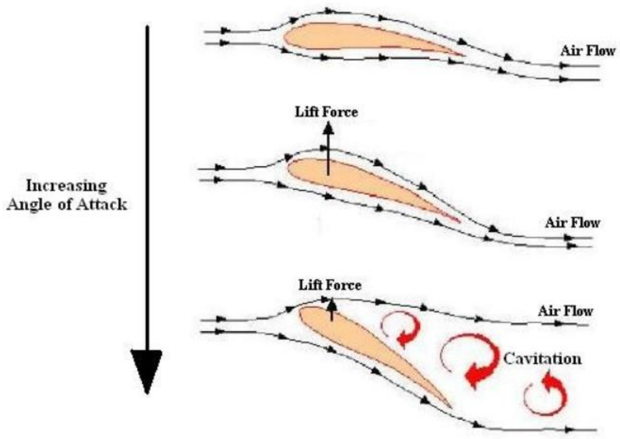


Figure 3.5.-Coanda effect[4]

3.6.-boundary layer

In fluid mechanics, the boundary layer or border layer of a fluid in the area where the movement of this is disturbed by the presence of a solid with which it is in contact. The boundary layer is understood as one in which the velocity of the fluid approaches the movement in motion from zero to 99% of the speed of the undisturbed current.1

The limit capacity can be laminar or turbulent; although areas of laminar flow and turbulent flow can also coexist in it. Sometimes it is useful for the turbulent sea boundary layer. In aeronautics applied to commercial aviation, it is usually decided to have profiles that generate a capacity of turbulence, which remains adhered to the profile of an adult that can not be lost, that is, to stop generating aerodynamic sustainability in a sudden manner due to detachment of the boundary layer.

The thickness of the boundary layer in the area of the edge of attack or arrival is small, but increases along the surface. All these characteristics are modified depending on the shape of the object (lower resistance to the lower aerodynamic resistance capacity present on the surface: eg fusiform shape of a wing profile)

3.6.1.-Laminar Boundary Layer Flow

The laminar boundary is a very smooth flow, while the turbulent boundary layer contains swirls or "eddies." The laminar flow creates less skin friction drag than the turbulent flow, but is less stable. Boundary layer flow over a wing surface begins as a smooth laminar flow. As the flow continues back from the leading edge, the laminar boundary layer increases in thickness.

3.6.2.-Turbulent Boundary Layer Flow

At some distance back from the leading edge, the smooth laminar flow breaks down and transitions to a turbulent flow. From a drag standpoint, it is advisable to have the transition from laminar to turbulent flow as far aft on the wing as possible, or have a large amount of the wing surface within the laminar portion of the boundary layer. The low energy laminar flow, however, tends to break down more suddenly than the turbulent layer.

4.- Types of Wind Turbines

Wind energy conversion systems are designed to convert the energy of wind movement into mechanical power, that is the movement of a machine. In wind turbine generators, this mechanical energy is converted into electricity and in windmills this energy can be stored in batteries, or used directly.

Wind turbines are classified into two general types: horizontal axis and vertical axis. A horizontal axis machine has its blades rotating on an axis parallel to the ground. A vertical axis machine has its blades rotating on an axis perpendicular to the ground.

4.1.-Horizontal Axis

This is the most common wind turbine design. In addition to being parallel to the ground, the axis of blade rotation is parallel to the wind flow. Some machines are designed to operate in an upwind mode, with the blades upwind of the tower. In this case, a tail vane is usually used to keep the blades facing into the wind. Other designs operate in a downwind mode so that the wind passes the tower before striking the blades. Without a tail vane, the machine rotor naturally tracks the wind in a downwind mode. Some very large wind turbines use a motor-driven mechanism that turns the machine in response to a wind direction sensor mounted on the tower

4.1.1.-Windmills

They are designed to operate at lower wind speeds than wind turbines for electricity generation. Windmills, 'store' the energy they produce in water tanks so that water is available for feeding livestock, or irrigation in times where there is no wind. These windmill water pumping designs have also been used to provide electricity for rural electrification by using a battery system and low voltage systems. Today the more modern and efficient triple bladed rotor is commonly used in such stand-alone power systems

Figure 4.1.-Homemade windmill[6]

4.1.2.-Small wind turbines

Small wind energy systems, can be used in connection with electricity transmissions and distribution systems (called grid-connected systems), or in stand-alone applications that are not connected to the utility grid. A grid-connected wind turbine can reduce consumption of utility-supplied electricity for lighting, appliances, and electric heat. When the wind system produces more electricity than the household requires, the excess can be sold to the utility. With the inter-connections available today, switching takes place automatically.

Stand-alone wind energy systems can be appropriate for homes, farms, or even entire communities (a co-housing project, for example) that are far from the nearest utility lines. Either type of system can be practical if the following conditions exist.

Small wind generator sets for household electricity supply or water pumping represent the most interesting wind-energy applications in remote areas. Wind turbines for domestic or rural applications range in size from a few watts to thousands of watts and can be applied economically for a variety of power demands. In areas with adequate wind regimes (more than five meters per second annual average), simple wind generators with an output range of 100 to 500 W can be used to charge batteries and thus supply enough power to meet basic electricity needs. In the past reliability of small wind turbines was a problem.

Figure 4.2.Small wind turbine[6]

4.1.3.-Offshore wind turbines

Offshore wind energy is a promising application of wind power, particularly in countries with high population density, and difficulties in finding suitable sites on land. Construction costs are higher at sea, but energy production is also higher.

Figure 4.3.- Offshore wind turbine[6]

4.1.4.-Common modern wind turbines

Usually three-bladed, sometimes two-bladed or even one-bladed (and counterbalanced), and pointed into the wind by computer-controlled motors. The rugged three-bladed turbine type has been championed by Danish turbine manufacturers. These have high tip speeds of up to 6x wind speed, high efficiency, and low torque ripple which contributes to good reliability

Figure 4.4.- Modern turbines[6]

4.1.5.-Advantages/disadvantages horizontal

Blades are to the side of the turbine's center of gravity, helping stability. Ability to wing warp, which gives the turbine blades the best angle of attack. Allowing the angle of attack to be remotely adjusted gives greater control, so the turbine collects the maximum amount of wind energy for the time of day and season. Ability to pitch the rotor blades in a storm, to minimize damage. Tall tower allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%. Tall tower allows placement on uneven land or in offshore locations. Can be sited in forests above the treeline. Most are self-starting. Can be cheaper because of higher production volume, larger sizes and, in general higher capacity factors and efficiencies.

HAWTs have difficulty operating in near ground, turbulent winds because their yaw and blade bearing need smoother, more laminar wind flows.

The tall towers and long blades (up to 180 feet long) are difficult to transport on the sea and on land. Transportation can now cost 20% of equipment costs. Tall HAWTs are difficult to install, needing very tall and expensive cranes and skilled operators.

Supply of HAWTs is less than demand and between 2004 and 2006, turbine prices increased up to 60%. At the end of 2006, all major manufacturers were booked up with orders through 2008. The FAA has raised concerns about tall HAWTs effects on radar in proximity to air force bases. Their height can create local opposition based on impacts to viewsheds.

Offshore towers can be a navigation problem and must be installed in shallow seas. HAWTs can't be floated on barges.

Downwind variants suffer from fatigue and structural failure caused by turbulence.

The aerodynamics of a horizontal-axis wind turbine are complex. The air flow at the blades is not the same as the airflow far away from the turbine. The very nature of the way in which energy is extracted from the air also causes air to be deflected by the turbine. In addition, the aerodynamics of a wind turbine at the rotor surface include effects that are rarely seen in other aerodynamic fields.

4.2.-Vertical Axis

Although vertical axis wind turbines, have existed for centuries, they are not as common as their horizontal counterparts. The main reason for this is that they do not take advantage of the higher wind speeds at higher elevations above the ground as well as horizontal axis turbines. A vertical axis machine need not be oriented with respect to wind direction. Because the shaft is vertical, the transmission and generator can be mounted at ground level allowing easier servicing and a lighter weight, lower cost tower. Although vertical axis wind turbines have these advantages, their designs are not as efficient at collecting energy from the wind as are the horizontal machine designs

Figure 4.5.-Vertical axis turbine[6]

4.2.1.-Advantages/disadvantages vertical

Easier to maintain because most of their moving parts are located near the ground. This is due to the vertical wind turbine’s shape. The airfoils or rotor blades are connected by arms to a shaft that sits on a bearing and drives a generator below, usually by first connecting to a gearbox. As the rotor blades are vertical, a yaw device is not needed, reducing the need for this bearing and its cost.

Vertical wind turbines have a higher airfoil pitch angle, giving improved aerodynamics while decreasing drag at low and high pressures. Mesas, hilltops, ridgelines and passes can have higher and more powerful winds near the ground than up high because of the speed up effect of winds moving up a slope or funnelling into a pass combining with the winds moving directly into the site. In these places, VAWTs placed close to the ground can produce more power than HAWTs placed higher up.

Low height useful where laws do not permit structures to be placed high. Smaller VAWTs can be much easier to transport and install.

Does not need a free standing tower so is much less expensive and stronger in high winds that are close to the ground. Usually have a lower Tip-Speed ratio so less likely to break in high winds.

Most VAWTs produce energy at only 50% of the efficiency of HAWTs in large part because of the additional drag that they have as their blades rotate into the wind. This can be overcome by using structures to funnel more and align the wind into the rotor (e.g. "stators" on early Windstar turbines) or the "vortex" effect of placing straight bladed VAWTs closely together.

There may be a height limitation to how tall a vertical wind turbine can be built and how much sweep area it can have.

Most VAWTS need to be installed on a relatively flat piece of land and some sites could be too steep for them but are still usable by HAWTs.

Most VAWTs have low starting torque.

A VAWT that uses guyed wires to hold it in place puts stress on the bottom bearing as all the weight of the rotor is on the bearing. Guyed wires attached to the top bearing increase downward thrust in wind gusts. Solving this problem requires a superstructure to hold a top bearing in place to eliminate the downward thrusts of gust events in guyed wired models.

5.-Energetic study

The study Will be about the electricity waste by a "standard" house referring to the necesities of a family.

That study is very important because with the minimum power it will be decided too the situation of the turbine the wind that needs etc…

5.1.-Energetic expense of a family

That study consists in plus all the household-electric machines and illumination, due to all the machines will not be all together switched on at the same time there is a coefficient of simultaneity that determines a minimum power.

In the following there are more or less all the household-electric machines of a standard family with their power, hour of consumption per day and the energy waste per day.

Waste energy tale of a standart family			
Hosehold-electric	**Power(W)**	**Hours consumption (h/day)**	**Total(W*h/day)**
Fridge	225	24	5400
Beater	300	0.25	75
Washing machine	2000	0.25	500
Microwave	600	0.5	300
TV	95	3	285
Video	75	1	75
Oven	1000	0.25	250
Hoover	900	0.25	225
Electric Ceramic-Glass Range	1100	2	2200
Computer	200	2	400
Ilumination	**Power(W)**	**Hours consumption (h/day)**	**Total(W*h/day)**
Kitchen	150	2	300
Bathroom	100	2	200
Room 1	100	2	200
Room 2	100	1	100
Salon	200	3	600
Hall	70	1	70
Receiver	80	0.25	20
TOTAL	**7325**		**10850**

Table 5.1.- Waste energy tale of a standart family

The power that the wind turbine have to generate will be less than the total of the table, using a Coefficient of simultaneity of 60 % the final power will be, equation

$$\mathbf{P_{installed} = F_{coefficient\ of\ simultaneity}.P = 0,6\ .7325\ W = 4395\ kW}$$

6.Aeolian study

6.1.-wind speed. Dynamic wind Pressure

Its important to know the power that the wind of the study zone could give,
so in that part of the work is going to be determined the power curves of the wind turbine General elements.

The project will be developed in the Romania in Iasi.That part of Romania has consistent winds during whole year furthermore that part has problems with the electrical provisioning so installing an off-grid small wind generator to provide energy it will be a solution to the energetic provisioning.

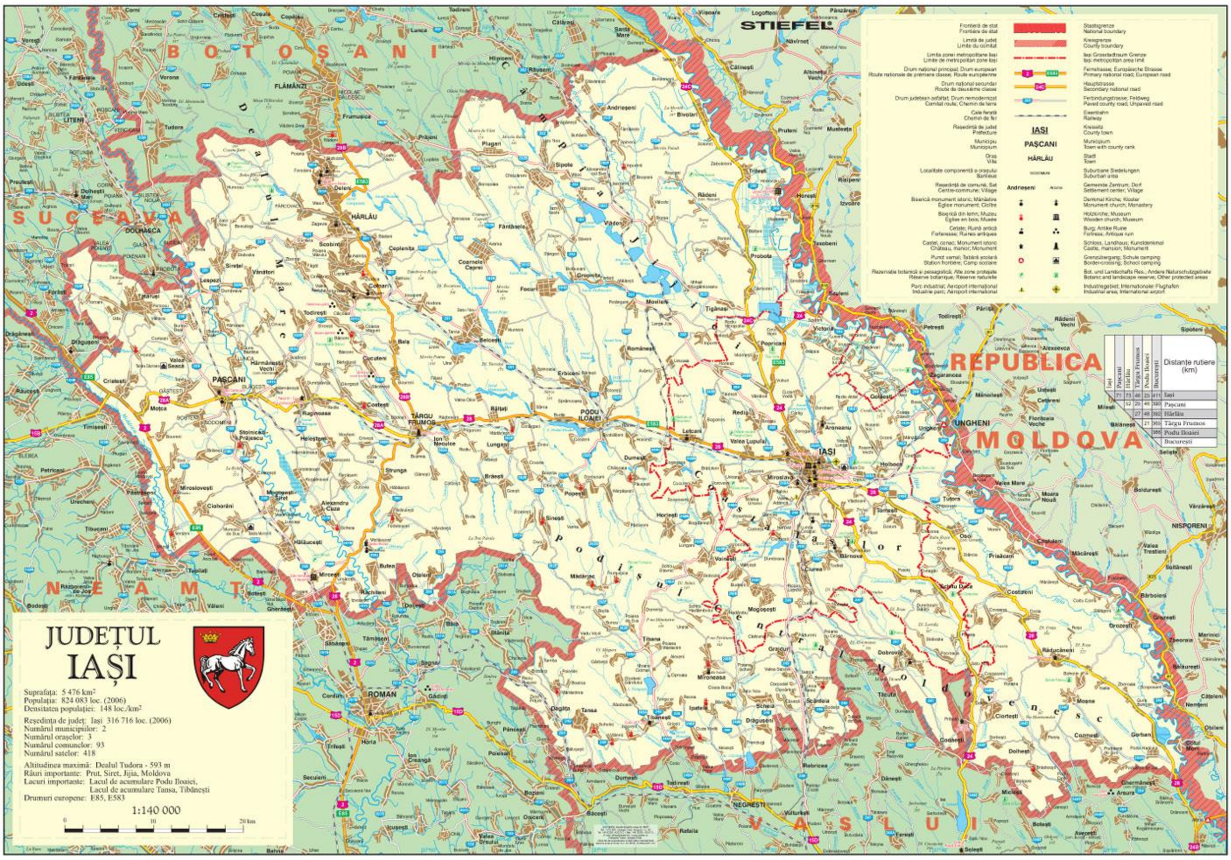


Figure 6.1.-Judetul Iasi[7]

The instantaneous values of wind velocity and dynamic wind pressure contain an average component and a fluctuating component of the mean. Both wind speed and dynamic wind pressure are modeled as random speeds. Its medium component is modeled as a random variable; The fluctuating versus average component is modeled as a stationary, normal, and average zero process. The average values of the wind velocity and the dynamic pressure are determined on the basis of their reference values and the roughness and orography of the terrain. The fluctuating wind velocity component is represented by the turbulence intensity, according to which the maximum wind speed and dynamic pressure values are determined.

6.2.-Winter Action Zone in Romania

The statistical analysis carried out for the zoning natural wind hazard in Romania had as maximum velocity of the annual wind of entry to 10 m above the ground, measured more than 140 meteorological stations of the national administration of Meteorology until 2005. The results of the statistical analysis are characteristic wind velocities (reference) with IMR = 50 years, calculated from the distribution of Gumbel for maximums. For the determination of the reference values of the dynamic wind pressure reference values have been processed at the wind speed sites of the meteorological stations that have received the records. Data zoning Map of dynamic wind pressure reference values for altitudes less than or equal to 1,000 m

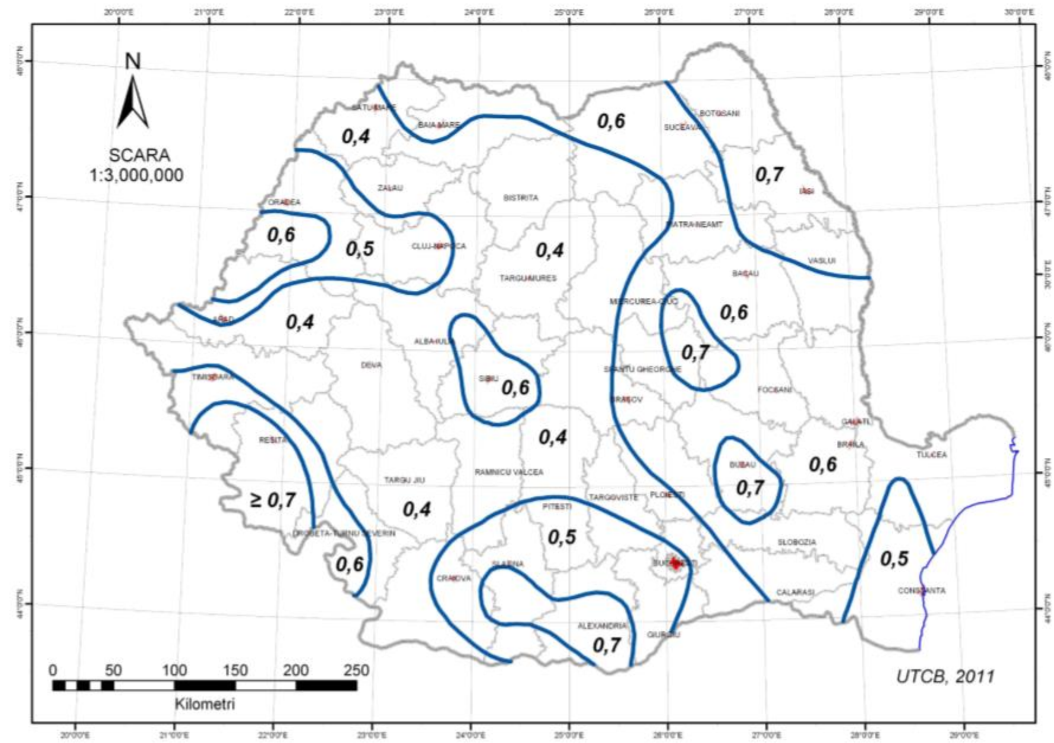


Figure 6.2.- Romania wind map[7]

6.3.-Maximum value of the wind in Iasi

Zoning of dynamic wind pressure reference values, QB in KPa, with IMR = 50 years

It is presented in reference Values of the dynamic pressure of the wind to 337 cities in Romania, placed in elevations of less than or equal to 1,000 m.

The reference value of the dynamic wind pressure to a location at an altitude Z more than 1000 m can be determined with the ratio:

$$q_{b,z>1000m} = c_{z>1000m} \cdot q_b$$

where:

$q_{b,z>1000m}$ is the reference value of the dynamic wind pressure for a location at an altitude of z above 1000 m;

q_b is the reference value of the dynamic wind pressure at the site of the zoning map shown in Figure 2.1;

$c_{z>1000m}$ Is the altitude factor that can be determined, roughly, with the relationship

$$c_{z>1000m} = 1 + 1{,}6 \cdot \left(\frac{z}{1000} - 1 \right)$$

For sites located at altitudes above 1000 m and in areas with special wind exposure (south-west Banat), it is recommended to obtain primary data from the NMA and consult specialized construction institutions to analyse this data.

The reference value of the wind velocity with an average recurrence interval of 50 years for a site located at an altitude of less than or equal to 1000 m is determined according to the dynamic reference value of the wind pressure of the site (see zoning Map In Figure 2.1). and the data in table A. 1) and is calculated with the ratio:

$$v_b = \sqrt{\frac{2 \cdot q_b}{\rho}} = \sqrt{1{,}6 \cdot q_b}$$

Where ρ is the density of the air equal to 1.25 kg/m3, and QB is the reference value of the dynamic wind pressure measured in PA (1 kPa = 1000 pa). The characteristic wind velocity values with an average recurrence interval of 100 years and 10 years can be calculated simplistically according to the wind velocity characteristic for an average recurrence interval of 50 years with the Following relationships:

$$\frac{v_{b,\,IMR=100\,ani}}{v_{b,\,IMR=50\,ani}} \cong 1{,}10$$

$$\frac{v_{b,\,IMR=10\,ani}}{v_{b,\,IMR=50\,ani}} \cong 0{,}75$$

The characteristic values of the dynamic wind pressures defined with an average recurrence interval of 100 years and 10 years can be calculated by simplifying according to the characteristic value of the dynamic wind pressure with an average interval of recurrence of 50 years with the following relationships:

$$\frac{q_{b,\,IMR=100\,ani}}{q_{b,\,IMR=50\,ani}} \cong 1{,}15$$

$$\frac{q_{b,\,IMR=10\,ani}}{q_{b,\,IMR=50\,ani}} \cong 0{,}65$$

Table dynamic wind pressure reference values for 337 urban locations in Romania

Nr.	Localitate	Județ	q_b, kPa (IMR=50 ani)
143	Grivița	IALOMIȚA	0,6
144	Gurahonț	ARAD	0,4
145	Gura Humorului	SUCEAVA	0,6
146	Hațeg	HUNEDOARA	0,4
147	Hârlău	IAȘI	0,7
148	Hârşova	CONSTANȚA	0,6
149	Holod	BIHOR	0,6
150	Horezu	GORJ	0,4
151	Huedin	CLUJ	0,5
152	Hunedoara	HUNEDOARA	0,4
153	Huşi	VASLUI	0,7
154	Ianca	BRĂILA	0,6
155	IAŞI	IAŞI	0,7
156	Iernut	MUREŞ	0,4
157	Ineu	ARAD	0,5
158	Isaccea	TULCEA	0,6
159	Însurăței	BRĂILA	0,6
160	Întorsura Buzăului	COVASNA	0,6
161	Jimbolia	TIMIŞ	0,4
162	Jibou	SĂLAJ	0,4

Table 6.1.-Romania qb values[7]

The reference value of wind velocity (wind velocity), VB is the wind velocity characteristic averaged for 10 minutes, determined at a height of 10 m, regardless of wind direction, in the Category II open field with the Conventional roughness length, z0 = 0.05 m) and with a probability of one year of 0.02 (corresponding to a median recurrence interval of IMR = 50 years). The wind action is considered horizontal and directional. In the case of directional expression, the wind velocity reference value VB is multiplied by a directional factor, which takes into account the distribution of wind velocity values in different horizontal directions. In the absence of directional wind velocity measurements, the directional factor is equal to 1.0.

The dynamic reference value of the wind pressure (wind pressure), QB is the characteristic value of the dynamic wind pressure calculated with the reference value of the wind velocity:

$$q_b = \frac{1}{2}\rho \cdot v_b^2$$

Where ρ is the density of the air that varies according to the altitude, the temperature, the latitude and the station. For standard air (ρ = 1.25 kg/m3), the reference pressure (expressed in Pascali) is determined by the ratio:

$$q_b\,[\mathrm{Pa}] = 0{,}625 \cdot v_b^2\,[\mathrm{m/s}]$$

Reference values of dynamic wind pressure in Romania are set out in the zoning map.

Map the zoning of the wind dynamic pressure reference values in Figure 2.1 is valid for altitudes less than or equal to 1 000 m. The reference value of the dynamic wind pressure at a location at a Z-height greater than 1000 m may be determined as indicated below for mountainous areas or areas at an altitude of 1000 m is recommended for recent primary data recorded by the National meteorological NMA Administrative view. In addition, it is necessary to determine if the value of the factor is recommended to use the last primary data NMA directional REDC. The wind velocity reference value for a location reference value is obtained from the dynamic wind pressure corresponding to the site (taken from the map)

So for our case in Iasi we will obtain the reference value of the wind.
First of all we should take the density of the wind we will assume normal wind so (ρ = 1,25 kg / m3).

$$q_b\,[\mathrm{Pa}] = 0{,}625 \cdot v_b^2\,[\mathrm{m/s}]$$

So the top expression will be now entering now with this in the about Iasi.Table 6.1 to look for our value.

We obtain qb=0,7 kPa for Iasi.

Now we have more or less the calculus of the wind we need to look the altitude of the windmill to see if we have to add other factors.

Our windmill is for a countryside house so we assume the heigh is <1000m so its not necessary to add anything, because this expression is for heights >1000m.

$$q_{b,z>1000\mathrm{m}} = c_{z>1000\mathrm{m}} \cdot q_b$$

So obtain:

$$v_b = \sqrt{\frac{2 \cdot q_b}{\rho}} = \sqrt{1{,}6 \cdot q_b}$$

Vb=33.46 m/seg it is the maximum reference value for the wind in Iasi.

It will be use for check the worst situation and be sure that our windmill and windmill parts will resists the worst situation than could appear in the place where it is locate.

6.4.-Weibull distribution.

Wind speeds in most of the world can be modelled using the Weibull Distribution. This statistical tool tells us how often winds of different speeds will be seen at a location with a certain average (mean) wind speed. Knowing this helps us to choose a wind turbine with the optimal cut-in speed (the wind speed at which the turbine starts to generate usable power), and the cut-out speed (the speed at which the turbine hits the limit of its alternator and can no longer put out increased power output with further increases in wind speed).

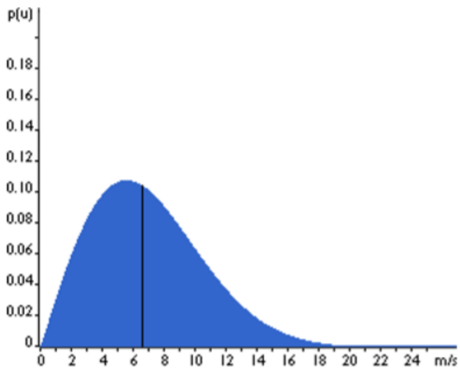


Figure 6.3.- Weibull distribution[6]

Pictured above is an example of the Weibull Distribution of Wind Speeds for a site with an average (mean) wind speed of 7 metres per second (from Danish Wind Industry Association). It demonstrates visually how low and moderate winds are very common, and that strong gales are relatively rare. The line at 6,6 metres per second marks the median wind speed. 50% of the time the wind is lower than the median and 50% of the time it is stronger than the median.

The shape of the Weibull Distribution depends on a parameter called, Shape. In Northern Europe and most other locations around the world the value of Shape is approximetely 2. Standard performance figures provided by wind turbine manufacturers typically use a Shape value of 2 making this distribution a Rayleigh Distribution.

The higher the value of Shape (from 1 to 3) the higher the median wind speed - i.e. locations with lots of low wind speeds as well as some very strong winds would have a value of shape of below 2, locations with fairly consistent wind speeds around the median would have a shape value of 3.

So in our case is obviusly that our value of shape is 2.

6.5.-Stats wind in Iasi

After having the maximum value of the wind in Iasi it is very important to obtain the main value of the wind in Iasi.

For that I pick a windmap with stats of Iasi

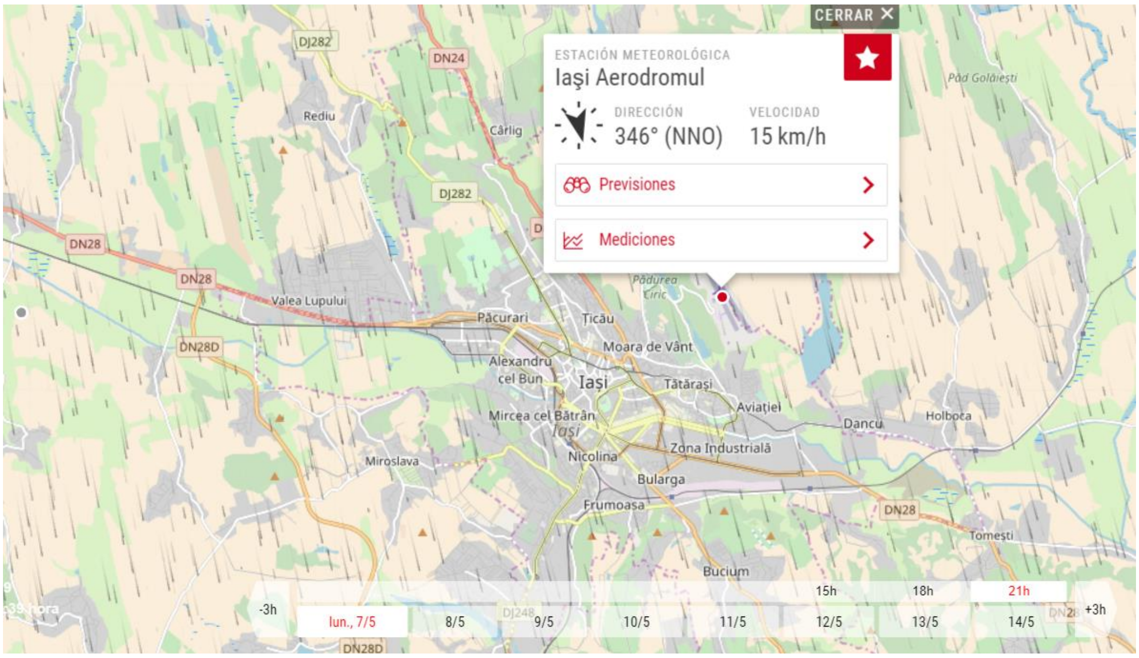


Figure 6.4.-Windmap Iasi[7]

Obtain from there the following table with a normal year.

Iaşi Aerodromul

Mes del año	ene 01	feb 02	mar 03	abr 04	may 05	jun 06	jul 07	ago 08	sep 09	oct 10	nov 11	dic 12	Año 1-12
Dirección del viento dominante													
Probabilidad de viento >= 4 Beaufort (%)	14	17	22	23	15	12	8	9	11	13	13	14	**14**
Velocidad media del viento (km/h)	13	13	15	15	13	13	11	11	13	13	13	13	**13**
Temperatura media del aire (°C)	-1	0	8	14	20	24	26	26	21	12	8	2	**14**

Figure 6.5.- Windmap values Iasi[7]

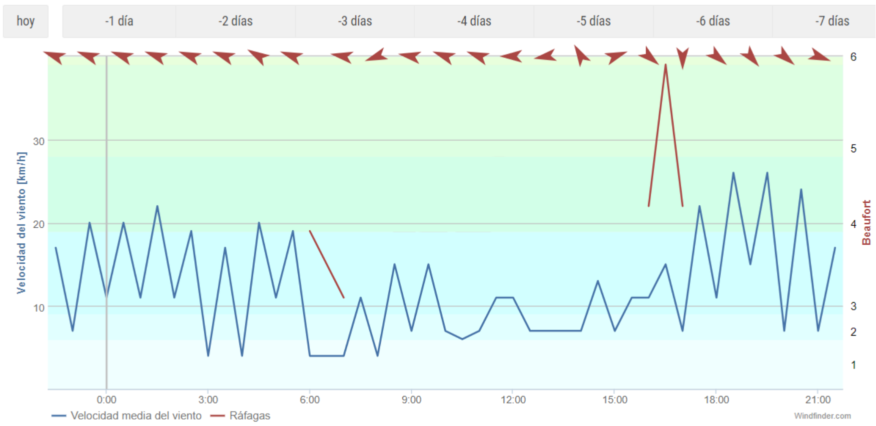


Figure 6.6.-Representation values Iasi[7]

With the main value of the graphs and the stats obtain we can get a real value of the wind following the Weibull distribution.

After that is very important to calculate the value of the density, I use the webage of the Danish windmill assotiation who gives a calculator introducing the main parameters.

Can see in the following picture

fórmula de aproximación

Altura sobre el mar	103	m	actualización

Cálculo exacto

presión atmosférica	1024	hPa	(500-1100 hPa)
temperatura	14	° C	(-50 ° -50 ° C)
humedad relativa	64	%	actualización

resultado

Densidad del aire = 1,238 kg / m³

Calculado con la fórmula exacta para:
presión de aire = 1024 hPa
temperatura = 14 ° C
humedad relativa = 64%

Figure 6.7.-Density Air Iasi[7]

The density of the wind in iasi introducing the media values will be 1,238 kg/m^3.

Its important to know how the wind goes with the height in the same page there is a calculator specially for that can introduce our dates and check that our windmill its not so height(5 meters) in the place where the wings are there will be no changes for the speed of the wind.

Altura sobre el suelo	103	m	
velocidad del viento	13	m / s	
Longitud de rugosidad z_0 (ver tabla a continuación)	0.1	m	actualización

resultado

Altura sobre el suelo	velocidad del viento
150 m	13.70 m / s
140 m	13.58 m / s
130 m	13,44 m / s
120 m	13.29 m / s
110 m	13.12 m / s
100 m	12.94 m / s
90 m	12,75 m / s
80 m	12.53 m / s
70 m	12.28 m / s
60 m	11.99 m / s
50 m	11,65 m / s
40 m	11.23 m / s
30 m	10.69 m / s
20 m	9.93 m / s
10 m	8.63 m / s

Figure 6.8.-Density with the height Iasi[7]

6.6.-Distribution for our case

The wind follows a weibull distribution in this case a distribution with 9 m/s of mean speed. Calculate the distribution is complex so using three main values of the graphic there is the following that explains the hours that the generator works per day and the wind distribution.

work hours per day	wind speed(m/s)	%
3	5	0,33
4	9	0,44
2	15	0,22

Table 6.2.-Values Weibull distribution

With those values is possible to find a considered wind speed, that speed will be the mean speed to calculate the Aeolian power and estimate a diameter for the turbine.

Vconsidered

Vconsidered=5*0.33+13*0.44+15*0.22=9 m/seg

$$P_{aeolian} = \frac{1}{2}.\rho.A.v^3$$

After calculating the considered speed and knowing the density of the wind the next step is to calculate the rotor diameter necessary. Using the equation before it is done the table with the output power depending on the diameter of the blades

After calculating the considered speed and knowing the density of the wind the next step is to calculate the rotor diameter necessary. The table is made by the program with the output power depending on the diameter of the blades.

Diameter(m)	Aelian power(W)
1	354.5
2	1417.64
3	3189.70
4	5670.58
4.5	7176.83
5	8860.29

Table 6.3.-Diameter-Aelian power values

Following the table the diameter of the rotor that is needed is around 3 metres or more than 3 meters and a half, but that values are not real because there is another coefficient (Beltz coefficient) that it haven't still used but is must be considered to calculate the output power.

The energetic study said us than our requeriments are

$P_{installed} = F_{coefficient\ of\ simultaneity}.P$ = 0,6 .7325 W =4395 kW

6.7.-Beltz Limit

Betz's law indicates the maximum power that can be extracted from the wind, independent of the design of a wind turbine in open flow. It was published in 1919, by the German physicist Albert Betz.[1] The law is derived from the principles of conservation of mass and momentum of the air stream flowing through an idealized "actuator disk" that extracts energy from the wind stream.

Wind turbines extract energy by slowing down the wind. For a wind turbine to be 100% efficient it would need to stop 100% of the wind but then the rotor would have to be a solid disk and it would not turn and no kinetic energy would be converted. On the other extreme, if you had a wind turbine with just one rotor blade, most of the wind passing through the area swept by the turbine blade would miss the blade completely and so the kinetic energy would be kept by the wind.

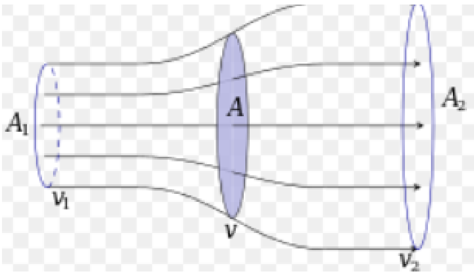


Figure 6.9.- Beltz limit

The mass of the air streaming through the rotor during one second is

$$m = \rho F (v_1 + v_2)/2$$

Where m is the mass per second, is the density of air, F is the swept rotor area and [(v1+v2)/2] is the average wind speed through the rotor area. The power extracted from the wind by the rotor is equal to the mass times the drop in the wind speed squared (according to Newton's second law):

$$P = (1/2)\, m\, (v_1^2 - v_2^2)$$

Substituting m into this expression from the first equation we get the following expression for the power extracted from the wind:

$$P = (\rho/4)\, (v_1^2 - v_2^2)\, (v_1 + v_2)\, F$$

Now, let us compare our result with the total power in the undisturbed wind streaming through exactly the same area F, with no rotor blocking the wind. We call this power P_0 :

$$P_0 = (\rho/2)\, v_1^3\, F$$

The ratio between the power we extract from the wind and the power in the undisturbed wind is then:

$$(P/P_0) = (1/2)\,(1 - (v_2 / v_1)^2)\,(1 + (v_2 / v_1))$$

We may plot P/P 0 as a function of v 2 /v 1 by 35xcel

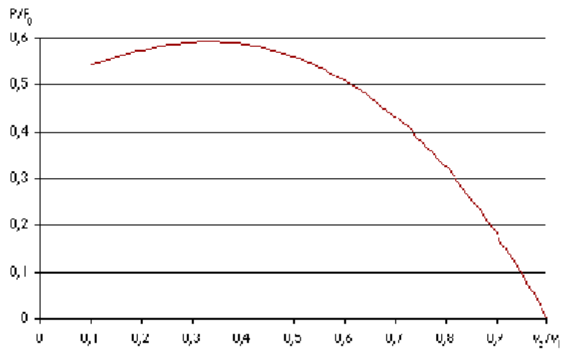


Figure 6.10.-Plot P/P0

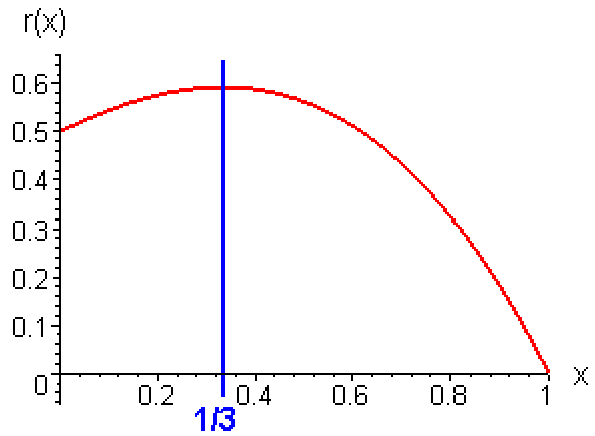


Figure 6.11.-Plot V/V0

We can see that the function reaches its maximum for v2 /v1 = 1/3, and that the maximum value for the power extracted from the wind is 0,59 or 16/27 of the total power in the wind.

Substituting the Beltz component (Cp =0.59 [3]) in the equation, to calculate the output power becomes the following table:

$$P_{eolica} = C_p.\frac{1}{2}.\rho.A.v^3$$

Diameter(m)	Electrical power(W)
1	209.155
2	836.4076
3	1881.923
4	3345.6422
4.5	4234.3297
5	5227.5711

Table 6.4.- Diameter-Electrical power values

But this is not the only parameter to know, theoretical maximum power efficiency of any design of wind turbine is 0.59 (i.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine). Once you also factor in the engineering requirements of a wind turbine, strength and durability in particular, the real world limit is well below the Betz Limit with values of 0.35-0.47 (figure 3.5) common even in the best designed wind turbines. By the time you take into account other ineffiencies in a complete wind turbine system - e.g. the generator, bearings, and power transmission and so on - only 10-30% of the power of the wind is ever actually converted into usable electricity.

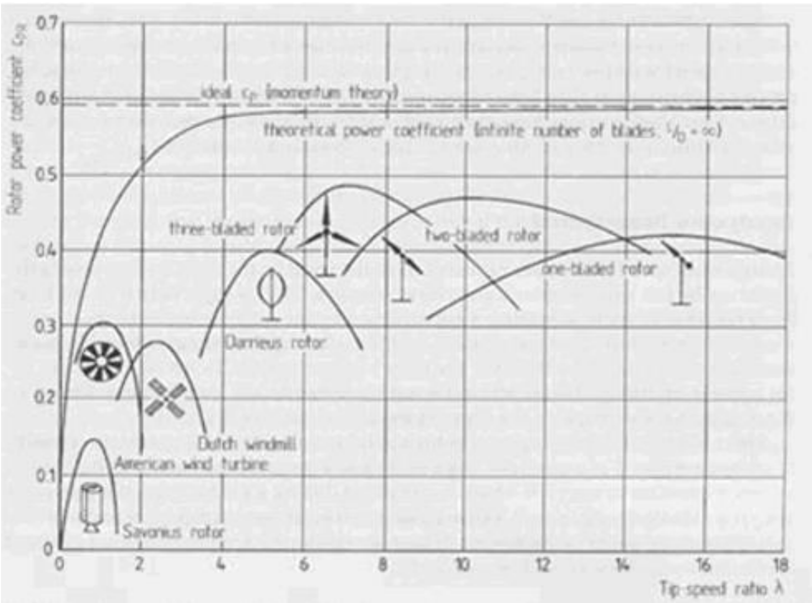


Figure 6.12.- Tip speed ratio-rotor power graph[6]

As it is showed after(next chapter) whit a three bladed turbine and a tip speed of 5.1 the power coefficient is 0,45. Then substituting that value in the equation there is the table that's shows the electrical power depending on the diameter off the rotor and the efficiency parameters. [6]

With a $C_p = 0{,}45$; $\eta_{electricsystem} = 0{,}95$;[3]

$$P_{electrical} = \eta_{electricsystem} . C_p . \frac{1}{2} . \rho . A . v^3$$

Diameter(m)	Electrical power(W)
1	151.54875
2	606.0411
3	1363.59675
4	2424.17295
4.5	3068.09483
5	3787.77398

Table 6.5.- Diameter-Electrical power values corrected

As it can be seen on the table the rotor diameter needed for that application is, that is a big diameter for a small application. Using batteries bank as it will be shown that the rotor diameter need is reduced.

6.8.-Power selection of the wind generator

With the last table is possible to determinate the minimum necessary diameter to generate the enough power to supply energy for the house.

The demand of electricity of the housing is not always the minimum power calculated and if is used a battery system the size of the blades can diminish. Since one will see later on it is selected an alternator, so it is necessary to install to the exit of this one a battery charger to be able to load the batteries. The battery charger is a conversor of A.C to D.C. To the exit of the batteries it is necessary to install an inverter that turns her D.C. to A.C.

The total consumption of energy is, according to the enerfgetic study, is **10850** W·h/day so, the batteries have to be capable to give this value. But it is necessary to add the consumption of energy of the electrical system, That is estimated in 10 % [3] of the total consumption of energy. Then estimating that the wind blows 10 hours per day, the consumption of energy and the consumption of the electric system, the minimum power of the generator will be.

$$P_{elec\text{-}wid\text{-}generator} = \frac{El - lost.Energy}{Funcionality - hours} = = 1326.11W$$

We must interpolate to calculate the mean value

To find the diameter of the blades there is the following table, which shows the Aeolian and electric power depending of de blades diameter.

Diameter(m)	Aelian power(W)	Electrical power(W)
1	354.5	151.54875
2	1417.64	606.0411
3	3189.70	1363.59675
4	5670.58	2424.17295
4.5	7176.83	3068.09483
5	8860.29	3787.77398

Table 6.6.- Diameter final values

Finally it is selected a generator with a 3 metres blades diameter, that diameter gives 1363W of power, seemed to 1326 W that is the minimum necessary power.

6.9.-Cavitacion on the wings

if the speed of the blades trespass that velocity could appear the cavitacion phenomenon, this could diminish the yield of the generator, shorten the life of the blades, vibrations and noise.

To calculate that value is used the equation.For that calculation is used the rated speed for the blades of 325 rpm, the maximum of the interval that the manufacturers give.

$$v_{pp} = \omega . r = n.\frac{2\pi}{60}.r = \quad 325 * \frac{2 * \pi}{60} * 1.5 = 51.05 \text{ m/seg} < \text{ 340 m/seg}$$

To finish with the main design of the wind generator it is necessary to chose how many blades will have.

First of all it have to be calculated the tip speed ratio λ with the equation and then look for in the following table.

$$\lambda = \frac{v_{pp}}{v} = \frac{\omega . r}{v} = \frac{n.\frac{2\pi}{60}.r}{v} = \frac{325 * \frac{2 * \pi}{60} * 1.5}{9} = 5.67$$

λ	Nº of blades
1	6-20
2	4-12
3	3-8
4	3-5
5-8	2-4
5-15	1-2

Table 6.7.- Number of the blades

The tip speed ratio is 5.67 then the Theoretical number of blades is in the interval (2,4).

Four blades is the perfect number to equilibrate the inertial forces but this will increase the cost of the product, two blades is the cheapest solution but increases the rotation speed increasing also the live to fatigue of the generator, then the selected solution is three blades.

7.-Design of the parts

7.1.-Parts of a Wind Turbine

A wind turbine usually comprises the following parts

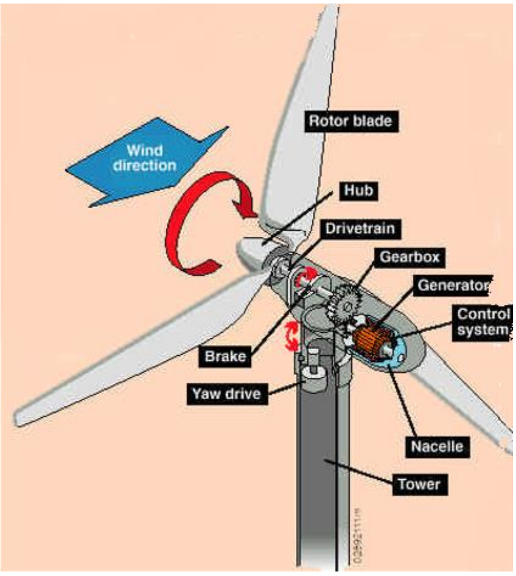


Figure 7.1.-Parts of a wind turbine[8]

-Rotor: The blades of the rotor are designed to spin in the wind, driving the turbine generator. Sometimes gearing is used to increase the frequency for electricity generation.

-Generator: This generates the electricity when there is sufficient wind to rotate the blades. There are now many designs of generator, including some with new powerful permanent magnets. Electricity is transferred to the next stage (either for storage, exporting to the grid or for direct use) using cabling.

-Directional system: Horizontal axis machines require a mechanism to swing them into line with the wind. Small machines usually have a tail assembly for furling. Large machines usually have a 'servo mechanism' that orients them into the direction of maximum output.

-Protection system: Modern wind turbines are usually equipped with mechanisms to prevent damage in excessively high winds. Large machines may use active methods involving aerodynamic and mechanical brakes to shut down generation at high wind speeds. Smaller systems may use passive methods such as furling or changing the blades' pitch so that they present a smaller surface to the wind and thereby reduce the speed of rotation.--

-Tower: The tower raises the turbines assembly well above the turbulent air currents close to the ground and captures higher wind speeds, as described earlier in this fact file. Tower design is particularly critical, as it must be as tall as economically possible, robust, enable access to the turbine for maintenance, and yet not add unnecessarily to the cost of the system. A particularly important aspect of tower design is elimination of resonance between the frequency range of rotating blades and the resonant frequency of the tower.

Wind turbines come in many sizes and configurations and are built from wide range of materials. In simple terms, a wind turbine consists of a rotor that has wing shaped blades attached to a hub; a nacelle that houses a drivetrain consisting of a gearbox, connecting shafts, support bearings, the generator, plus other machinery; a tower; and ground-mounted electrical equipment.

The wing shaped blades on the rotor actually harvest the energy in the wind stream. The rotor converts the kinetic energy in the wind to rotational energy transmitted through the drivetrain to the generator. Generated electricity can be connected directly to the load or feed to the utility grid.

The weight and cost of the turbine is the key to making wind energy competitive with other power sources, because research programs have significantly improved the efficiency of the rotor and maximized the energy capture of the machine. The real opportunity today is through better, low cost materials and though high volume production, while ensuring the reliability is maintained. The typical weight and cost of the primary turbine components today are shown in the following table In addition there are foundations and conventional ground-mounted systems, including transformers, switching and other power equipment.

Component	% of Machine Weight	% of Machine Cost [5]
Rotor	10-14	20-30
Nacelle and machinery, less	25-40	25
Gearbox and drivetrain	5-15	10-15
Generator systems	2-6	5-15
Weight on Top of Tower	35-50	N/A
Tower	30-65	10-25

Table 7.1.-%cost and weight on aerogenerator

There appear to be several areas where technological progress and cost reduction are needed. Turbine subsystem costs are generally evenly split between rotor, nacelle, drivetrain power systems, and the tower. There is no single component that dominates turbine cost. The rotor is the highest cost item on most machines and must be the most reliable. Towers are normally the heaviest component and could benefit from weight reduction, but lightening the rotor or tower-top weight has a multiplier effect throughout the system including the foundation.

7.2.-Components of Wind Energy Systems

It is referred to the electronical part and how the windmill produces electricity to the public and your own red.

There are two big systems on-grid and off-grid, explained better in the economical part because it have a very importal body in the economical problem.

Both systems, on-grid and off-grid have the same components, the only difference is that the off-grid systems need batteries to store energy and the connected ones need an AC utility meter to count the sold energy to the grid.

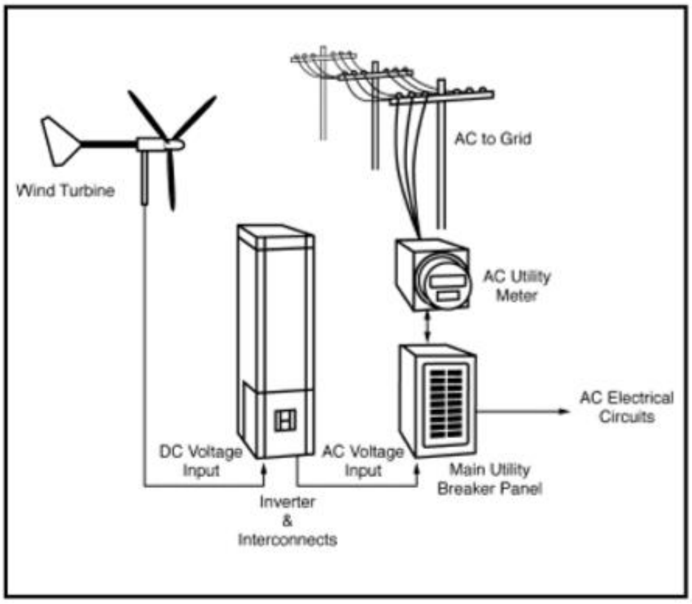


Figure 7.2.- Off grid system[6]

7.3.-Materials Usage nowadays

A wide range of materials are used in wind turbines. There are substantial differences between small and large machines and there are projected changes in designs that will accommodate the introduction of new material technologies and manufacturing methods.

To arrive at a total, the material usage is weighted by the estimated market share of the various manufacturers and machines types.

	Large Turbines and *(Small Turbines*[1]*)*							
Component/ Material (% by weight)	**Permanent Magnetic Materials**	**Pre-stressed Concrete**	**Steel**	**Aluminum**	**Copper**	**Glass Reinforced Plastic [4]**	**Wood Epoxy [4]**	**Carbon Filament Reinforced Plastic [4]**
Rotor								
Hub			*(95)* - 100	*(5)*				
Blades			5			95	*(95)*	*(95)*
Nacelle [2]	*(17)*		*(65)* - 80	3 - 4	14	1 - *(2)*		
Gearbox [3]			98 -*(100)*	*(0)* - 2	*(<1)* - 2			
Generator	*(50)*		*(20)* - 65		*(30)* - 35			
Frame, Machinery & Shell			85 - *(74)*	9 - *(50)*	4 - *(12)*	3 - *(5)*		
Tower		2	98	*(2)*				

Notes:
1. Small turbines with rated power less than 100 kW- (listed in italics where different)
2. Assumes nacelle is 1/3 gearbox, 1/3 generator and 1/3 frame & machinery
3. Approximately half of the small turbine market (measured in MW) is direct drive with no gearbox
4. Rotor blades are either glass reinforced plastic, wood-epoxy or injection molded plastic with carbon fibers

Table 7.2.- Large Turbine/Component material

The trends in design and manufacturing differ between small and large turbines. Small machines tend to use lighter weight castings in an effort to reduce costs. Many parts are die cast aluminum in small turbines, while in large machines steel castings or forgings are needed to meet strength and structural fatigue requirements. The size of steel castings for large turbines, especially the blade hub units, is one of the manufacturing challenges.

Material fatigue properties are an important consideration in wind turbine design and materials selection. During the expected 30 year life of a wind turbine, many of the components will need to be able to endure 4 x 108 fatigue stress cycles. This high cycle fatigue resistance is even more severe than aircraft, automotive engines, bridges and most other man-made structures.

7.4.-Material Usage Trends

The component development trends described above are reflected in the following material use projections. The overall annual material usage trends are shown in the following figure for two periods, from 2001 though 2005 and for 2006 though 2010. Introduction of much of the new technology discussed above is expected to be incorporated in commercial machines during the later period. Materials used in machines installed in the U.S. are included as part of the global totals.

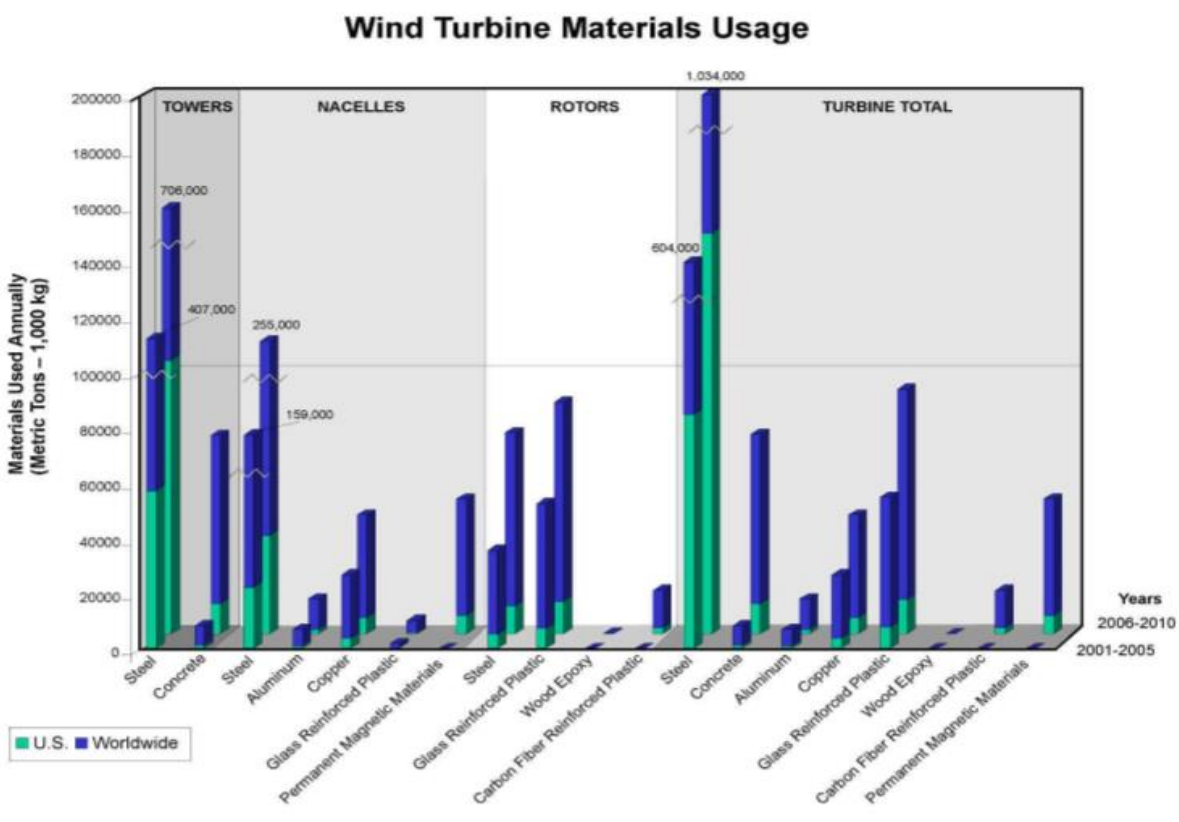


Figure 7.3.-Wind material usage trends

The following observations are based on the results of the material usage analysis:

• Turbine material usage is and will continue to be dominated by steel, but opportunities exist for introducing aluminum or other light weight composites, provided strength and fatigue requirements can be met.

• Small turbine production volume is increasing rapidly which can be accommodated by manufacturing mechanization and innovation that will lower costs.

• Elimination of the gearbox by using variable speed generators will increase through use of permanent magnetic generators on larger turbines increasing the need for magnetic materials.

• New high power electronics will help reduce the need for gearboxes and also decrease losses occurred during transmission of wind power to distant load centers.

• Simplification of the nacelle machinery may not only reduce costs, but also increase reliability.

• Blades are primarily made of GRP, which is expected to continue. While use of CFRP may help to reduce weight and cost some, low cost and reliability are the primary drivers.

• Increasing the use of offshore applications may partially offset this trend in favor of the use of composites.

• Prestressed concrete towers are likely to be used more, but will need a substantial amount of steel for reinforcement.

• Wood epoxy, used in early blade production, is not expected to be a material of choice despite excellent fatigue properties.

• Wind turbine component and materials manufacturing are major and expanding business opportunities for at least the next 10 years.

• The largest market for wind turbine systems and materials in the future will be outside North America and Europe, but this market will be slower in development.

7.5.-Device of orientation

The mechanism of orientation aligns the rotor with perpendicularly to the wind, without that device the rotor could have a mistake of orientation. That is very important because a bad orientation could be a loss of power so almost all the small generators has that devices.

There are different mechanisms of orientation, the most common are:

- Orientation by stabilizing fin

-Servomotor.

The first one is the most common, is used for small turbines, till 6 metres of diameter, and is the cheaper one. Consist in one fin that is fixed to the nacelle as is showed in the figure, then the wind will pass through the fin orientating the generator.

Figure 7.4.-Device of orientacion[15]

As is said before that is the most common solution that the manufacturers use for small generators so is the chosen device for that application. In that application the case and the device of orientation is not the same piece that will be manufactured each piece separatly.

The second mechanism is more complex, consist in motors that orientate the rotor depending on signals that receipt from a vane that is fixed to the nacelle. The nacelle receipt a signal from the vane and the servomotor rotates and orientates the rotor. That solution is adopted for a big generators, more than 6 metres of diameter.

I picked the first solution but without being manufacturing at the same time.It consists in three pieces join by two screws the back part with the piece for join and a back part which is Weld to this all this is join to the case with 4 screws as we can appreciate in the planes of the anexe 2.

For the vane in itself.The last piece in the windmill.Some manufacturers give dimensions for the vanes of the generators, to have a good functioning the vane has to have the area that is showed in the next equation

Avane=Arotor = 0 04*π*r^2=0.2827

Avane = 0 04*π*r^2 → 0.2827

With CATIA it has been designed a vane as is showed CATIA gives the área and all parameters of the vane 0,48 m2 , with that area is enough to assure the good orientation of the rotor.

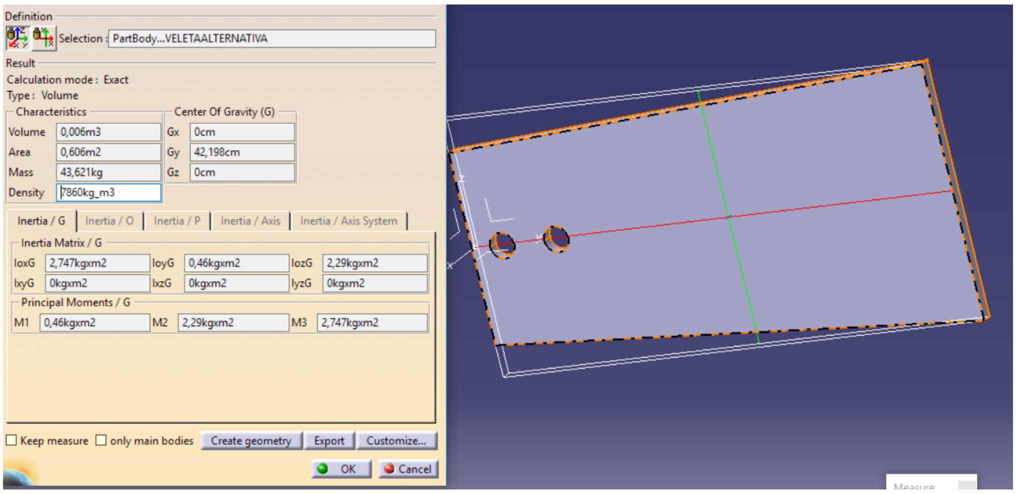


Figure 7.5.-Surface of the vane

This piece is made of course by Steel, because is the easiest way to manufacture and one of the cheapest material, every company Works with it.

The piece that connect with the bane is a steel piece, Weld in one side and in the other join with the bane by two screws.

The model in catia is:

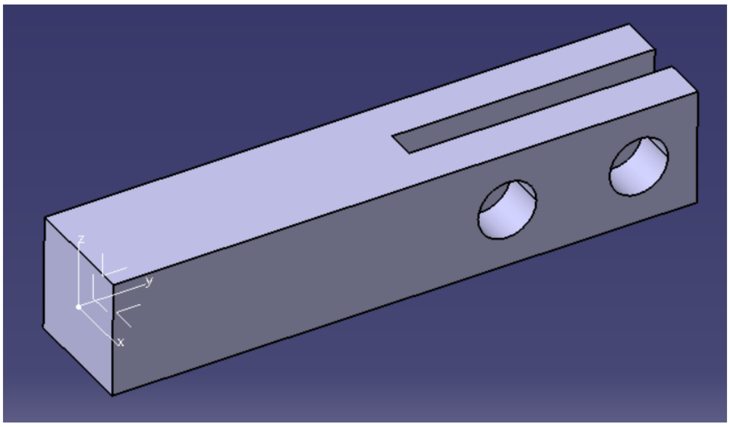


Figure 7.6.- Conexión Vane

It is easy to manufacted from a rectangule of Steel, just two drills and one in the middle part.

The last piece which join with the main part is made by foundry, because the parts of the sides has a difficult geometry, the geometry of the piece is a bit strange to try to keep the aerodinamical profile that must have all the case of the windmill, to avoid the wind and have the less forcé possible.

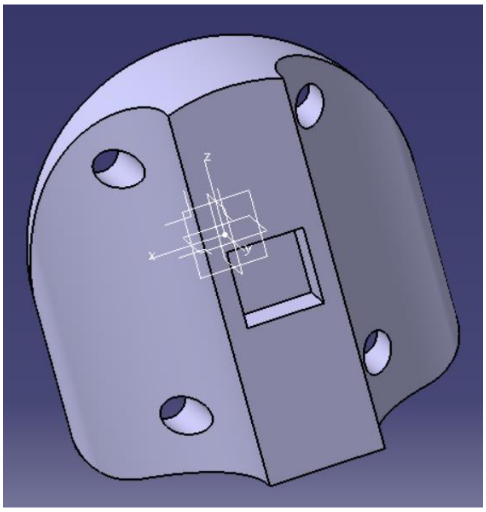


Figure 7.7.-Vane back part

Is made by a Steel foundry,All the foundries of the Project have been simulated in catia, with the following characteristics

Elastic Modulus	103 Gpa
Tensile strength	700 MPa
Density	7200 Kg/m^^{3}
Coefficient of Poisson	0.26

Table 7.3.-Foundry characteristics

The company which is choose to manufact is called “fundiciones fumbarri durange S.A” spanish company specialized in this kind of pieces, in the north part of spain in Pais Vasco.

7.6.-Power transmission

When the wind pass across the blades of the generator this ones will rotate giving kinetic energy, the best way to pass that rotation to an axis rotation is by an wedge.

Fitting the blades between the blade-hub and the blade plate and joining the blade-hub with the horizontal axis by a wedge it will get a cheap and useful solution.

Also to help the wedge have been add 6 screws for the 3 wings, 2 crews for each wing to support the forcé.

All of this join to the shaft in a piece made by Steel to resist and because is cheaper, called “conexión-nose”

Then the axis will move the alternator and that one will pass the mechanical energy into a electrical energy.

7.6.1.-Blade-hub

As is explained before the blade-hub will pass the energy from the wind to a rotational speed. To keep together the horizontal axis and the blade-hub there are different solutions:

- Giving the form of the blade-hub to the last part of the axis and Weld it. Maybe its a bit more expensive than the rest but the join by wedge its the best possible and there is no chance to separate giving a hard fix.

- Fitting the blade-hub to the axis by interference. That solution is cheap but the problem is that once both parts are fitted then it cannot be dismantled.

- Fitting the union by a wedge with screws. That is not good because if the unión its not good enaugh done it can be slide, making the windmill useless.But can be add a Weld to assure the conctact.

-That join is very important and it has to be proved that the inertial forces produced for the rotation of the blades will not separate the join so to try to avoid this we choose the wedge unión with a screw for avoid tthe vibrations.

Our solution Will be be Weld but with a screw of security in the nose to avoid the vibrations and the excentricity and to be sure that all the mix rotates together, avoiding forces between components.

7.6.2.-Nose

The nose has an aerodinamical profile is the first element of all mechanism to take the wind so it must have it to reduces the forces and try to make a turbulent profile.

It is Weld to the conexión piece and have a screw of security inide to avoid the excentricity of the shaft and to be sure to rotate at the same speed.

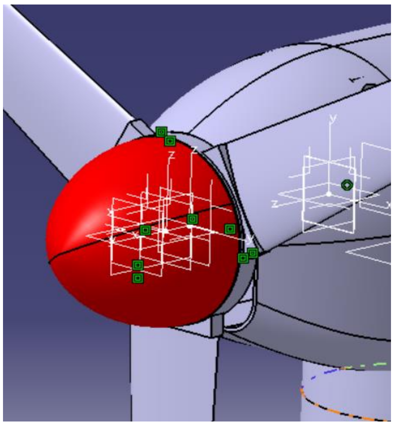


Figure 7.8.- Nose

Is made by a Steel foundry,All the foundries of the Project have been simulated in catia, with the table 7.3. charactterictis.

The company which is choose to manufact is called “fundiciones fumbarri durange S.A” spanish company specialized in this kind of pieces, in the north part of spain in Pais Vasco.

Connected with the nose there Will be a piece with six holes made by Steel to join the wings with it with screws, the nose Will be empty without material to be able to occur this.

The piece with the holes to connect the wings:

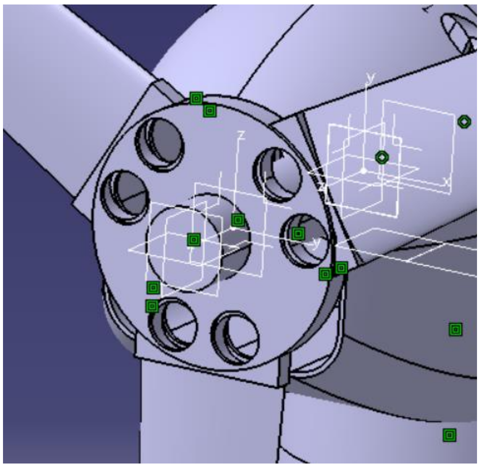


Figure 7.9.- Conexión piece

The best choice to this piece is the Steel is a easy piece with 7 holes(6 for the wings) and for the top shaft and three holes for the wings with a difference of 120º each one.

As we can see in the following detail of the nose for the security screw of the piece:

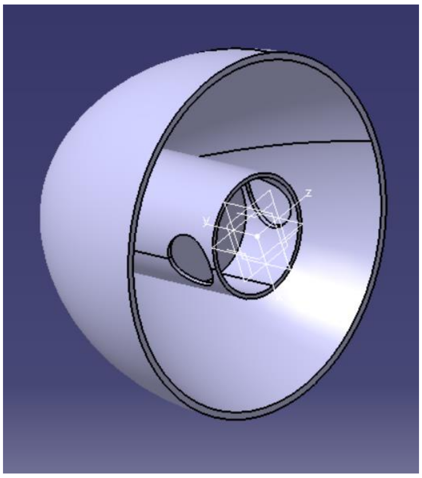


Figure 7.10 Inside nose

7.7.-Bearing

For that application are chosen bearings SKF, there will be two bearings holding the horizontal axis one is free and the other one is fixed. The bearing chosen are rigid ball bearing because that ones have a good behaviour with radial and axial loads, the fixed one will support a axial and a radial load while the other one will just support a radial load. As is showed in the annexe where the live of the bearings is proved. To have a minimum of maintenance the bearing chosen does not need oil. The bearing B is inside a SKF pillow as is showed in the figure 4.4, that pillow will be fitted to the gearbox by screws.

Because the pillow is fixed it will support the axial loads and the screws will assure the union between the pillow and the gearbox. The other bearing is joined by interference to the nacelle lid then with the axis and the nacelle lid the two rings are fitted.

Here are also shown the diagram of forces, used and explained in the annexes part to calculate the live of the bearings.

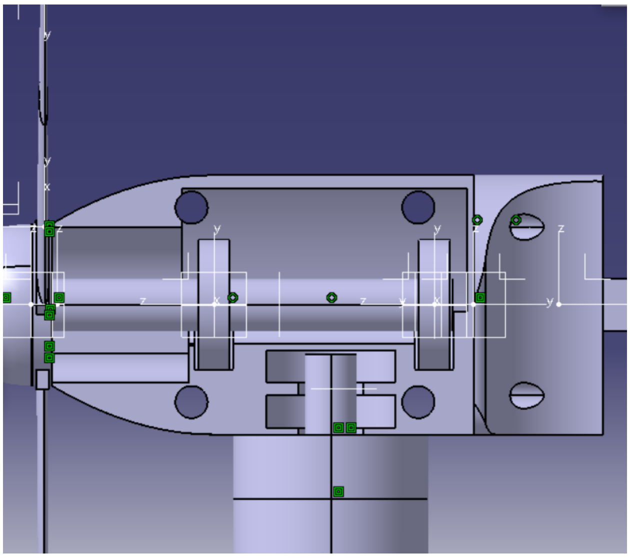


Figure 7.11.- Bearings view

7.8.-Nacelle/cases

In the nacelle will be fixed some components of the power transmission alternator and the brake… This elements are fitted to the nacelle by screws, inside the nacelle there are two big supports, each one for each element.

The nacelle will be opened separating both sides by 4 screws , that closing is very important because have all the engines part ant too many components inside thats why in the annexes the union is proved.

The bearings is fitted to the nacelle by the shafts, that cylinder has to be mechanized to hold inside the bearing, furthermore it will have a special form to assure that the dirty from outside does not come inside the nacelle.

Both cases in CATIA:

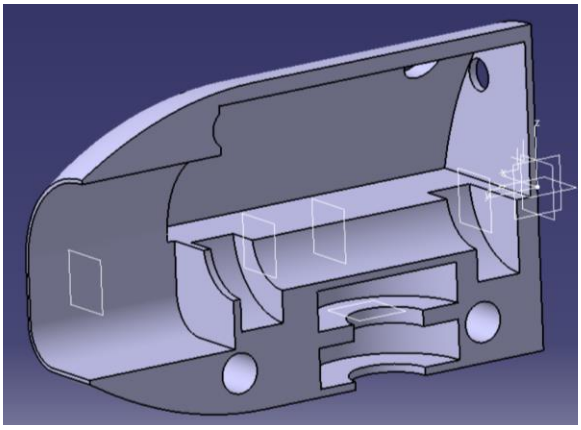


Figure 7.12.- Right Side Case

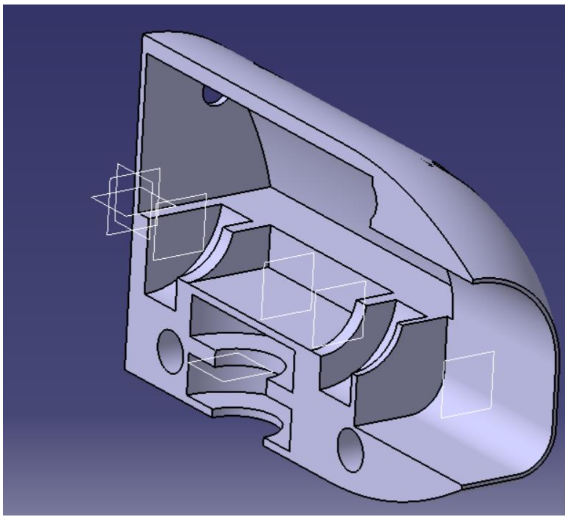


Figure 7.13.- Left Side Case

The material of the nacelle has to have a good characteristics to resist all the parts so is chosen a Steel foundry, and have a difficult geometry.Because of the geometry i pick a Steel foundry to be easier to be manufactured.

Is made by a Steel foundry,All the foundries of the Project have been simulated in catia, with the table 7.3. characterictis

The company which is choose to manufact is called “fundiciones fumbarri durange S.A” spanish company specialized in this kind of pieces, in the north part of spain in Pais Vasco.

7.9.-Shafts

There are two big shaft in the mechanism the horizontal one and the vertical one.

The material selected for the shafts is steel St 42 (manufactured by lamination) that material is used for requested axis.

Both shafts are fitted two radial bearings, and the horizontal has plus the alternator and the brake . As is showed in the annexe the axis will suffer fatigue due to the rotation of the blades.

So the fatigue of the horizontal axis has been proved in the annexes 1.

Is very important to prove the fatigue because is used to e one of the main problems in this kind of mechanism as said before in the introduction part.

7.10.-Tower

The tower is the element that sustains all the mechanisms of the small generator.

There are 3 big families of towers to this kind of structure.

-Guyed lattice towers, where the tower is permanently supported by guy wires. These towers tend to be the least expensive, but take up a lot of space on a yard. A radio broadcast tower is a good example of a guyed lattice tower.

-Guyed tilt-up towers, which can be raised and lowered for easy maintenance and repair.

-Self-supporting towers, which do not have guy wires. These towers tend to be the heaviest and most expensive, but because they do not require guy wires, they do not take up as much space on a yard.

In the following figure there are the two tower types that adjust better to the application.

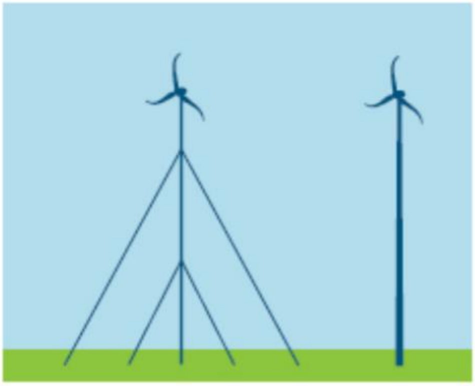


Figure 7.14.-Types of tower[22]

The two most common types of towers are guyed and monopole. Both are available in various designs. Some can be tilted-down for easy access while others require a crane for installation and service.

Guyed towers are less expensive than monopole towers. However, because the guy radius must be one-half to three-quarters of the tower height, guyed towers require enough space to accommodate them.ç

Monopole towers are more expensive but they offer the consumer an easy way to perform maintenance. Monopole towers can be lowered to the ground during hazardous weather such as hurricanes.

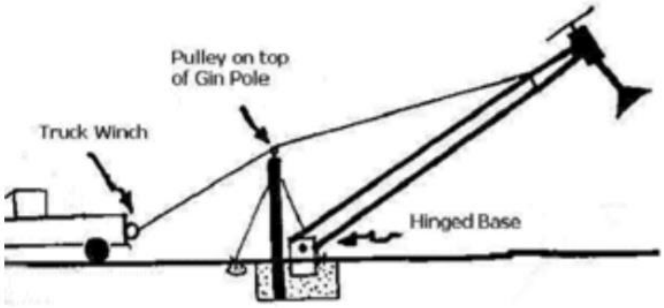


Figure 7.15.- Lowered tower during strong winds[22]

For the reasons explained before the tower system chosen is a guyed tower, about the material of the tower the most common used for that appliances is steel , some manufacturers use aluminium but aluminium towers are prone to cracking so in that project it will be used steel.

In the next picture is presented the pier foundation of the small generator, the tower is joined to the foundation by screws, most manufacturers for small generators that have similar characteristics use that type of foundation so for this project is chosen the same solution.

Figure 7.16.-Pier Foundation[22]

About the cables from the alternator will pass across the vertical axis (hollow) and then across the tower till the foundation as is showed in the figure

Figure 7.17.-Cable across the tower[22]

7.10.1.-Design of the Tower

The tower is one of the most important parts of the generator is the one witch will support the nacelle so it has to have a good relation between the displacements due to the loads and the Von Mises tensions. A high displacements can disorientate the rotor losing Aeolian power and a high Von Mises tensions in the joins could damage the material.

It is a must to add at some point of the tower Sound isolators any noise transmitted down the steel tower passes through sound isolators that are made of hardened neoprene rubber They absorb most vibrations before they reach ground level

The tower must have 28 holes for Weld the stairs and up of this there wil be three supports welded to the shaft to connect cables to avoid the Little displaicments, movements, vibrations…

The cables must be longer than the height of the windmill made by Steel and must work at traction.It doesnt been calculated because it is not a structutal element.

The structure can work without the cables, the cables are a plus to avoid problems.So it is not a principal problema for the full mechanism.In future checks and improvements of the windmill this should be a main part.

The material of the tower is Steel it material should be a good resistance and Weld capacity

To reduce the weight of the piece.Has been searched a profile which is empty inside and a company that can produce this kind of profile because of the principal problema the height of 4,8 meters.

The 3D model of the tower in catia is:

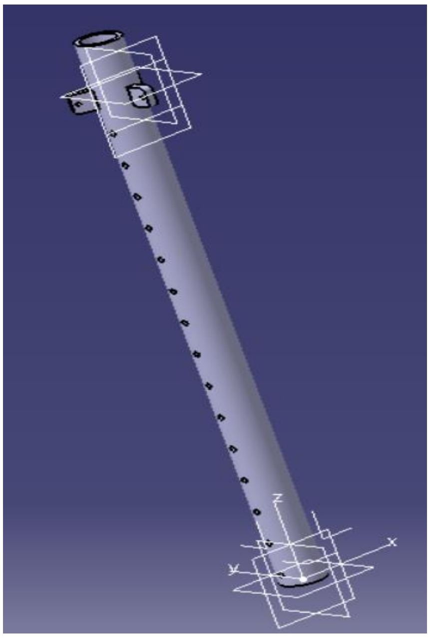


Figure 7.18.-3D model of the principal shaft

Finally there is a spanish company who can produce this kind of pieces/shaft even higher The company which is choose to manufact is called “fundiciones fumbarri durange S.A” spanish company specialized in this kind of pieces, in the north part of spain in Pais Vasco.

7.10.2.-Base

To avoid vibrations must have to be sure to avoid as much as i can vibrations and to pass across al the cables we must have a base in the windmill that can solve all this problems.

I choose a rectangular profile with 4 big holes that Will join with the ground and a central hole to introduce the principal shaft of the tower.

The 3D model of the base in catia is:

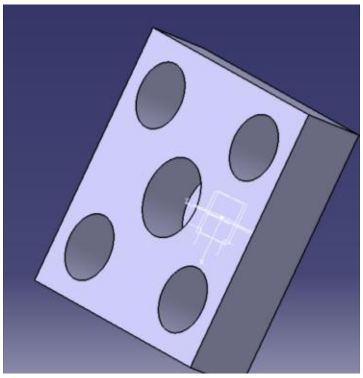


Figure 7.19.- 3D model of the base

It is made by Steel,becuase is cheaper and easy to mechanism and should be heavy as Steel is.

It should be heavy and it is for avoid ad give good reference to all structure.

It is a must to add sound isolators any noise transmitted down the steel tower passes through sound isolators that are made of hardened neoprene rubber They absorb most vibrations.

7.10.3.-Top Cap

The top cap is a piece of conexión with the vertical shaft inside it.

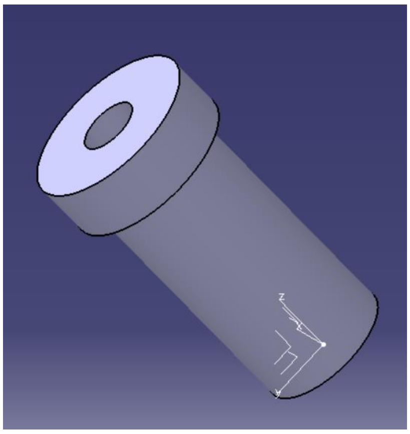


Figure 7.20.-3D model of the top cap

It funtion in the mechanism is to avoid the rotation forcé and the rotation of the principal shaft because of the orientation system to redude forcé vibrations and of couse to minimace it all at máximum possible it is add this piece.

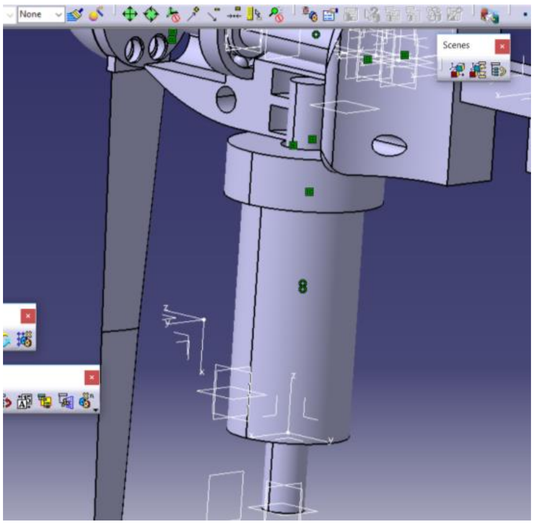


Figure 7.21.-Detail of the top cap

It is made by Steel.It is not so complicated to mechanism from a cilinder of Steel.Steel is cheaper and resistance thats why i pick Steel as it material.With it own weight can be join perfectly to the mechanism but to avoid any problem it should be Weld to the principal shaft.

7.10.4.-Tower analysis with ANSYS

In order to get better results it has been analyzed the tower alone, applying the loads from the wind power, gravity and the height of the nacelle there are the following results. All the analysis has been done in the worst case calculated in the part before where i check that the máximum wind in iasi could be 33,46 m/s if the results are good in that case then there will not be problems for the other cases.

There will be two main forces the weight of the structure, the mass is give by CATIA 3D MODEL and the Force of the wind in the worst case as I calculated before this is when winds goes at 33,46 m/seg.So the same process than in the annexes 1.

The equations are:

$$F_{aero} = 0.62*A*v^2 = 0.62*\pi*(\frac{1}{4}*3^2)*33.46^2 = 4906.54N$$

$$F_{masa} = m*9.8 = 463*9.8 = 4537.8N$$

I introduce the forcé in ansys with the 3D model of the principal shaft. And ill obtain the 3 main characterisctis of the shaft.As we can see in the following pictures these are:Equivalent stress,deformation and the normal stress.

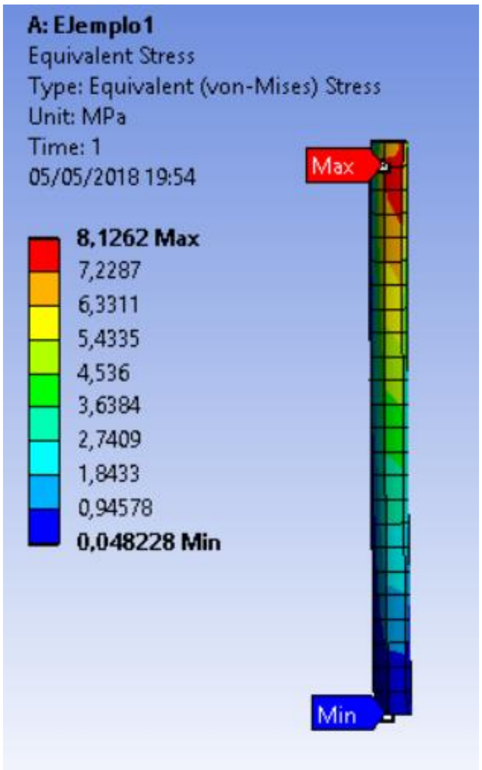


Figure 7.22.-Ansys equivalent stress

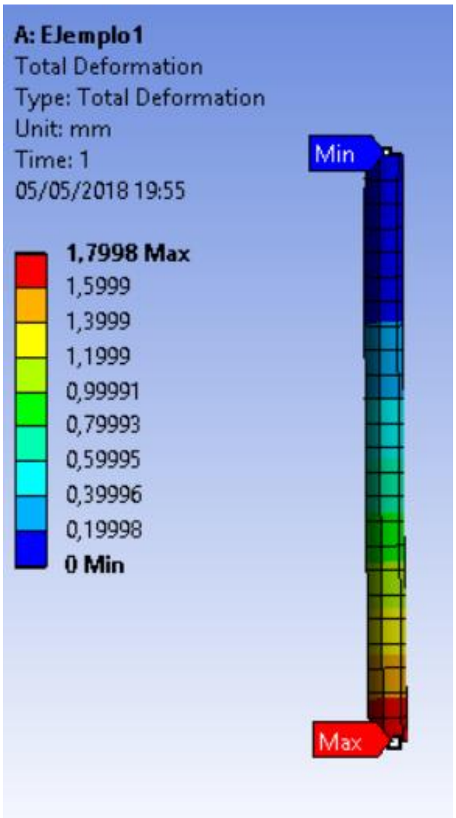


Figure 7.23 ANSYS total deformation

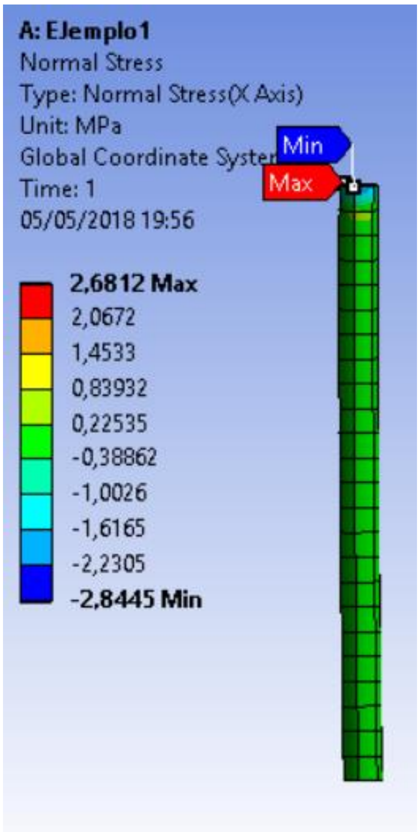


Figure 7.24.-ANSYS normal stress

The máximum deformation occurs on the top part, this is the most expected thing to happen being the model practically equal to a recessed-free barín the worst situation possible with a bar of 4,8 meters of length the máximum deformation is 1,79 mm it is note ven 2 mm that displacement is not considered very high, furthermore that simulation it has been done in the worst case with winds of 25m/s, during most part of the generators live there wont be that kind of winds.

About the von misses analysis, have to be less that the yield strength because if the tensions trespass that limit then the material cannot recover the initial form becoming each time weaker. As we can see in the pictures before it is far away of take the value of the Steel.

So in conclusión I can affirm that wont be any problems with the main part of the structure.

7.11.-Stairs

The stairs of the windmill consist in simple cold-bent pieces of Steel, which are really cheap, to manufactured this pieces you only need a bar of Steel.

These pieces will be weld to the principal shaft of the windmill, 28 of them forming in this case a full stair to be able to climb to the top part of the windmill and reparais something or check any problem.

7.11.1.-Stairs analysis with ANSYS

To look the stress and the deformation of each piece i simulated in ansys with the forcé of the weight of one person estimate in 100 kg

To a forcé of 100 kg considering the Weld as a fix support.

After the simulation,we obtain by ANSYS first the total deformation:

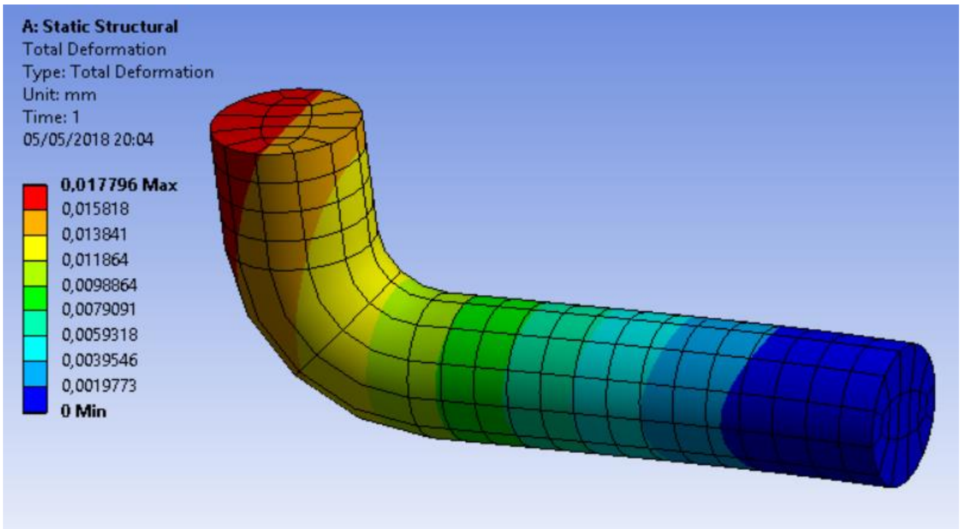


Figure 7.25.-Stairs Total deformation

And then the equivalent stress:

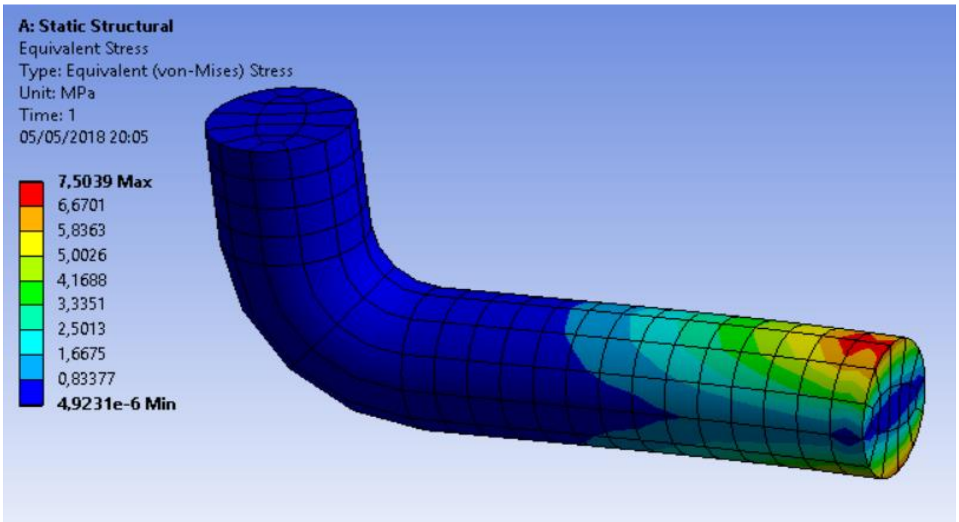


Figure 7.26.- Stairs Equivalent stress

The máximum stress is in the Weld part but it is really low, and we are proposing the worst situación ever, that is the one with the wind power.

Referring to the demorfation it is really low is 100 times less than a mm and occurs on the oposite side to the stress as it is normal.

About the von misses analysis, have to be less that the yield strength because if the tensions trespass that limit then the material cannot recover the initial form becoming each time weaker. As we can see in the pictures before it is far away of take the value of the Steel.

So in conclusión I can affirm that wont be any problems with the stairs.

7.12.-Generator

The generator, is one of the most important parts of the small wind generator because is the part that pass the kinetic energy from the blades to electrical energy.

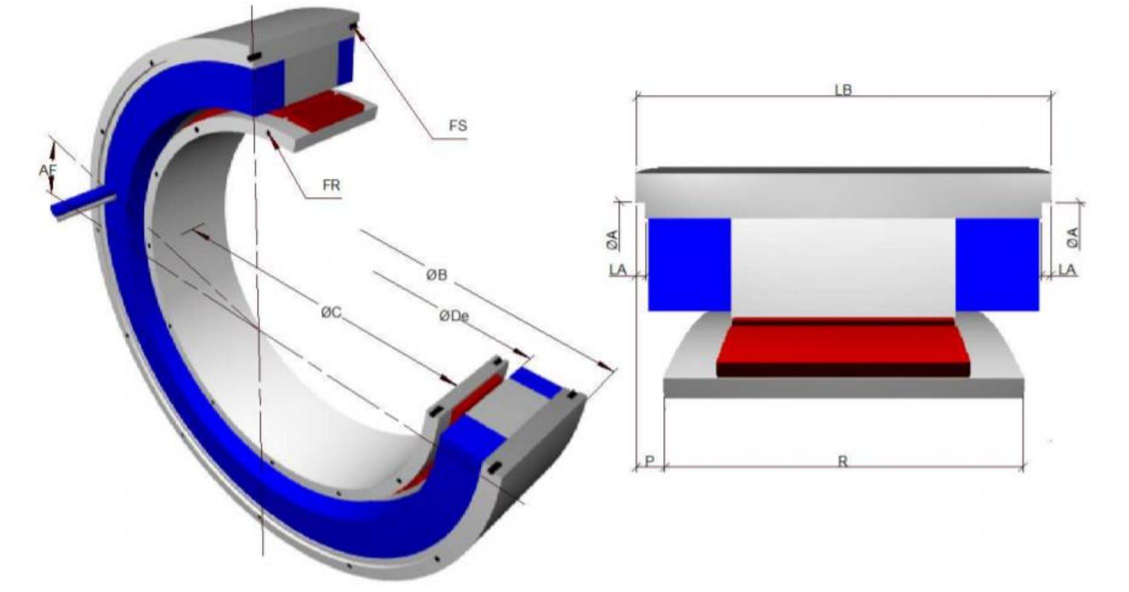
To optimize the power is important to choose one alternator that pas the maximum kinetic energy to electrical and with the maximum range of velocities so the alternator chosen is 145 STK “alternators for wind turbines” this alternators are from ALXION one manufacturer specialized in alternators for wind turbines, and have the following characteristics:

- No speed multiplier, no gear
- No maintenance
- Highest power-to-weight ratio in Direct Drive
- Simplification of mechanical design
- Easy mechanical interface
- Cost optimization

ALXION which is the company has many alternators depending on the requirements of the wind generators is chosen the alternator. Next there are the different range of velocities, power and dimensions.

These tables could be found on the webpage of the company and its the offer inside the 145 STK model.Which is the best to a low power instalation like this.

This first one reference the geometry of the alternator:



		145STK1M	145STK2M	145STK3M	145STK4M	145STK5M	145STK6M	145STK7M	145STK8M
Housing internal centering diameter	A H8	130	130	130	130	130	130	130	130
Angle wire output / tapped holes	AF	22°30'	22°30'	22°30'	22°30'	22°30'	22°30'	22°30'	22°30'
Housing external centering diameter	B f8	145	145	145	145	145	145	145	145
Rotoric internal centering diameter	C H7	56	56	56	56	56	56	56	56
Housing internal diameter	De	78.5	78.5	78.5	78.5	78.5	78.5	78.5	78.5
Rotoric fixation holes	FR	8xM5 sur Ø63	8xM5 sur Ø63	8xM5 sur Ø63	8xM5 sur Ø63	8xM5 sur Ø63	8xM5 sur Ø63	8xM5 sur Ø63	8xM5 sur Ø63
Housing fixation holes	FS	8xM5 sur Ø136	8xM5 sur Ø136	8xM5 sur Ø136	8xM5 sur Ø136	8xM5 sur Ø136	8xM5 sur Ø136	8xM5 sur Ø136	8xM5 sur Ø136
Depth of housing internal centering diameter	LA	2	2	2	2	2	2	2	2
Housing length	LB ±0.15	92	119	146	173	200	227	254	281
Alignment rotor / housing	P ±0.1	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Maximum rotoric contact diameter	Pmax	75	75	75	75	75	75	75	75
Rotor length	R +0.15	59	86	113	140	167	194	221	248

Figure 7.27.-145STK generator[23]

This second one refers to the tecnical characteristics of the alternator.

			145STK2M		145STK4M		145STK6M		145STK8M	
	Rated speed	Rpm	650	1500	650	1500	650	1500	650	1500
Rated Power at Rated speed	Rated power (1)(2)	W	571	1752	1307	3389	1962	4904	2633	6462
	Input torque at rated speed(1)(2)	N.m	11.2	13.9	25.4	25.2	36	35.9	47.8	47
	Efficiency at rated power (1)(2)	%	75	81	76	86	81	87	81	88
	Current at rated power (1)	Amps	1.4	4.3	3.2	8	4.8	13	6.4	16
	Voltage at rated power (1)(2)(3)	V	244	250	243	260	246	231	249	248
Rated Power at Half speed	Rated Power at half speed (1)(2)	W	204	690	493	1566	739	2319	1075	3097
	Input torque at half speed (1)(2)	N.m	8.9	11.5	20.7	25.4	28.8	36	43.5	47.8
	Efficiency at half speed (1)(2)	%	68	77	70	78	76	82	73	83
	Number of poles (number of pairs of poles)		12 (6)							
	Cogging torque	N.m	0.2		0.4		0.6		0.8	
	Phase résistance at 20°C	Ohm	19.8	4.53	8.6	1.4	4.11	0.59	3.18	0.51
	Phase inductance (5)	mH	105	24	60	10	34	4.9	25.8	4.1
	Voltage at no load (back emf) at 20°C (4)	V	365	393	390	367	357	312	361	334
	Rotor inertia	10^{-3} Kg.m2	1.28		2.24		3.19		4.14	
	Weight	Kg	6.2		10.4		14.5		18.7	
	Power cable square section (6)	mm²	4x1.5		4x1.5		4x1.5		4x1.5	
	Power cable diameter	mm	Ø8.6		Ø8.6		Ø8.6		Ø8.6	

Table 7.4.-Altenator electrical characteristics[23]

As we can see in the tables the rated power comes from 200 W to 5,5 kW the rated speed from 650 RPM to 1500 RPM and the hollow shaft is of 56mm diameter.

Inside this model there are 4 different models which are 145STK2M, 145STK4M, 145STK6M, 145STK8M, depending on the power and the speed you need for the windmill.

The graph power speed gave by the company is:

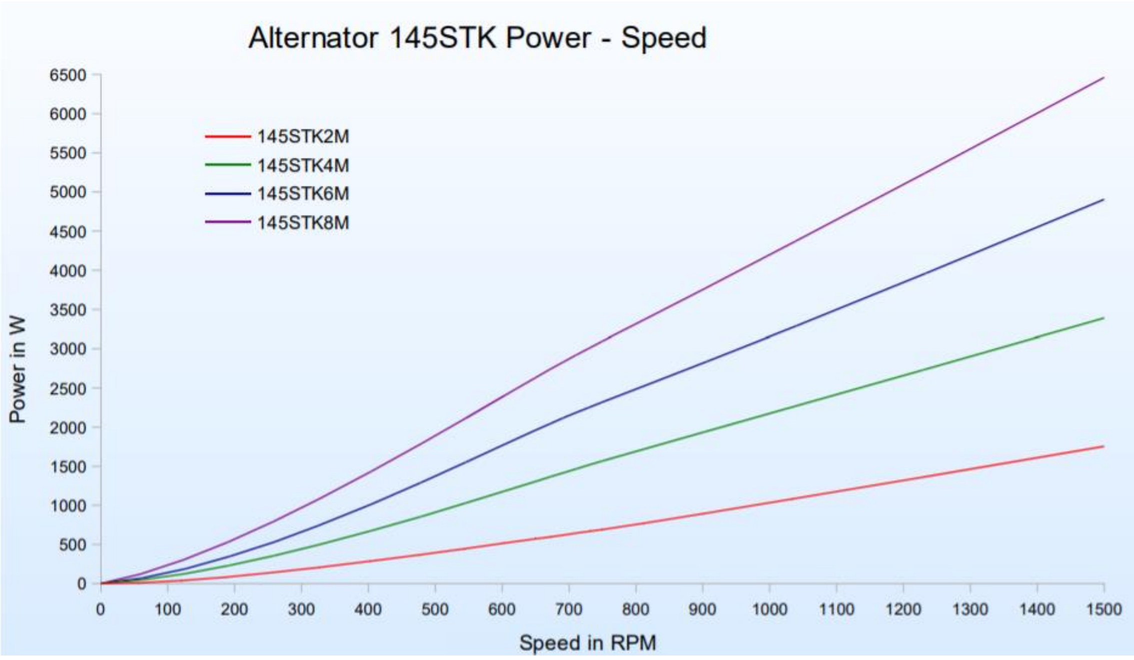


Figure 7.28.-Alternator curve Power/speed[23]

Considering the main wind speed there is 325 rpm as we calculated in the wind velocity parto f the memory with that value there is the following table following the graph of the alternator 145STK Power -Speed which is before posted.

Alternator	Power (W)
145SKT2M	300
145SKT4M	600
145SKT6M	950
145SKT8M	1350

Table 7.5.-Alternator power Excel values

The needed power is 1326 W so the alternator choosen is 145SKT8M that gives untill 1350 W.

7.13.-Stand alone battery system

Stand alone systems need a pack off batteries that supply energy while there is not enough wind. This systems are composed for a battery charger that pass from AC to DC then the batteries, after the batteries there is an inverter that pass from DC to AC.

There are many battery kinds but the most used for renewable systems are lead-acid batteries and nickel-cadmium batteries, the second ones are much more expensive so the batteries chosen for that application are lead-acid.

7.13.1.-Battery installation

Batteries emit a corrosive and explosive mixture of hydrogen and oxygen gas during the final stages of charging. This can ignite if exposed to a flame or spark so they must be installed in a well ventilated environment, preferably in an appropriately designed structure away from the house.

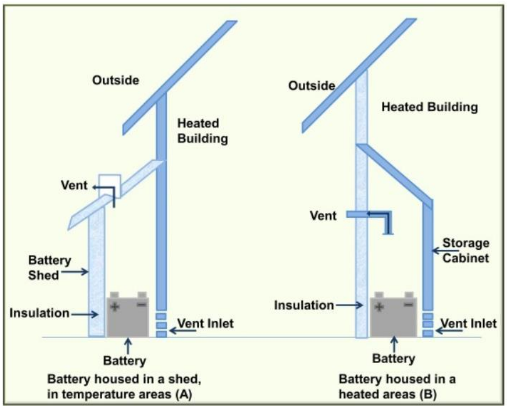


Figure 7.29.-Battery installation[25]

Because the gases rise, ventilation design must permit air to enter below the batteries and exit the room at the highest point. To install the batteries pack it have to be followed the next advices.

Ventilation can be achieved naturally or by installing fans and electrical vents. The amount of ventilation required depends on the number of battery cells and the charging current. A large battery bank using large charging currents needs more ventilation.

Do not install electronic components above a battery bank because of the risk of explosion and the possibility of component corrosion.

Install batteries in a drip tray to trap any spilled acid. Alternatively, wash any spillage to a sump and then neutralise it with bi-carbonate of soda (baking soda).

Batteries should be mounted on stands to keep them clear of the ground. If the batteries are ground mounted they should be thermally insulated from the ground temperature. They should not be installed directly onto concrete, as concrete will cool to ground temperature, causing the electrolyte to stratify. This is detrimental to a battery's long-term life and performance. Low electrolyte temperatures also reduce the capacity of a battery.

Batteries must not be installed where they will be exposed to direct sunlight, as high temperatures may cause electrodes to buckle.

The typical area required for the installation of a battery bank is:

- 12V; 12m x 0.25m or 0.7m x 0.6m
- 24V; 2m x 0.6m
- 48V; 3m x 0.7m

The batteries can be as high as 700mm, and if installed in a box it must have a removable lid or at least 500mm clearance above them to allow access for a hygrometer to check the charge level.

Access to the battery room or container should be limited to responsible people trained in system maintenance and shut down procedures.

Safety signs are required in accordance with Australian Standards.

The installation must include a switch/fuse near the batteries to enable the bank to be electrically isolated from the rest of the system

7.13.2.-Battery live

To ensure a long Battery live we must sure to check if our equipment keep clean and tight and ensuring the electrolyte is kept above minimum levels. Using only distilled water when topping up the electrolyte level.

Batteries are dangerous items and must be treated cautiously. There are three main dangers with batteries:

-Explosion or fire from the battery gases.

-Short-circuiting the terminals.

-Acid burns from wet, lead-acid batteries.

Ensure that when working with batteries you do not short across the battery terminals. Under Australian Standards the terminals must be covered (shrouded) to prevent accidental shorting.

Wet, lead-acid batteries contain a fluid electrolyte that contains sulphuric acid. This can cause serious burns to the skin and eyes. Always wear protective clothing and eye protection. If "acid" is spilt it must be diluted with water and neutralised with sodium bi-carbonate. These should be readily accessible and stored near the battery bank.

Batteries need specific charge regimes that include equalisation charging. The system designer will explain this process. The equalisation charge will either be controlled by the system or require the owner to connect a generator and battery charger. Specific gravity readings are the best method to determine the charge level. A safe method for performing this will be explained by the system designer.

System owners should read and fully understand the manufacturer's manual for their battery bank.

7.13.3.-Braking system

When the winds are too strong it must be a brake system that stop the rotation of the blades because appear strong loads that can damage some parts of the generator. There are many brakes systems, the one chosen for the project is a hydraulic-mechanical brake, that kind of brakes can apply strong forces without been to many big, due to there is not many space inside the nacelle and it is needed a strong force to stoop the rotation of the blades it has been chosen that option.

The nacelle will be connected to an anemometer, when the wind speed pass the maximum value, 25 m/s the brake will receive a signal and will actuate, then till the wind do not decrease the brake will not be opened. The brake it also can be activated when the customer want, for example if there has to be changed some pieces.

First choosing the brake it have to be calculated the moment that needs to be applied in the axis to stop the rotation, it is calculated as is showed in the next equations.

$$J = \sum X_i^2 .m_i$$

$$C = \frac{J.n}{9{,}55.t}$$

With Catia i can obtain the mass and the Xg for the wings,which is the object than must be stop.

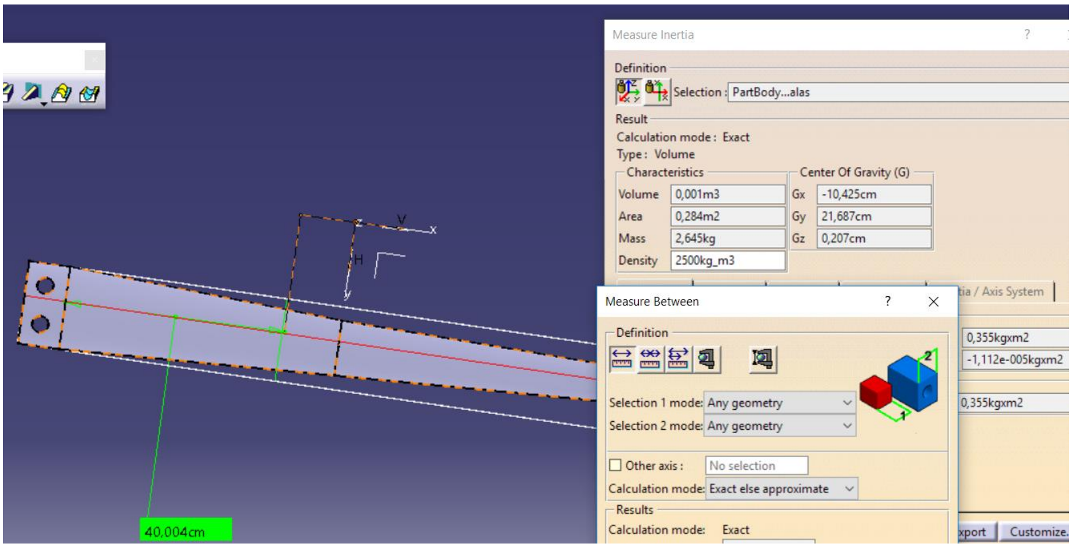


Figure 7.30.- Rg Wings CATIA

So as we can see the weight of each wing is 2,6 kg and the Xg 0,4.

$$J = \Sigma 3*0.4^2*2.6 = 1.248\ Kgm^2$$

$$C = \frac{1.248*1500}{9.55*5} = 39.02\ Nm$$

Coremo is a manufacturer specialized in brakes, they have a special division of brakes called “mini” that can adjust very well to the characteristics of the small turbine. With the dimensions needed and the technical data of the catalogues the brake chosen is MINI CL5.

The brake will be fitted in the nacelle by screws as the alternator and the pillow that support the bearing B.

7.14.-Blades

The most common design for blades for a small wind generators are **fixed step blades,** (like a normal knife than you can find in your kitchen)that ones are not the most efficient but incorporate a system to change the attack angle depending on the speed of the wind it would increase a lot the cost of the small turbine so it has been chosen the first solution.

One solution to solve the strong loads that push the blades when the pressure of the wind is high is to change the attack angle along the blade, giving bigger angles in the last part of the blade. That has been the solution chosen in the annexe part one there is a superficial design of the blades where there is designed the blade taking an attack angle and the lengthened. The design of that part is not more detailed because it has been considered that is not the objective of the Project and also is not a good solution for the cost of the wings.

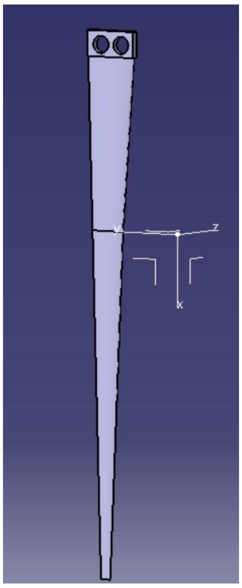


Figure 7.31.-3D model of the wing

About the materials to manufacture the blades there are different options, but before give the options it have to be stipulated the main characteristics of the blades:

- Light
- Perfectly homogeneous
- Rigid
- Resistant to the mechanical fatigue
- Resistant to erosion and to the corrosion
- Low cost in order that the small generator is as for competitive price

The materials that adjust to that characteristics are:

- Wood; simple, light, easy to work and it resists well to the fatigue ·

- Metals; light alloys of aluminium are used with silicon or with magnesium, with these materials are obtained very low costs if they are manufactured in big Series. One of the disadvantages is that the aluminium resists badly to the fatigue, which It limits its employment.

-Synthetic Materials; resins, fibers and plastic: they stand out for its low weight, Insensibility to the corrosion and its good resistance to the fatigue but the cost is more raised that in the previous cases.

The option chosen is the third one use compression molded fibreglass. The type of fibreglass chosen for the blades is a Glass-E, that type of fibreglass is used for most of the manufacturers and the main characteristics are, shown in the next table.

Elastic Modulus	72 Gpa
Tensile strength	3500 MPa
Density	2540 Kg/m^3
Coefficient of Poisson	0.22

Table 7.6.-Wings material characteristics

That is the most expensive option, but the cost does not increase so much compared with the other options and the final characteristics that gives the material are perfect for the application.Like the installation and the wings are one of the most important parts of the windmill

The rotor and its three rotor blades constitute a rather flimsy structure, consisting of cantilever-mounted blades on a central hub. The basic design aspects for a rotor blade are the selection of material and shape. The material should be stiff, strong, and light. The shape should be aerodynamic, similar to that of an airplane wing.

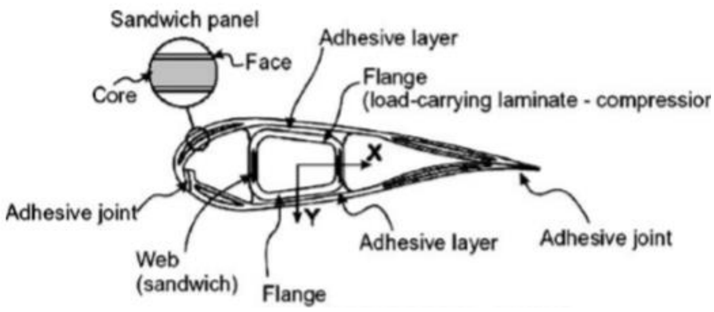


Figure 7.32.-Wing Inside[28]

The shape of a rotor blade in cross section is shown in Figure 4.16. The aerodynamic contours are formed by the (outer) relatively thin shells. They are supported structurally by a longitudinal beam or by webs, which carry a substantial part of the load on the blade. In the longitudinal direction, the rotor blades are tapered and twisted. The tapering is needed to economize with weight of the material because of the increasing loads from tip to root of a cantilever structure. The tapering, both in external shape and in thickness of the shells/beams/webs, is usually designed to ensure the same materials loadings, e.g., a maximum strain as design allowable. The challenge for the designers is thus to go beyond the simple plank and integrate the aerodynamic shape, the tapering and the twist, into a design of the blade structure that is optimized with respect to materials selection and cost-effective production.

7.15.-Maintance

Inside the tasks of maintenance it is necessary to distinguish between preventive or planned maintenance and the correction or not planned to answers to the problems discovered by the user.

In this chapter one speaks about preventive maintenance. Inside the tasks of maintenance annual inspections must be realized of:

- Inspection and adjustment of the nuts
- Inspection of the blades
- Inspection of the axis
- Inspection of the alternator
- lubricate the bearings of the support of the nacelle
- Inspection of the electrical connections

7.16.-Future Component Development Trends

There are new component developments underway now that will significantly change the materials usage patterns. Generally there are trends toward lighter weight materials, as long as the life-cycle cost is low. Specific development trends in turbine components are discussed below:

-Rotors: Most rotor blades in use today are built from glassfiber-reinforced-plastic (GRP). Other materials that have been tried include steel, various composites and carbonfilament-reinforced-plastic (CFRP). As the rotor size increases on larger machines, the trend will be toward high strength, fatigue resistant materials. As the turbine designs continually evolve, composites involving steel, GRP, CFRP and possibly other materials will likely come into use.

-Gearboxes:The step-up gearbox used on large turbines today is expected to be replaced in many future machines. Most small turbine designed for battery charging use a variable speed, permanent magnet, variable frequency generator connected to a rectifier. As high power solid state electronics are improved, larger and larger machines are likely to use AC-DC-AC cycloconverters. This is the case on turbines being developed by Northern Power Systems (100 kW), the ABB (3 MW), and in some commercial machines. This trend will increase the use of magnetic materials in future turbines. Large epicyclic gear boxes used in large ships, may continue to be the drive system for some large turbines.

-Nacelles: The nacelle contains an array of complex machinery including, yaw drives, blade pitch change mechanisms, drive brakes, shafts, bearings, oil pumps and coolers, controllers and more. These are areas where simplification and innovation can pay off.

-Towers Low cost materials are especially important in towers, since towers can represent as much as 65% of the weight of the turbine. Prestressed concrete is a material that is starting to be used in greater amounts in European turbines, especially in off-shore or near-shore applications. Concrete in towers has the potential to lower cost, but may involve nearly as much steel in the reinforcing bars as a conventional steel tower

8.-Economical Topic

In this chapter there are studied all the economic aspects of the project to see if the project is viable from the economic point of view. First of all there is a presentation with the cost os some different windmills after i present the estimation of the budget of the project and from this is studied the profitability of the investment and the pay-back of the investment.

Small wind systems involve a significant initial investment, they can be competitive with conventional energy sources when you account for a lifetime of reduced or altogether avoided utility costs, especially considering escalating fuel costs.

The cost of a wind system has two components:

-initial installation costs

-operating expenses

Installation costs include the purchase price of the complete system (including tower, wiring, utility interconnection or battery storage equipment, power conditioning unit, etc.) plus delivery and permitting costs, installation charges, professional fees and taxes, also the prices of the installation changes depending of the kind of installation.

There are two kinds of installations, grid-connected and off-grid systems.And of course each one generates money in a different way.

8.1.-Grid-connected installation

The cost of buying and installing a small wind energy system typically ranges from about $3,000-5,000 per kilowatt for a grid-connected installation, less than half the cost of a similar solar electric system. The length of the payback period (or, the time it takes to "break even") depends on the system you choose, the wind resource at your site, your power provider's electricity rates, and financing and incentives available.

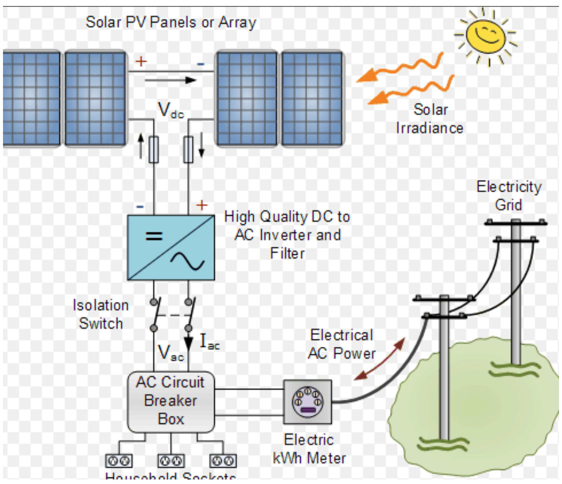


Figure 8.1.-Grid connected system[6]

Can see in the figure how this system Works just changing the solar for wind the system in the house and the way it connects to the public red its the same.

Small wind owners with strong average wind speeds who can take advantage of rebate programs can usually recoup their investments within fifteen years. Most of the power generated by a grid-connected system can be valued at the retail rate of electricity, reducing the amount of time it takes for a system to pay for itself.

8.2.-Off-Grid Systems

Remote systems, with operating battery storage typically cost more, averaging between $,4,000 and $5,000 per kilowatt. Individual batteries cost from $150 to $300 for a heavy--duty, 12 volt, 220 amp-hour, deep-cycle type. Larger capacity batteries, those with higher amp--hour ratings, cost more. A 110-volt, 220 amp-hour battery storage system, which includes a charge controller, costs at least $2,000.

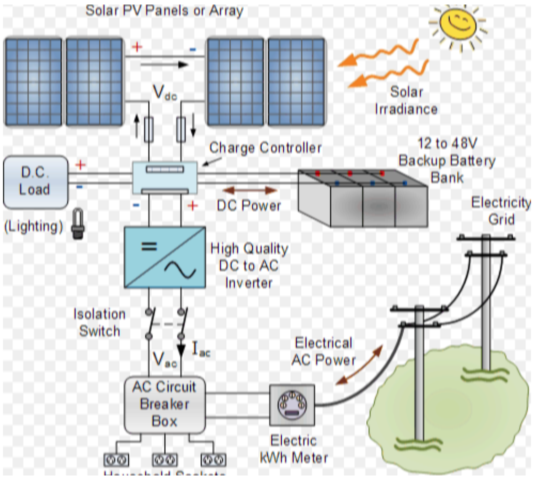


Figure 8.2.- Off-gridd systems[6]

Can see in the figure how this system Works just changing the solar for wind the system in the house and the way it connects to the public red its the same.

8.3.-Smaller wind energy systems

Systems smaller than 1 kW are more typically used in stand-alone applications, or as part of a hybrid system with solar PV cells. A 400-watt system can be installed for $960. In the following table there is a resume of the prices for the different systems.

Type of system	estimated cost (€/KW)	battery (€)	maintenance and service	payback (years)	usefull life (years)
Grid connected	3000-5000	not necessary	2%-3% of the inicial cost	8-16	20
off-grid	4000-5000	120-240	2%-3% of the inicial cost	8-16	20
smaller wind generators	1000-2000	120-240	2%-3% of the inicial cost	7-8	10

Table 8.1.-Type of system/cost

Remote systems may require operating battery storage. Individual batteries cost from 96€ to 192€ for a heavy-duty, 12 volt, 220 amp-hour, deep-cycle type. Larger capacity batteries, those with higher amp-hour ratings, cost more. A 110-volt, 220 amp-hour battery storage system, which includes a charge controller, costs at least 1280€.

8.4.-Estimated cost $/kWh

The statistics referred in the bibliography shows the electricity prices for household end users in Romania semi-annually from 2010 to 2017.In the first half of 2016, the average electricity Price for house hold was 12,6 Euro cents / KWh.This decreased to under 12 euro cents the following year.

As we can see in the following table.

TIME/DATE	Euro cents per KW/h
2010 S1	10.31
2010 S2	10.52
2011 S1	10.82
2011 S2	10.85
2012 S1	10.5
2012 S2	10.75
2013 S1	13.23
2013 S2	12.79
2014 S1	12.9
2014 S2	12.48

Table 8.2.-Statics cost electricity Romania

The cost of the energy produced by small (<10 kW) wind turbines over their lifetimes has been estimated to vary from $0.07/kWh, for a low cost turbine constructed in a windy area, to $0.96/kWh, for a high cost turbine constructed in a low wind área.

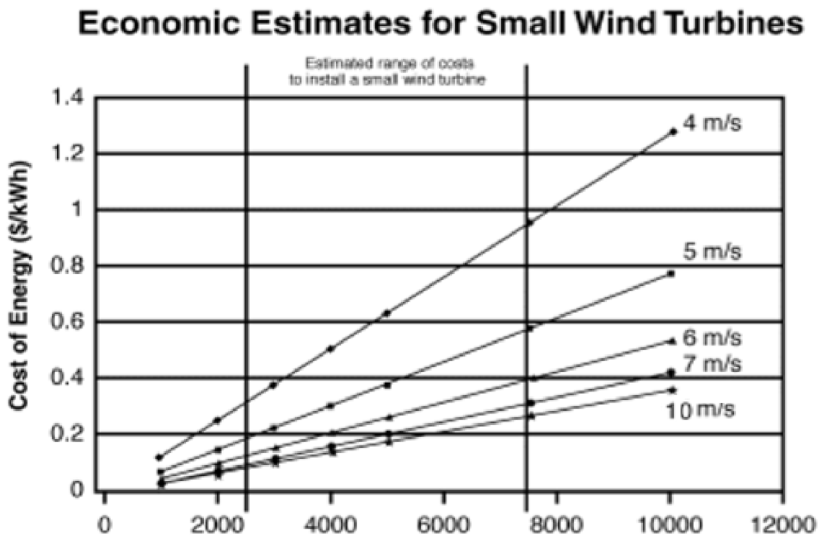


Figure 8.3.-Economic Estimates for small wind turbines

Then with the estimated costs and knowing that the cost of the Kwh sold for the company is around 0,126 euros/Kwh it can be seen that the project will be viable, because of when we install the small wind generator the cost of the electricity is reduced.

Ill check after this chapter if it is or no.

8.5.-Budget of the Project

In the next table, there is an estimation of the cost of the project. The prices of the main elements has been taken from the magazine "Wind power" and Financing-and-Investment-Trends-2016 as is showed in the references while the rest of the pricesbearings are from catalogues from SKF, screws and joins from nbk webpage which is the company Will sell us this equipment,the Steel Price and foundries are taking from "fundiciones fumbarri Durango S.A." Spanish company specialized in metals and foundries.

The cost of the foundries has been estimated by the volumen in catia plus the cost of manufacturing its the way more close to the reality.The rest of the pieces have the exact cost it have.

Part	Price in euros	Price in leis
Alternator	*300*	*1350*
Battery	*250*	*1125*
Battery charger	*120*	*540*
Bearing 6416 SKF	*60*4=240*	*1080*
Blades	*400*3=1200*	*8100*
Brake	*250*	*1125*
Base	*380*	*1710*
cases	*700*	*3150*
Foundries	*1000*	*6300*
Inversor	*200*	*900*
Lubricators	*30*	*135*
Tower	*1200*	*5400*
Stairs,cables and tower supports	*20*28=560+40*3+60*3=860*	*3870*
Welds	*240*	*1080*
Installation cost	*2500*	*11250*
Total	**7490**	**33705**

Table 8.3.-Total Budget of the project

8.6.-Subsidies to the wind power

To promotes the Aeolian energy the Spanish government give subsidies for the Aeolian projects, in that part of the memory there is explained this subsidies and included in the butget of the project

First of all and reading the article 3 of the “orden” 3273 (council of Industry and Environment), it is seen that the project can receipt a subside due to is an installation less that 100KW.

Following the annexe 1of the article 7 is known the exact receipt quantity, for that case, less that 5KW the subside is 2,4 €/W installed

$$Subside = 2{,}4 euro / W . 1800 = 4320 euros$$

Then the table presented before in the first part of the Budget it is:

Part	Price in euros	Price in leis
Alternator	*300*	*1350*
Battery	*250*	*1125*
Battery charger	*120*	*540*
Bearing 6416 SKF	*60*4=240*	*1080*
Blades	*400*3=1200*	*8100*
Brake	*250*	*1125*
Base	*380*	*1710*
cases	*700*	*3150*
Foundries	*1000*	*6300*
Inversor	*200*	*900*
Lubricators	*30*	*135*
Tower	*1200*	*5400*
Stairs,cables and tower supports	*20*28=560+40*3+60*3=860*	*3870*
Welds	*240*	*1080*
Installation cost	*2500*	*11250*
Total	**7490**	**33705**
Subside	**-4320**	**-19440**
TOTAL	**3170**	**14265**

Table 8.4.-Budget after Spanish goberment subsides

How the windmill its made for Romania I have to check the Romanian law to know how much is the help from the goberment, with the help of my tutor Mss Oana Dodun Romania has the law 220/2008 who refers to renavable energy specially from the wind and it referrs to help a subside of the 50% of the cost of the windmill.

So in this case we have:

Part	Price in euros	Price in leis
Alternator	*300*	*1350*
Battery	*250*	*1125*
Battery charger	*120*	*540*
Bearing 6416 SKF	*60*4=240*	*1080*
Blades	*400*3=1200*	*8100*
Brake	*250*	*1125*
Base	*380*	*1710*
cases	*700*	*3150*
Foundries	*1000*	*6300*
Inversor	*200*	*900*
Lubricators	*30*	*135*
Tower	*1200*	*5400*
Stairs,cables and tower supports	*20*28=560+40*3+60*3=860*	*3870*
Welds	*240*	*1080*
Installation cost	*2500*	*11250*
Total	**7490**	**33705**
Subside	**-3745**	**-16852.5**
TOTAL	**3745**	**16853**

Table 8.5.-Budget after Romanian goberment subsides

So its very close with this romanian bdget Will start the calculus.

8.7.-Study generation of energy

In this subpart is determined the price of the Kwh generated by the small wind generator after will be compared that price with the price of the kWh given by the electrical companies and then will be possible assure if the project is profitable or not economically speaking.

The internal rate of profitability that indicates the viability of the Project,it is one of the main parameters to determinate it is able or no.It is a economical parameter.

The internal rate of profitability depends of the ECB. The internal rate of profitability depends on the applied interest rate "r" and on the years of useful life of the installation "n".

The rate of interest applied r is the average interest rate of the money in the moment of the study. This parameter does that the financial expenses associated with the investment change so the price of the generated energy is major or minor. As for the useful life of the small generator "n" is the time estimated of functioning of the installation.

Following some studies for 2018 which comes from the ecb Will be aproximately of 0,075 and one "n" of 18 years of in the equiation we can estimate the TIR with the following equiation.

$$TIR = \frac{r}{\left(1 - \frac{1}{(1+r)^n}\right)} \qquad \frac{0.075}{\left(1 - \frac{1}{(1+0.075)^{18}}\right)} = 0.0925$$

This way the formula that fixes the capital cost C_c for kWh generated it will be a function of the initial investment "I", of the internal rate of profitability "TIR", of the power of the installation "P" and of the parameter named factor of capacity FC, which represents the quotient between the energy produced annually in kWh and the one that might produce if the small generator was working constant.

$$C_c = \left(\frac{I}{P}\right) \cdot \left(\frac{TIR}{FC.8760}\right)$$

$$FC = \frac{\text{H working}}{\text{H one-year}} = \frac{9*365}{24*365} = 0.38$$

$$Cc = \left(\frac{7490}{1363}\right) * \left(\frac{0.0925}{0.38*8760}\right) = 0.0763 \text{ Euros /Kwh}$$

Finally, the cost of generation of every kWh comes given by the sum of the capital costs plus the operation and maintenance costs. Inside the annual costs of operation and maintenance reinstatements can be included but to simplify it is supposed that these costs suppose 2 % of the initial investment. In the following equation there is specified the calculation of the costs of operation and maintenance.

$$Cc = \frac{0.02*I}{P*FC*8760} = \frac{0.02*7490}{1363*0.38*8760} = 0.033 \text{ Euros / Kwh}$$

Then the costs of generation of electricity are the sum of the capital costs plus the costs of operation and maintenance.

Price / KWh =Cc + Com = 0.1093 Euros / Kwh

8.8.-Calculation of the pay-back of the investment

The pay-back of the investment is the time that passes until the investment is amortized. For it, it is necessary to study the movement of funds during the first years of development of the installation. The movement of funds is the difference between expenses and income that the investment generates.

The expenses of the installation are:

-Initial investment

-Expenses of operation and maintenance

The income that the installation generates is:

- Saving consumption of electricity

The expenses of the installation are known, first one is the initial investment. About the expenses of operation and maintenance are not known as is said in the part before it is supposed 2 % of the initial investment (to simplify the expenses of operation and maintenance overheads are supposed and invariable for time). Then the expenses of the installation are the following equations:

Com=0,02*I=0.02*7490=149.8 Euros

Cinstallation=3745 Euros

The saving consumption of electricity is calculated with the annual electricity bill that it should paid to the electrical company if there was in use the service that they offer.

I Will call in this way:

- Term of invoicing of energy; it is the product of the emaciated energy, EC (kW · h) for the price of the term of the energy you (euros/Kwh).

From the Romanian company E-on i obtain the Price of the electricity which is:

"Moldova (Judeţele Iaşi, Bacău, Vaslui, Neamţ, Botoşani, Suceava).Tariful avizat pentru E.ON Energie România S.A este de 0,4975 lei/kWh, exclusiv TVA."
So, from 1st January 2018 the prices for householders is liberalized ... there are differ ent companies in different parts of Romania ... the price is 0,597 lei with VAT.

Changing this to euros,our final prince is 0.1326 euros/Kwh

It is necessary to add the rent and the VAT (In romania it is 19 % on the whole of the invoice). In the following table appears the format of the invoice of electricity.

Energy	EC*te
Rent	0.72*N
TOTAL	EC*te+0.72*N
VAT	19%
TOTAL BILL	1.19*(EC*te+0.72*N)

Table 8.6.-Total Bill

According to this the romanian tariffs are:

EC=E_{mean} *365=10850 Wh/day *365 =3960.25 Kwh/year

Save=1.19*(3960.25*0.13260+0.72*12)=635.1825 euros/year

With the cost of the initial investment, the costs of operation and maintenance and the incom that generate (saving consumption of electric power) it is possible to calculate the return period of the investment.

Concept	0	1	2	3	4	5	6	7	8
Investments	3745	0	0	0	0	0	0	0	0
Costs	149	171	171	171	171	171	171	171	171
Total payments	3894	171	171	171	171	171	171	171	171
Total collections	635	635	635	635	635	635	635	635	635
Funds movements	-3259	464	464	464	464	464	464	464	464
Acumulated funds movements	-3259	-2795	-2331	-1867	-1402	-938	-474	-10	454

Table 8.7.-Period of investment

In the table there is detailed the annually movements of funds, where is observed that the return period (PAYBACK) is 7-8 years because the seventh year you only lose 10 euros.

9.-Conclusions

The cost to generate 1KWh (0.11 Euros /Kwh) is less than the price that the electrical company sell us the electricity about (0.13 Euros /Kwh) , but that value is not realistic because actually the European Union gives a lot of incentives, subsidies, to the owners that decide to get a kind of renewable energy to supply themselves, so if there will not be that helps from the government for sure the wind power for small application will not be profitable.

One of the most important causes for that is the low yield of the blades, only a few part from the wind power is profitable, about 40% then we have to plus the loss of the alternator, about 5%, so actually for small applications, as the project application, is needed a big rotor diameter to supply energy so that kinds of applications are only useful for places where the electricity cannot arrive or places that have problems with the electric grid.

Another important problem with that type of applications is that nobody can assure a constant strong wind during all the year so is needed a battery system that save electricity for the days that there is not enough wind. In order to solve that problem there are some hybrid systems that mix solar panels small wind turbines and gas-oil motors then the electricity supply is more guaranteed.

About the economical analysis done in the project it can be seen that the initial investment is returned, pay-back, in the seventh-eighth year so knowing that the estimated live time for that type of installations is about 18 years there will be a gain.

But one of the most important thing about the wind power and maybe the main reason why all the governments are wasting money and time is that is a clean and free energy and is a very new technology with many parts to be improved so after all the advantages and disadvantages it has to be think that there is a lot to investigate.

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[36]DYNAMIC ANALYSIS OF A WIND TURBINE BLADE By SAMBIT SARANGI

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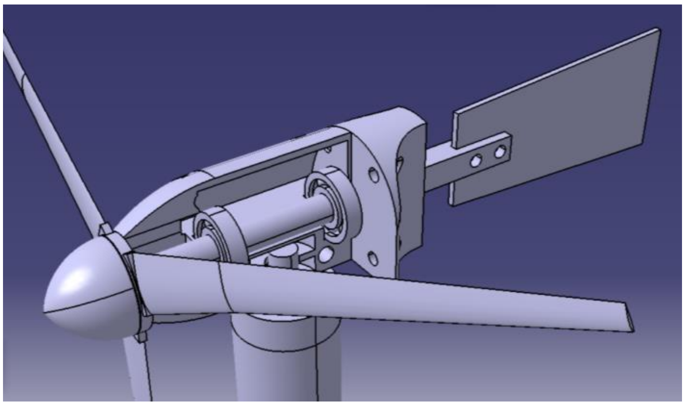

Design of a windmill for a romanian countryside home

ALVARO BARINAGA RODRIGUEZ

ANNEXES 1

CALCULATIONS

SUMMARY ANNEXES

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List of tables

1.-Design of the Blades

The blades are an important part of the small generator. In that part there is a small study of the main design parameters like the attack angle, profile, length, sustentation coefficients, number of blades and inclination angle.

First of all it is explained the main parameters.

- The profile of the spade is the intersection of a blade with a cylinder which axis is the rotation axis of the rotor.

- The width of the profile L or also called string of profile is the maximum length of a transverse section of the blade.

- The angle of attack α is the angle formed by the string of the profile and the direction of the relative speed w.

- The angle of inclination β is the angle that form the relative speed w with plane of rotation of the helix.

- The angle of sustentation is the angle that forms the string of the profile with the plane of rotation of the helix.

In the following figure there are drawn the main parameters of the blade study.

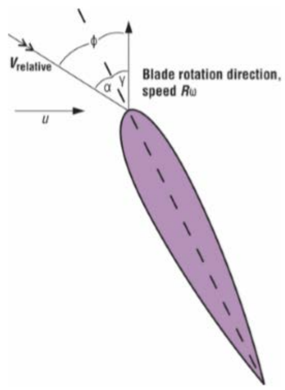


Figure A1.1 Speed diagram

There are two forces that affect on the blades, the lift and drag power.

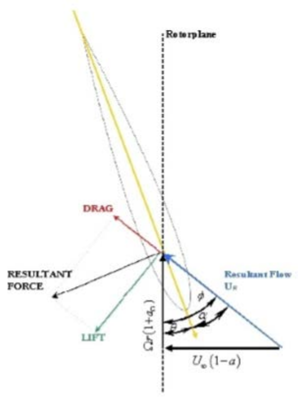


Figure A.1.2.Force diagram

The parameters are explained in the following table

$u_1 = U_\infty(1-a)$	the rotor disk induced velocity
$\Omega r(1+a_\Omega)$	velocity due to rotation
U_r	resultant hydrodynamic velocity
θ	local blade twist, the angle between the zero lift line to the blade translational velocity
ϕ	advance angle as given in equation
$\alpha = \phi - \theta$	hydrodynamic incidente

Table A1.1 angles explanation

Both forces can be calculated by the following equations

$$F_{Lift} = C_x . \frac{1}{2} . \rho . v^2 . S$$

$$F_{Drag} = C_y . \frac{1}{2} . \rho . v^2 . S$$

- Cx and Cy are the sustentation coefficients calculated by the profile NACA 4412.
- ρ is de air density
- v . is the speed of the wind
- S is the area of the rotor diameter

To design the blades it has to be chosen an attack angle that makes the relation $\frac{Cx}{Cy}$ get the maximum value, the Cy must be the maximum value and Cx the minimum value. Then with a profile NACA 4412 and the maximum value for the relation explained it can be founded the attack angle.

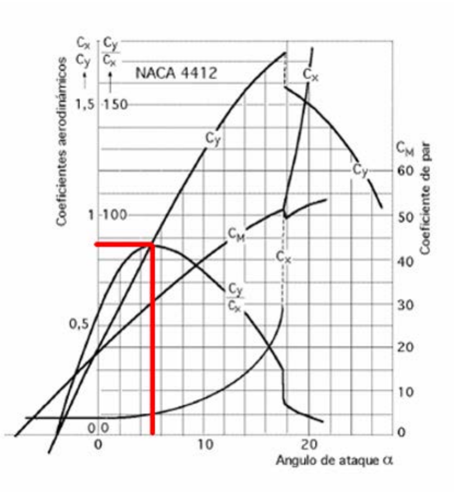


Figure A1.3.-Attack Angle

After showing the main parameters of the blades is explained witch parameters has been used to model the blades with the program used (CATIA). The following table shows the main parts of the design of the blades. In the model drawn with CATIA it has been used a similar profile form, the main dimensions used for the blades are:

Lengthened	1.5 m
Attack Angle	5º
Maximum chord	150 mm

Table A.1.2.main Blade dimensions

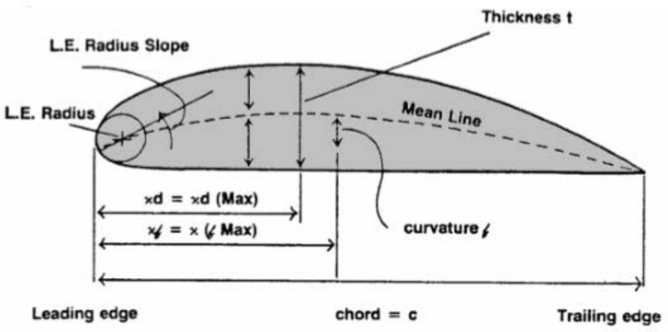


Figure A.1.4. Dimensions of the blade

The picture shows the main dimensions of the blade profile. As is said before it has been chosen the same profile for the blades but due to the blade design and optimization is not the object of the project there is not an exhausted study for the dimensions of the blade profile.

2.-Efforts on the Blades

2.1.-Centrifugal force

The centrifugal force pushes the blades towards out and tends to extract them from the blade-hub. To calculate the centrifugal force it is necessary to know the mass of every blade Mblade, The distance from the axis of rotation, the gravity center of the blade rG and the speed in the c.d.g. of the blade. As the geometry of the spade is not known, it is supposed That the c.d.g. of the spade is to the half of its length. In the equation appears the expression for the centrifugal force Fcentrifugal.

$$F_{Centrifugal} = \frac{1}{2}.m_{pala}.\frac{v_G^2}{r_G}$$

The velocity of the blade gravitational center is calculated in the next equation

$$v_G = \omega.r \rightarrow n.\frac{2\pi}{60}.r_G$$

With these two equations we can obtain the rest this is:

$$F_{Centrifugal} = \frac{1}{2}.m_{pala}.\frac{\left(n.\frac{2\pi}{60}.r_G\right)^2}{r_G}$$

$$F_{cetrifugal=}0.5 * 2.6 * \frac{\left(325*\frac{2*\pi}{60}*0.4\right)^2}{0.4} = 602.32N$$

$$\text{With} \quad n = \frac{\lambda*60*v}{\pi*D} = \frac{5.67*60*9}{\pi*3} = 325$$

With Rg=0,4

Catia can calculate the Rg, with our 3D model of the windmill as we can see in the picture:

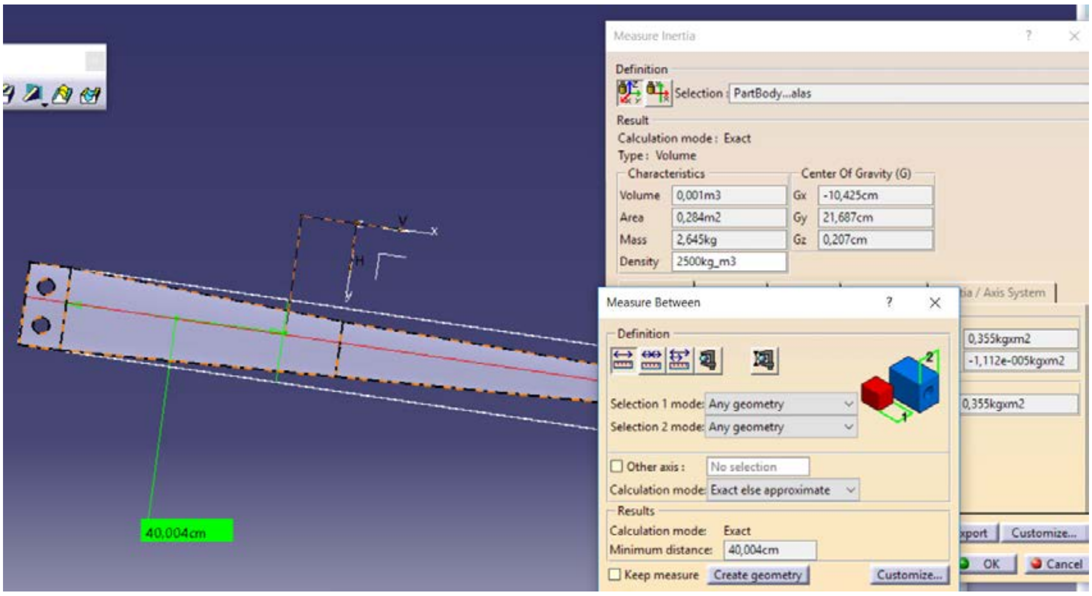


Figure A2.1.-Rg of the blade

2.2.-Calculation of the aerodynamic resistance of the blade

There is an equation that gives an approximated value of the aerodynamic force that the blades will support while is rotating, for three bladed turbines the equation is

$$F_{aerodinamic} = 0,62 * A * v^2_{mean}$$

$$F_{aerodinamic} = 0,62 * \frac{\pi * D\hat{}2}{4} * 9^2 = 355 \text{ N}$$

When the wind turbine is not rotating there is another expression that estimates the wind 7robl, equation

$$F_{estatic\ wings} = 2 * \Omega * F_{aerodynamic}$$

Ω is the coefficient of solidity, The solidity indicates the relation between the geometric 7rob of the 7robl and the 7rob swept by it. The expression of the solidity coefficient is showed in the following equation.

$$\Omega = \frac{Nblades * S\ blades}{Arotor}$$

The sodidity coefficient 7rob be estimated with the following graphic , knowing that is a three bladed turbine and the tip speed coefficient λ, there 7rob not be a 7roblema to get a value from the graphic.

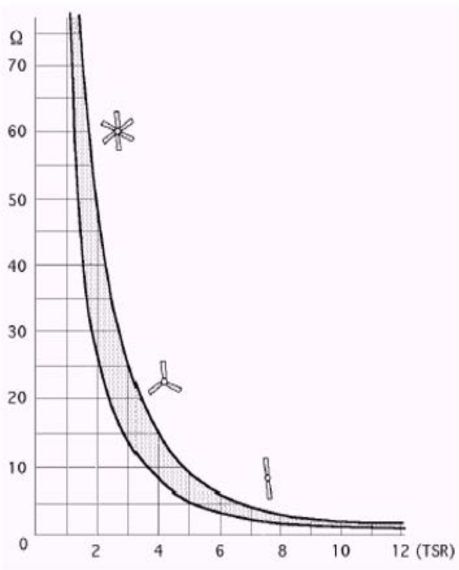


Figure A2.2.-Solidity coefficient

With the tip speed ratio 6 the maximum solidity coefficient is 10%

The Surface of the wings are 0.284 m^2 as we could see before catia gives us this área.With this, now is going to be calculated Ωand compared with the coefficient founded with the graph

$$\Omega=\frac{Nblades*S\ blades}{Arotor}=\frac{3*0.284}{\frac{\pi*3^2}{4}}=0.1205$$

The coefficient of the blades designed is less that the maximum from the graphic, then there is a good relation between the area of the blades and the swept area

Finally is calculated the $F_{estatic}$ for one Blade.

$$F_{estatic}=2*0.1205*355=85.55\ N$$

Due to the generator is composed for three Blades

$$F_{estatic}=3*85.55=26.65\ N$$

2.3.-Calculation of the flexor moment on the wings

The flexor moment is calculated using the aerodynamic force, and substituting the correspond values in the following equation

$$M_{flexor}=dg*F_{aerodynamic}$$

It will be calculated for both options, first for the static one and then with the dynamic

$$M_{flexor}=dg*F_{aerodynamic}=0.4*355=142\ N$$

$$M_{flexor}=dg*F_{estatic}=0.4*85.5=34.2\ N$$

3.- Calculation of the horizontal axis bearings

The most important thing, which is the clue of the forcé are the wind speeds these are represented in the following table, as we can calculate in the memory before of the Project.

work hours per day	wind speed(m/s)	%
3	5	33
4	9	44
2	15	22

Table A3.1.Speed table

The rotation speed of the generator changes depending on the wind speed, following the weibull distribution showed in the memory and the table 3. there is the following graphic A3.1

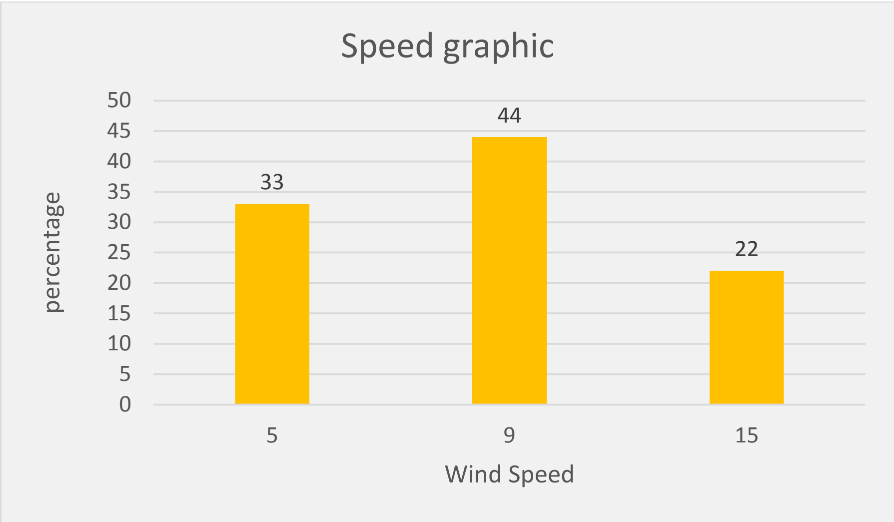


Figure A3.1.Speed Graphic

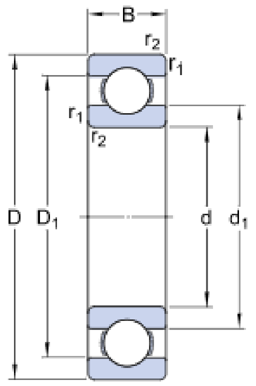
Exist also an imbalance force that appears due to the dirt that can be accumulated on the blades, the wear of the blades can also origin that force.

$$Fd=m*e*\boldsymbol{\omega}^2$$

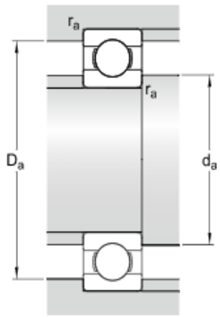
$$e=K*D=0.0010*3=0.003$$

With the geometry to enter in our case I choose the following bearing and after we Will calculate how many hours it Will resist.I choose the company SKF which is very famous and has a huge offer of bearings.I Will choose the model 6416 which is a rigid balls bearing.

Here are the tables of the most important parameters of the bearing



d		80	mm
D		200	mm
B		48	mm
d_1	≈	116.5	mm
D_1	≈	162.8	mm
$r_{1,2}$	min.	3	mm



d_a	min.	96	mm
D_a	max.	184	mm
r_a	max.	2.5	mm

Figure A.3.2 Bearing parameters and top views

The company SKF gives the Calculation factors to be able to desing our mechanism which are Kr=0.035,F0=12,3.

Type	Rigid Balls bearing
Designation	6416
D(mm)	200
d(mm)	80
B(mm)	48
C(N)	163000
C0(N)	125000
N(min-1) max oiling with fat	4800
N(min-1) max oiling with oil	7500
Mass(Kg)	6.86

Table A3.2.Bearing characteristics 6416

Later is calculated the live of the bearing but first of all is necessary to draw the forces diagram of the horizontal axis. The following figure A3.3 shows the forces that appear in the horizontal axis.

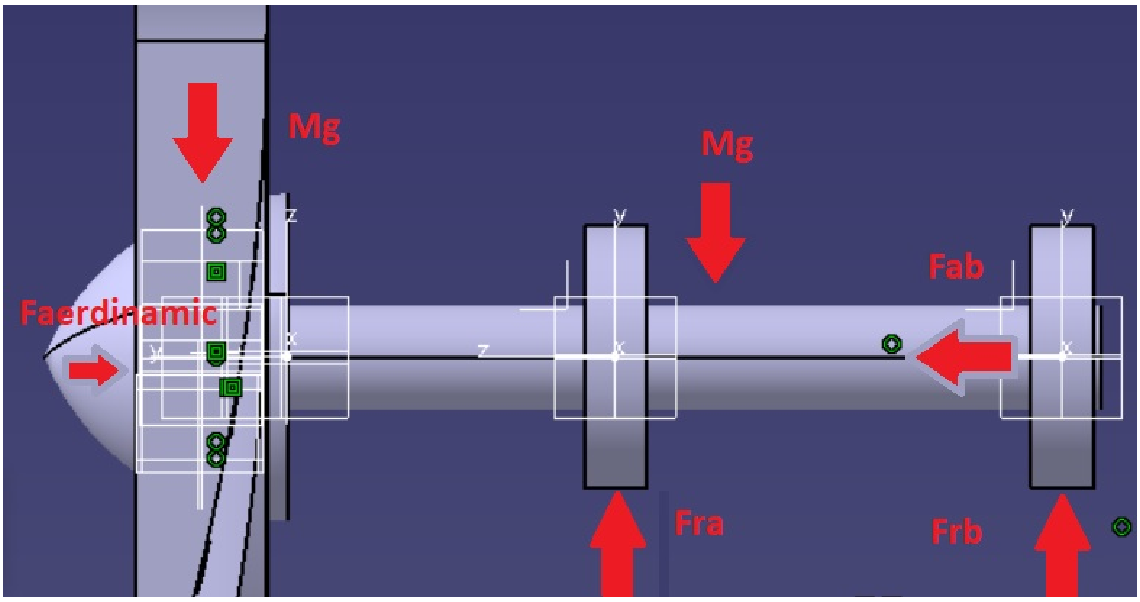


Figure A3.3 Graph of forces in catia

After knowing the forces is important to know the rotation speed of the bearings, the following equation relates the wind speed and the rotation speed. As is explained in the last part the bearings will have different speeds, with the the calculations will be divided in three parts depending on the wind speed, on each part it will be calculated the solicitations of each bearing, after that and combining the forces it is obtained the live of the bearings.

$$n = \frac{\lambda.60.v}{\pi.D}$$

λ tip speed ratio

n rotation speed

v wind speed

- **Speed (5m/s)**

In that case the speed of the wind is 4m/s, then the imbalance force the Aerodynamic force and the rotation speed are calculated in the following equations.

$$n = \frac{\lambda * 60 * v}{\pi * D} = \frac{5.67. * 60 * 5}{\pi * 3} = 180\ min^{-1}$$

$$Fd = m * e * \omega^{\wedge}2 = 3 * 0.003 * (180 * \frac{\pi}{30})^2 = 3.5 \text{ N}$$

$$F_{aero} = 0.62 * A * v^2 = 0.62 * \boldsymbol{\pi} * (\frac{1}{4} * 3^2) * 5^2 = 109 \text{ N}$$

According to the graph of the rigid solid the static equations are.

$$\sum F_x = 0 \rightarrow F_{Ba} = F_{aero}$$

$$\sum F_y = 0 \rightarrow F_{Br} + F_{Ar} + F_d = (m_{axis} + m_{blades}).g$$

$$\sum M_B = 0 \rightarrow F_{Ar}.a + F_d.(a+b) = \left(m_{axis}.\frac{a}{2} + m_{blades}.(a+b) \right).g$$

It has to be considered two options; first with the rotor balanced and the second one with the rotor unbalanced due to the imbalance force that came for the dirty and the wear of the blades.

Balanced rotor (Fd=0)

$\Sigma Fx = 0 \rightarrow Fba = Faero \rightarrow 109\ N$ N

$\Sigma Mb = 0 \ \rightarrow Far * 26.5 = (3.5*\frac{60.5}{2} + 9.8 * 60.5 + 5 * 68) * 9{,}8 \rightarrow \boldsymbol{Far}$ = **384 N**

The mass of the shaft is 3.5+ the disc 2 kg by catia + the paddles (2.6 kg *3)=7.8 kg = 9,8 kg+nose 5 kg=18.3 kg

$\Sigma Fy = 0 \rightarrow Fbr = (18.3)*9.8 \rightarrow$ **Fbr=179.34 N**

Unbalanced rotor (Fd=0)

$$F_d = F_{da} + F_{dB}$$

$$F_{dA}.a = F_d.(a+b)$$

Solving:

F_{da} = 11.5N

F_{db} = - 8 N

Due to the work conditions is considered that the machine will work without impact loads so the factor of appliance is f = 1,2, then the considered axial load is:

$F_{axial} = F_{aero}$ * f = 109*1.2 = 130.8 N

As the load is composed for a constant load and another one variable (imbalance force) the mean charge is calculated by the following equation.

$$F_m = f_m.(F_1 + F_2)$$

The parameter m F_m is calculated by the following figure

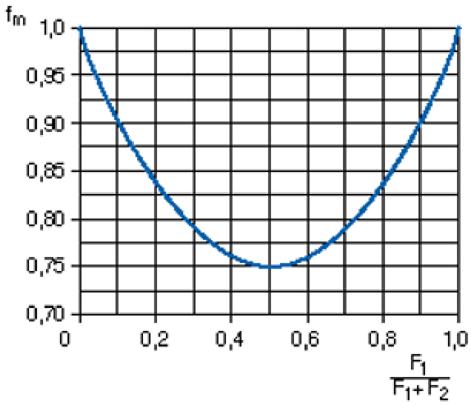


Figure A3.4 Factor fm

For the bearing A

$\frac{384}{384+11.5} \rightarrow f_m$=0,97

F_{Ar} = 0.97*(384+11.5)=382 N

For the bearing B

$\frac{179}{179-9} \rightarrow f_m$=1

F_{br} = 1*(179-9)=170 N

After to calculate the radial load it has to be calculated the combined load, the bearing A only has radial loads but the bearing B has axial and radial loads, as is showed in the figure.

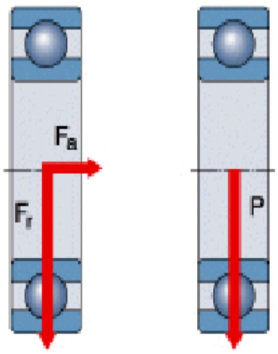


Figure A3.5 Loads

$P = X * F_r + Y * F_{axial}$

P equivalent dynamic bearing load

Fr actual radial bearing load

Fa actual axial bearing load

X radial load factor for the bearing

Y axial load factor for the bearing

To estimate X and Y is used the following figure:

		$F_a/F_r \leq e$		$F_a/F_r > e$	
F_a/C_0	e	X_1	Y_1	X_2	Y_2
0.014*	0.19	1.00	0	0.56	2.30
0.021	0.21	1.00	0	0.56	2.15
0.028	0.22	1.00	0	0.56	1.99
0.042	0.24	1.00	0	0.56	1.85
0.056	0.26	1.00	0	0.56	1.71
0.070	0.27	1.00	0	0.56	1.63
0.084	0.28	1.00	0	0.56	1.55
0.110	0.30	1.00	0	0.56	1.45
0.17	0.34	1.00	0	0.56	1.31
0.28	0.38	1.00	0	0.56	1.15
0.42	0.42	1.00	0	0.56	1.04
0.56	0.44	1.00	0	0.56	1.00

*Utilice 0.014 si $F_a/C_0 < 0.014$.

Figure A3.6 Table factors of the bearing

Calculation for the bearing B

$P = X * F_{Br} + Y * F_{Ba}$

$\frac{F_{axial}}{C_0} = \frac{130.8}{125000}$= →1.04*$10^{-3}$ →e=0.19

As showed in the figure and the load will grow from one minimum value till one maximum, if is considered that grows linearly the combined load can be expressed as the equation

$$P = \frac{P_{c\,min} + 2.P_{c\,max}}{3}$$

.

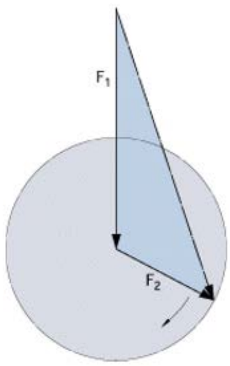


Figure A3.7.- Load distribution

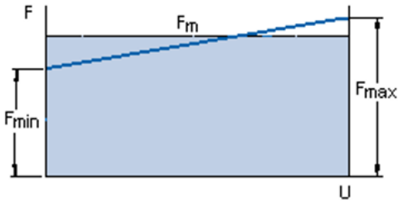


Figure A3.8 Load distribution.

Balanced rotor (Fd=0)

$$\frac{Faxial}{Fradial} = \frac{130.8}{179} => e \qquad \rightarrow \begin{matrix} X = 0{,}56 \\ Y = 2{,}30 \end{matrix}$$

P_b = 0.56*179+2.3*130.8 = 401 N

Unbalanced rotor (Fd=0)

$$\frac{Faxial}{Fradial} = \frac{130.8}{170} => e \qquad \rightarrow \begin{matrix} X = 0{,}56 \\ Y = 2{,}30 \end{matrix}$$

P_b = 0.56*170+2.3*130.8 = 396 N

$$\text{Pb} = \frac{Pcmin + 2 * Pcmax}{3} = \frac{396 + 2 * 401}{3} = 399\ N$$

Calculation for the bearing A

Pcmin =382 N

Pcmax = 384N

$$\text{Pa} = \frac{Pcmin + 2 * Pcmax}{3} = \frac{382 + 2 * 384}{3} = 383.5\ N$$

- **Speed (9 m/s)**

In that case the speed of the wind is 9 m/s, then the imbalance force the Aerodynamic force and the rotation speed are calculated in the following equations.

$$n = \frac{\lambda * 60 * v}{\pi * D} = \frac{5.67.*60*9}{\pi * 3} = 324\ min^{-1}$$

$$Fd = m * e * \omega\text{^}2 = 3*0.003*(324*\frac{\pi}{30})^2 = 10.36N$$

$$F_{aero} = 0.62*A*v^2 = 0.62*\boldsymbol{\pi}*(\frac{1}{4}*3^2)*9^2 = 355\ N$$

It has to be considered two options; first with the rotor balanced and the second one with the rotor unbalanced due to the imbalance force that came for the dirty and the wear of the blades.

<u>Balanced rotor (Fd=0)</u>

$\Sigma Fx = 0 \rightarrow Fba = Faero \rightarrow 355\ N$ N

$\Sigma Mb = 0 \rightarrow Far * 26.5 = (3.5*\frac{60.5}{2} + 9.8 * 60.5 + 5 * 68) * 9{,}8 \rightarrow \boldsymbol{Far} =$ **384 N**

The mass of the shaft is 3.5+ the disc 2 kg by catia + the paddles (2.6 kg *3)=7.8 kg = 9,8 kg+nose 5 kg=18.3 kg

$\Sigma Fy = 0 \rightarrow Fbr = (18.3)*9.8 \rightarrow$ **Fbr=179.34 N**

<u>Unbalanced rotor (Fd=0)</u>

$$F_d = F_{da} + F_{dB}$$

$$F_{dA}.a = F_d.(a + b)$$

Solving:

Fda = 34.01 N

Fdb = -23.6 N

Due to the work conditions is considered that the machine will work without impact loads so the factor of appliance is f = 1,2, then the considered axial load is:

$$Faxial = Faero * f = 1{,}2 * 355 = 426\ N$$

As the load is composed for a constant load and another one variable (imbalance force) the mean charge is calculated by the following equation

$$F_m = f_m.(F_1 + F_2)$$

The parameter m F_m is calculated by the following figure

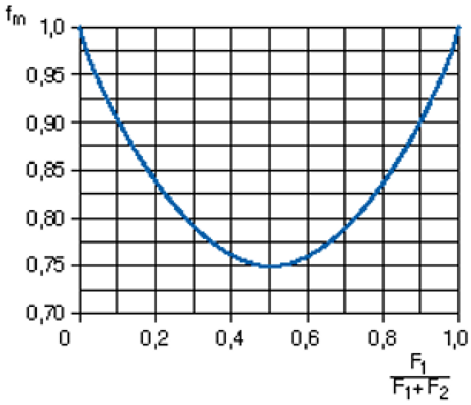


Figure A3.4 Factor fm

For the bearing A

$\frac{384}{384+34} = 0.9 \rightarrow f_m$=0,88

F_{Ar} = 0.88*(384+34)=367.84 N

For the bearing B

$\frac{179}{179-23} > 1 \rightarrow f_m$=1

F_{br} = 1*(179-23)=156 N

After to calculate the radial load it has to be calculated the combined load, the bearing A only has radial loads but the bearing B has axial and radial charges.

Calculation for the bearing B

$P = X * F_{Br} + Y * F_{Ba}$

$\frac{F_{axial}}{C_0} = \frac{426}{125000} = \rightarrow 3.408*10^{-3} \rightarrow e=0.19$

As showed in the figure and the load will grow from one minimum value till one maximum, if is considered that grows linearly the combined load can be expressed as the equation

$$P = \frac{P_{c\min} + 2.P_{c\max}}{3}$$

.

Balanced rotor (Fd=0)

$$\frac{Faxial}{Fradial} = \frac{426}{179} > \text{ e } = 0.19 \qquad \rightarrow \begin{matrix} X = 0{,}56 \\ Y = 2{,}30 \end{matrix}$$

P_{bmax} = 0.56*179+2.3*426 = 1080 N

Unbalanced rotor (Fd=0)

$$\frac{Faxial}{Fradial} = \frac{426}{156} > \text{ e } = 0{,}19 \qquad \rightarrow \begin{matrix} X = 0{,}56 \\ Y = 2{,}30 \end{matrix}$$

P_{bmin} = 0.56*156+2.3*426 = 1067 N

$$\text{Pb} = \frac{Pcmin + 2 * Pcmax}{3} = \frac{1067 + 2 * 1080}{3} = 1075\ N$$

Calculation for the bearing A

There is only a radial force, then Y=0

Pcmin =367 N

Pcmax = 384 N

$$\text{Pa} = \frac{Pcmin + 2 * Pcmax}{3} = \frac{367 + 2 * 384}{3} = 378.3\ N$$

- **Speed (15m/s)**

In that case the speed of the wind is 15 m/s, then the imbalance force the Aerodynamic force and the rotation speed are calculated in the following equations.

$$n = \frac{\lambda * 60 * v}{\pi * D} = \frac{5.67 * 60 * 15}{\pi * 3} = 541\ min^{-1}$$

$$\text{Fd} = m * e * \omega\text{\^{}}2 = 3*0.003*(541.44*\frac{\pi}{30})^2 = 28.93\text{ N}$$

$$F_{aero} = 0.62*A*v^2 = 0.62*\boldsymbol{\pi}*(\frac{1}{4}*3^2)*15^2 = 986.06\text{N}$$

It has to be considered two options; first with the rotor balanced and the second one with the rotor unbalanced due to the imbalance force that came for the dirty and the wear of the blades.

Balanced rotor (Fd=0)

$\Sigma Fx = 0 \rightarrow Fba = Faero \rightarrow 986.06\ N$ N

$\Sigma Mb = 0\ \rightarrow Far * 26.5 = (3.5*\frac{60.5}{2} + 9.8 * 60.5 + 5 * 68) * 9{,}8 \rightarrow \boldsymbol{Far} =$ **384 N**

The mass of the shaft is 3.5+ the disc 2 kg by catia + the paddles (2.6 kg *3)=7.8 kg = 9,8 kg+nose 5 kg=18.3 kg

$\Sigma Fy = 0 \rightarrow Fbr = (18.3)$*9.8 → **Fbr=179.34 N**

Unbalanced rotor (Fd=0)

$$F_d = F_{da} + F_{dB}$$

$$F_{dA}.a = F_d.(a+b)$$

Solving:

Fda = 95 N

Fdb = -65.9 N

Due to the work conditions is considered that the machine will work without impact loads so the factor of appliance is f = 1,2, then the considered axial load is:

$Faxial = Faero * f\ = 1{,}2 * 986 = 1183\ N$

As the load is composed for a constant load and another one variable (imbalance force) the mean charge is calculated by the following equation

$$F_m = f_m.(F_1 + F_2)$$

The parameter m F_m is calculated by the following figure

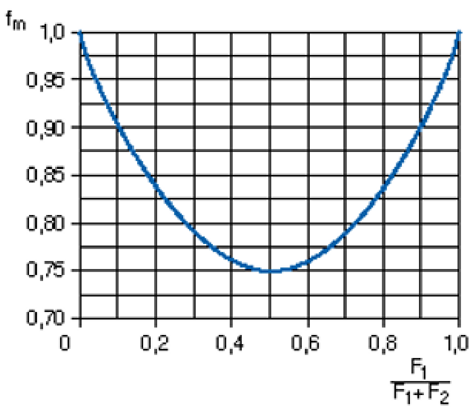


Figure A3.4 Factor fm

For the bearing A

$\frac{384}{384+95} = 0.8 \rightarrow f_m$=0,85

F_{Ar} = 0.85*(384+95)=407 N

For the bearing B

$\frac{179}{179-66} > 1 \rightarrow f_m$=1

F_{br} = 1*(179-66)=113 N

After to calculate the radial load it has to be calculated the combined load, the bearing A only has radial loads but the bearing B has axial and radial charges.

Calculation for the bearing B

$P = X * F_{Br} + Y * F_{Ba}$

$\frac{F_{axial}}{C_0} = \frac{1183}{125000}$=9.46*10^{-3} →e=0.19

As showed in the figure and the load will grow from one minimum value till one maximum, if is considered that grows linearly the combined load can be expressed as the equation

$$P = \frac{P_{c\,min} + 2.P_{c\,max}}{3}$$

.

Balanced rotor (Fd=0)

$$\frac{Faxial}{Fradial} = \frac{1183}{179} > e = 0.19 \quad \rightarrow \begin{matrix} X = 0{,}56 \\ Y = 2{,}30 \end{matrix}$$

P_{bmax} = 0.56*179+2.3*1183 = 2821 N

Unbalanced rotor (Fd=0)

$$\frac{Faxial}{Fradial} = \frac{1183}{113} > e = 0{,}19 \quad \rightarrow \begin{matrix} X = 0{,}56 \\ Y = 2{,}30 \end{matrix}$$

P_{bmin} = 0.56*113+2.3*1183 = 2784 N

$$\text{Pb} = \frac{Pcmin + 2 * Pcmax}{3} = \frac{2784 + 2 * 2821}{3} = 2808\ N$$

Calculation for the bearing A

There is only a radial force, then Y=0

Pcmin =384 N

Pcmax = 407 N

$$\text{Pa} = \frac{Pcmin + 2 * Pcmax}{3} = \frac{384 + 2 * 407}{3} = 400\ N$$

Once are calculated the different loads depending on the speed rotation is has to be calculated the equivalent dynamic load and the mean rotation speed, with the following equations calculated both parameters.

$$P = \sqrt{P_1^3 . \frac{n_1}{n_m} \frac{q_1}{100} + P_2^3 . \frac{n_2}{n_m} \frac{q_2}{100} + P_3^3 . \frac{n_3}{n_m} \frac{q_3}{100}}$$

$$n_m = n_1 . \frac{q_1}{100} + n_2 . \frac{q_2}{100} + n_3 . \frac{q_3}{100}$$

Substituting the speed parameters on the equation, there is the mean rotation speed of the generator

$$n = 180 * \frac{33}{100} + 324 * \frac{44}{100} + 541 * \frac{22}{100} = 325 \text{ min}^{-1}$$

The equivalent load of bearing A

$$Peq(a) = \sqrt{383^3 * \frac{180}{325} * \frac{33}{100} + 378^3 * \frac{324}{325} * \frac{44}{100} + 400^3 * \frac{541}{325} * \frac{22}{100}} = 385.9 \text{ N}$$

After having the equivalent loads for each bearing with the following equations are calculated the velocity and duration factors. Due to the load changes depending on the rotation speed there is the following equation.

$$f_L = \sqrt[3]{\frac{100}{\frac{q_1}{f_{L1}^3} + \frac{q_2}{f_{L2}^3} + \frac{q_3}{f_{L3}^3}}}$$

To estimate fl first is needed the factor fn , that one is calculated with the different speed rotations,then with this values are calculated the fl factors and substituted in the equation to estimate a mean fl. That is done for both bearings.

$$f_L = \frac{C}{P}.f_n$$

$$f_n = \sqrt[3]{\frac{33.\frac{1}{3}}{n}}$$

Substituting I obtain:

fn1A=0.57

fn2A=0.45

fn3A=0.37

fl1A=269

fl2A=208

fl3A=81

C=163000

flatotal=128

Finally we can obtain the hours of the bearing with the following equation:

L=500*fl^3

L=500*128^3=1042063901 Hours

Seeing the results the bearings have enough live hours for the solicitations that are exposed.

I repite now the process for the bearing B.

The equivalent load of bearing B

$Peq(b) = \sqrt{399^3 * \frac{180}{325} * \frac{33}{100} + 1075^3 * \frac{324}{325} * \frac{44}{100} + 2808^3 * \frac{541}{325} * \frac{22}{100}}$=1850 N

The parameters directly related with the life of this bearing are:

fn1B=0.56

fn2B=0.45

fn3B=0.38

fl1B=269

fl2B=15.6

fl3B=3.8

C=163000

flatotal=6.25

Finally we can obtain the hours of the bearing with the following equation:

L=500*fl^3

L=500*6.25^3=121204.87 hours

Seeing the results the bearings have enough live hours for the solicitations that are exposed.

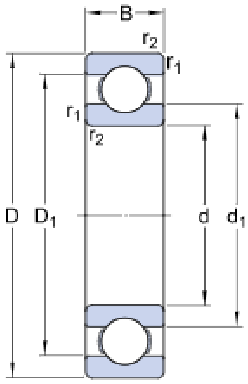
4.- Calculation of the vertical axis bearings

In that part is calculated the static capacity of the vertical bearings, is not calculated the dynamic capacity because the rotation speed of the vertical axis is going to be low.

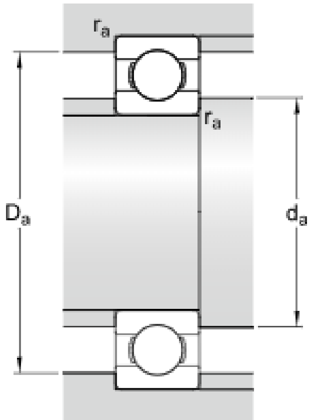
The bearings chosen are angular contact ball bearings because there is a high axial force and that type of bearings are design to support high axial forces

With the geometry to enter in our case I choose the following bearing and after we Will calculate how many hours it Will resist.I choose the company SKF which is very famous and has a huge offer of bearings.I Will choose the model 6416 which is a rigid balls bearing.

Here are the tables of the most important parameters of the bearing



d		80	mm
D		200	mm
B		48	mm
d_1	≈	116.5	mm
D_1	≈	162.8	mm
$r_{1,2}$	min.	3	mm



d_a	min.	96	mm
D_a	max.	184	mm
r_a	max.	2.5	mm

Figure A4.1 Bearing characteristics

The calculation factors which skf provides us are in this case: Kr=0.035,F0=12,3

And finally in the following table we can see the principal characteristics of the rigid ball bearing, which are:

Type	Rigid Balls bearing
Designation	6416
D(mm)	200
d(mm)	80
B(mm)	48
C(N)	163000
C0(N)	125000
N(min-1) max oiling with fat	4800
N(min-1) max oiling with oil	7500
Mass(Kg)	6.86

Table A.4.1 Bearing characterictics

Later is calculated the static load of the bearing but first of all is necessary to draw the forces diagram of the vertical axis. The following figure A4.3 shows the forces that appear in the vertical axis.

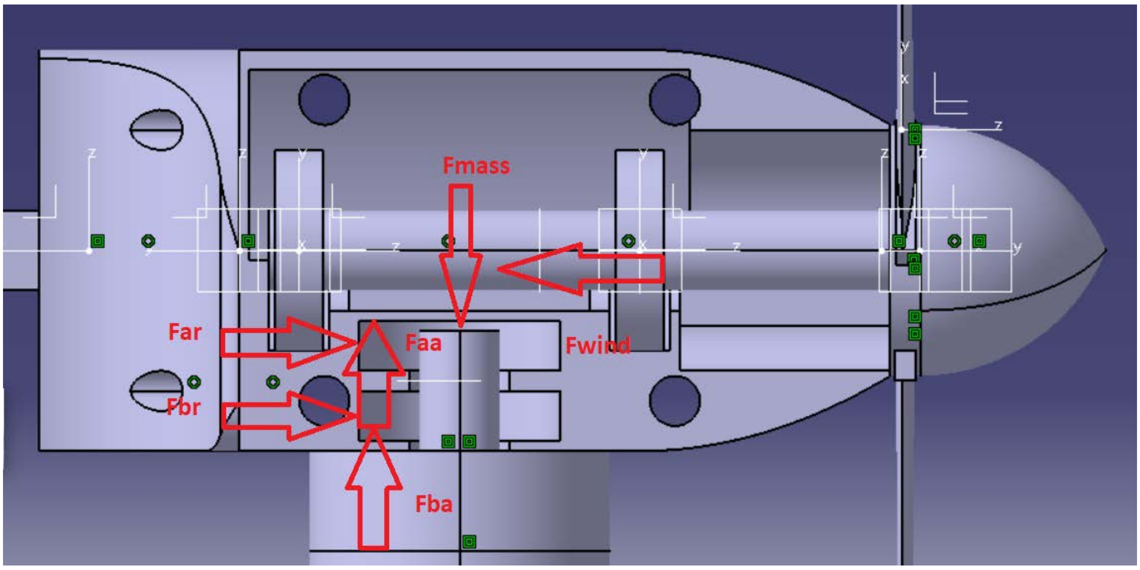


Figure A4.2.Force Diagram

$$\Sigma Fx = 0 \ \rightarrow Far + Fbr = Fwind$$

$$\Sigma Fy = 0 \rightarrow Faa + Fab = Fmass$$

$$\Sigma Mb = 0 \rightarrow -Fwind * (a + b) + Far * a = 0$$

The radial force that support the bearing is originated for the wind. That force is calculated for the worst case strong winds. We calculated in the other chapter the máximum wing speed in Iasi it was 33,45m/s appear high loads that can damage the generator so that will be the top work speed, Then the wind force is calculated in the following equation

$$Faero = 0{,}62 * A * v^2 = 0.62 * \pi * \left(\frac{3^2}{4}\right) * 33.45^2 = 4903.6$$

Faero=4903.6 N

Substituting on the equations

$$\Sigma Fx = 0 \ \rightarrow Far + Fbr = 4903.6\ N$$

$$\Sigma Fy = 0 \rightarrow Faa + Fab = Fmass$$

How the forces are in the same shaft and the bearings are completely the same the forcé of each bearing will be the Fmass/2.

The mass of the shaft is 3.5+ the disc 2 kg by catia + the paddles (2.6 kg *3)=7.8 kg = 9,8 kg+nose 5 kg=18.3 kg the mass of the two cases are one of 153 kg and the other of 148 kg.

$$\Sigma Fy = 0 \rightarrow Fy = Fmass = m * a \rightarrow (153 + 148 + 18.3) * 9.8 = 3129.14\ \text{N}$$

$$\frac{3129.14}{2} = 1564.57\ N \text{ for each bearing}$$

The distances for the bearings with the shaft are a=70mm b=95mm

$$\Sigma Mb = 0 \rightarrow -4903.6 * (95 + 70) + Far * 70 = 0 \ \rightarrow Far = 11557.1N$$

$$Fbr = 6653.47\ N$$

For each bearing is going to be calculated static and dynamic load.

Bearing A

$$Pa0 = Far + 0.52Faa = 11557.1 + 0.52 * 1564.57 = 12370.7N$$

$$\frac{Faa}{Far} = \frac{1564.57}{12370.7} < 1.14 \ \rightarrow Pa = Far + 0.55 * Faa \rightarrow Pa = 12417.61\ N$$

Bearing B

$$Pb0 = Fbr + 0.52Fba = 6653.47 + 0.52 * 1564.57 = 7467.05\ N$$

$$\frac{Fba}{Fbr} = \frac{1564.57}{6653.47} < 1.14 \ \rightarrow Pb = Fbr + 0.55 * Fba \rightarrow Pb = 7513.98\ N$$

Once calculated the equivalent static and dynamic load for both bearings it has to be proved if the bearing can support that loads.

The static load rating can be calculated by the following equation

$$C0 = S0 * P0$$

Knowing that the bearing will do slow rotation movement it is estimated s0 = 1,6, then getting the value of C0 and comparing with the value that is given on the tables is possible to know if the bearing is well dimensioned

Bearing A

$$C0 = s0 * P0 \rightarrow 1.6 * 12417.61 = 19868.176\, N < \ 125000\text{N} \ \rightarrow \boldsymbol{OK}$$

Bearing B

$$C0 = s0 * P0 \rightarrow 1.6 * 7513.98 = 12022.368\, N < \ 125000\text{N} \ \rightarrow \boldsymbol{OK}$$

5.-Calculation of the fatigue

Due that the wind speed is not constant, the blades receive a not constant power moment, this variations have to be considered because can damage the axis and produce his break.

To simplify the distribution of the wind it will be used the one that has been used to calculate the horizontal bearings.

work hours per day	wind speed(m/s)
3	5
4	9
2	15

Table A.5.1.-Wind speeds

Knowing the rotation speed of the blades and the wind speed too, it can be calculated the rotation speed of the horizontal axis. First it has to be calculated the wind power of each wind speed then with that values and using the efficiency of the turbine it will be calculated the mechanical power that receives the axis, then with the rotation speed of the axis it will be calculated the power that support.

$$Paelian = \frac{1}{2} * \rho * A * v^3$$

$$Paelian = \frac{1}{2} * 1{,}238 * \pi * 1.5^2 * 5^3 = 547 \text{ W}$$

$$Paelian = \frac{1}{2} * 1{,}238 * \pi * 1.5^2 * 9^3 = 3189\ W$$

$$Paelian = \frac{1}{2} * 1{,}238 * \pi * 1.5^2 * 15^3 = 14767.15 \text{ W}$$

$$Pmec = \boldsymbol{\tau} * \boldsymbol{\omega}$$

$$Pmechanical = 0.45 * 547 = 246.15 \text{ W}$$

$$Pmechanical = 0.45 * 3189 = 1435.05 \text{ W}$$

$$Pmechanical = 0.45 * 14767.15 = 6645.21 \text{ W}$$

$$246.15 = \boldsymbol{\tau} * 325 * \frac{2 * \pi}{60}$$

$$1435.0 = \boldsymbol{\tau} * 325 * \frac{2 * \pi}{60}$$

$$6645.2 = \boldsymbol{\tau} * 325 * \frac{2 * \pi}{60}$$

τ1 =**7.23 Nm**

τ2 =**42.17 Nm**

τ3 =**195.2Nm**

To calculate the live of the axis first must be calculated the critical section, in that case is the less radial section with 80 mm of diameter, for the different wind speeds, so first is calculated the resistant moment to the torsion for a circular secction, as is showed in the equation.

$$Wt = \frac{\pi}{16} * d^3$$

$$Wt = \frac{\pi}{16} * 80^3 = 100530.97\ mm^2$$

Then the calculation for the critical section it is calculated for the three wind speeds

$$\tau = \frac{M_t}{W_t}$$

$$\tau_1 = \frac{7.23 * 1000}{100530.97} = 0.071$$

$$\tau_2 = \frac{42.17 * 1000}{100530.97} = 0.41$$

$$\tau_3 = \frac{195.2 * 1000}{100530.97} = 1.94$$

For each point of calculation it must be calculated too the alternative and mean tension, as is showed in the following equations.

$$\tau_a = \frac{\tau_{\max} - \tau_{\min}}{2}$$

$$\tau_m = \frac{\tau_{\max} + \tau_{\min}}{2}$$

Substituting for the indicated values

$$\tau_1 = 0.0355$$

$$\tau_2 = 0.205$$

$$\tau_3 = 0.97$$

Now is calculated the fatigue limit

$$S_f = K_I . K_d . K_S . \frac{1}{K_f} . S_f^{'}$$

Sf it is the limit of fatigue of the standard manometer

$$S_f^{'} = 0{,}5 . R_m \rightarrow 0{,}5.410 = 205 \frac{N}{mm^2}$$

- Kl is the coefficient of the type of load to which the axis surrenders and in this case knowing that the load is basically a torsion load and knowing too that the material is the same in all the axis, steel then the Coefficient type of load has a value of 0,58.
- Kd is the coefficient of grandaria and has a value of 0,85
- Ks is the coefficient of ended superficially and has a value of 0,76
- Kf is the coefficient of tension concentration.

$$K_f = 1 + q(K_t + 1)$$

- q it is the sensibility to the fit and knowing that the radius of carves it is of 2 mm then the value of q is 0,97
- Kt is the theoretical coefficient of tension concentration knowing that the diameter maximum of the axis is of 80 mm, the minimum is of 80 mm and the radius is of the projection is of 2 mm, the coefficient of tension concentration is 1.

So Kf=1

Now is calculated the fatigue limit.

$$Sf = 0.58 * 0.85 * 0.76 * 1 * 205 = 77 \frac{N}{mm^2}$$

Knowing that the material of the axis is St 42 and that the break limit is Rm=410 N/mm2, fluency limit is Re=250 N/mm2 it is calculated Rte and Rtm, equations

$$R_{tm} = 0{,}8 . R_m = 0{,}8.410 = 328 \frac{N}{mm^2}$$

$$R_{te} = 0{,}58 . R_e = 0{,}58.250 = 145 \frac{N}{mm^2}$$

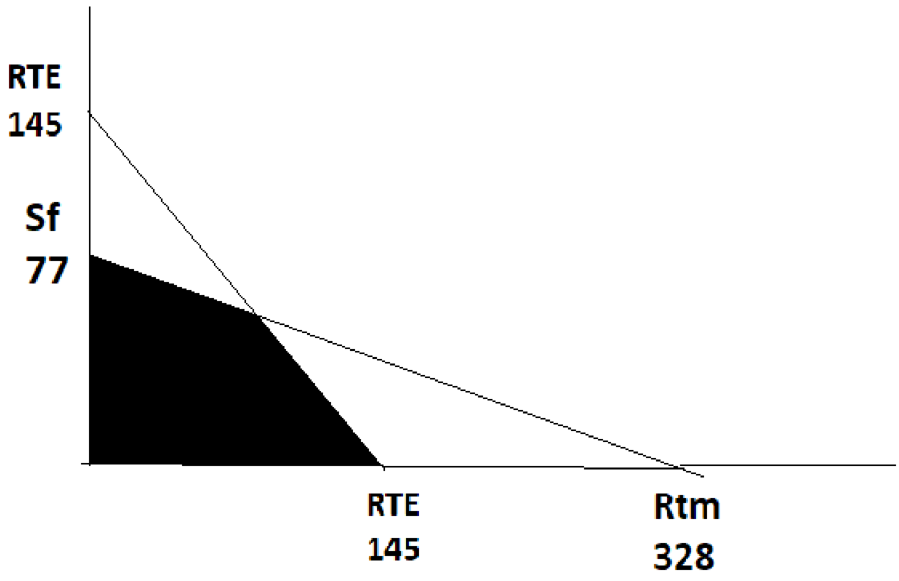


Figure A5.1.- Goodman diagram

Representing the Goodman diagram and situating the tensions calculated in the equations.It can be seen in the that any of the tensions pass the Goodman line that could say that the axis has infinite fatigue live.

6.-Calculation for the screws of the unión “Blade-nose”

The screws that join the blades with the blade-hub have to support a separation force, that force is the inertial force that is produced while the bladed rotate. In this part is proved the reliability of that join.

First of all it has to be estimated the maximum and minimum separation force, that force is calculated in the following equation

$$Fcentrifuga = \frac{\pi^2}{1800} * Mblade * n^2 * Rg$$

The generator will work between 0 and 25m/s wind speed then designing for the worst case, 25m/s, the escentrifuguF is

$$\mathrm{n} = \frac{\lambda*60*\mathrm{v}}{\pi*\mathrm{D}} = \frac{5.67*60*25}{\pi*3} = 902\ min^{-1}$$

$$Fcentrifuga = \frac{\pi^2}{1800} * 2.6\ kg * (902\ )^2 * 0.1 = 1159.88\ N$$

6.1.-Assembly force

The force that assures the join is the Fmin (minimum assembly force).

$$Fmin = \frac{Ft}{\mu * m * n}$$

F is the separating tangential force that is the centrifugal force that supports every Screw it is taken as a hypothesis that every screw supports the same force.

µ is the coefficient of rubbing, supposing the most unfavorable case, 0,15

m is the surface number in contact

n is the number of screws

$$Fmin = \frac{\frac{1159.88}{2}}{0.15 * 2 * 2} = 966.56\ N$$

Starting from the maximum force of assembly that admit the screws used in this union it is possible to determine that force of assembly that stays once has been considered Factor of tight and the accession of the union. For it it is necessary to know several information of the screws that next is detailed.

The company which made the screws give all the details about it which are explain in the following table

Part Number	M	L	D_1	L_1	B	L_2	Tension Rupture Load (N)*1	Qty per Pack	Mass (g)
SNST-M5-10	5	10	8.5	5	4	Full Thread	9080	1	1.5
SNST-M5-12	5	12	8.5	5	4	Full Thread	9080	1	1.7
SNST-M5-16	5	16	8.5	5	4	Full Thread	9080	1	2
SNST-M5-20	5	20	8.5	5	4	Full Thread	9080	1	2.3
SNST-M5-25	5	25	8.5	5	4	Full Thread	9080	1	2.7
SNST-M5-30	5	30	8.5	5	4	22	9080	1	3.1
SNST-M5-35	5	35	8.5	5	4	22	9080	1	3.6

Table A.6.1 Scews characteristics

With the hex nux

Part Number	M	B	T	t1	D	Qty per Pack	Mass (g)
SHNT-M5-F	5	8	5.5	1.1	12	1	1.3

Table A.6.2 Hex Nux characteristics

From the tables of the screws we obtain than the Force máximum and the ɑ are:

Fmax=9080 N; ɑ=1.6;

With this i am able to obtain the Fmin for the unión.

$$\alpha = \frac{F_{MAX}}{F_{MIN}} \rightarrow F_{MIN} = \frac{F_{max}}{\alpha} \rightarrow \frac{9080}{1.6} = 5675\ N$$

6.2.-Assembly forcé

Before calculating the accession of the join it is needed to know the rigidity of the screws and the pieces that are in the join.

Most of the parameters for the screws are normalize and we can obtain directly, there are thousand of information about it in internet.

Apart from that, we need to check with the company who made the screws parameters and calculate the rigidity following the equations.

In the following table we can find the useful áreas of the screws and minimal resistance áreas which are made our screws.

Tablas de normalización

Tabla 8-1

Diámetros y áreas de roscas métricas de paso grueso y fino*

Diámetro mayor nominal d, mm	Serie de paso grueso: Paso p, mm	Serie de paso grueso: Área de esfuerzo de tensión A_t, mm²	Serie de paso grueso: Área del diámetro menor A_r, mm²	Serie de paso fino: Paso p, mm	Serie de paso fino: Área de esfuerzo de tensión A_t, mm²	Serie de paso fino: Área del diámetro menor A_r, mm²
1.6	0.35	1.27	1.07			
2	0.40	2.07	1.79			
2.5	0.45	3.39	2.98			
3	0.5	5.03	4.47			
3.5	0.6	6.78	6.00			
4	0.7	8.78	7.75			
5	0.8	14.2	12.7			
6	1	20.1	17.9			
8	1.25	36.6	32.8	1	39.2	36.0
10	1.5	58.0	52.3	1.25	61.2	56.3
12	1.75	84.3	76.3	1.25	92.1	86.0
14	2	115	104	1.5	125	116
16	2	157	144	1.5	167	157
20	2.5	245	225	1.5	272	259
24	3	353	324	2	384	365
30	3.5	561	519	2	621	596
36	4	817	759	2	915	884
42	4.5	1 120	1 050	2	1 260	1 230
48	5	1 470	1 380	2	1 670	1 630
56	5.5	2 030	1 910	2	2 300	2 250
64	6	2 680	2 520	2	3 030	2 980
72	6	3 460	3 280	2	3 860	3 800
80	6	4 340	4 140	1.5	4 850	4 800
90	6	5 590	5 360	2	6 100	6 020
100	6	6 990	6 740	2	7 560	7 470
110				2	9 180	9 080

*Las ecuaciones y los datos utilizados para elaborar esta tabla se obtuvieron de la norma ANSI B1.1-1974 y B18.3.1-1978. El diámetro menor se determinó mediante la ecuación $d_r = d - 1.226\,869p$, y el diámetro de paso a partir de $d_p = d - 0.649\,519p$. La media del diámetro de paso y el diámetro menor se usaron para calcular el área de esfuerzo de tensión.

Figure A6.1.-Screws normalize parameters

For Screws M5 there is the following content:

$$A_1 = \frac{\pi * D^2}{4} = \frac{\pi * 5^2}{4} = 19.63\ mm^2$$

$$A_3 = 12{,}57\ mm^2$$

$$A_s = A_T = 12{,}57\ mm^2$$

Knowing that EC = 210000 MPa and substituting the values in the next equation there is the rigidity of the screws.

$$K_C = \frac{E_C}{\frac{2.l'}{A_S} + \frac{l_1}{A_1} \frac{l_3}{A_3}}$$

Kc=98334.61N/mm

Substituting in the equation there is the equivalent rigidity of the pieces.Which is:

$$K_p = \frac{\pi}{4} . \frac{E_p}{l_p} \left[\left(d_e + \frac{l_p}{10} \right)^2 - d_f^2 \right]$$

Kp=560774.28 N/mm

6.3.-Calculation of the accession of the unión

After the assembly of the pieces there is a loss of force produced for the accession of the union, that loss of force cn be calculated by the equation

$$\Delta \mathrm{Fm} = \delta \mathrm{x} * \mathrm{C} * \mathrm{Kp}$$

Δx is the accession and it is estimated addend the accession of each join including the coil

C is the factor that relates Kc and Kp

$$C = \frac{K_C}{K_C + K_P} = 0.15$$

In that join there is 4 accessions; 2 screw-piece and 2 piece-piece, then the accession is, equation.

$$\delta \mathrm{x} = 4.4\mu\mathrm{m} + 5\mu\mathrm{m(coil)} = 21\mu\mathrm{m}$$

Substituting in the equation

$$\Delta \mathrm{Fm} = \delta \mathrm{x} * \mathrm{C} * \mathrm{Kp}$$

there is the loss of force produced for the accession, equation

$$\Delta \mathrm{Fm} = 21\mu * 0.15 * 560774.28 = 1766.43\ N$$

6.4.-Checking of the assembly forcé

To know the assembly force after the accession it has to be reduced the force that is loosed during the accession

$$F_m' = F_{Min} - \Delta F_M = 5675 - 1766.43 = 3908.57N$$

Now it can be calculated the safety coefficient

$$Cs = \frac{F'_m}{F_{m-necessary}} \rightarrow \frac{3908.57N}{966.56\ N} = 4.045 \geq 1$$

There will be any problem in the join because the safety coefficient in more than one.

6.5.-Checking of the screw

The checking of the screw must be in the worst case before the accession of the union.

Checking screws propierties

Physical property

	TB340C（Grade 2 Titanium）
Specific Gravity	4.51
Melting Point（℃）	1668
Longitudinal Elastic Modulus（GPa）	106
Thermal Conductivity（W/（m・K））	17.16
Linear Expansion Coefficient（K^{-1}）	8.4×10^{-6}
Electric Resistance（μΩ・m）	0.55
Amplitude Permeability（μ）	1.0001（Nonmagnetic）

Values in chart are for reference only. They are not guaranteed values.

Mechanical property

	TB340C（Grade 2 Titanium）
Tensile Strength（N/mm^2）	340-510
0.2% Proof Stress（N/mm^2）	215 or Higher
Elongation（%）	23 or Higher

Values in chart are for reference only. They are not guaranteed values.

Table A6.3.-Properties of the scew by the company

From there we can obtain the following Resistences.

-Re= 340 Mpa

-Rm=510 Mpa

Alter in the equation is calculated the σ_{adm} and the σ of the screw and the σ of the screw and the compared, if the $\sigma_{adm} > \sigma$ then there will be not breaking problems with the screws.

σ_{adm}=Re*0.9=0.9*340=306 N/mm^2

σ_{adm}=Fm/At=9080/36.6=248,08 N/mm^2

.

where the At is obtain from the table Figure A6.1. as before

As we can see 248,08<306

There Will be not poblems.

7.-Calculation for the screws of the unión Case

The screws that join the case with,that force is the produced by the mass of the nacelle and the aerodynamic force produced for the wind. This forces create a moment that separate the join. In this part is proved the reliability of that join.

First of all it has to be estimated the maximum and minimum separation force, that force is calculated in the following equation

As we said we Will take the máximum wind speed for iasi that is 33,46 m/seg calculated before in the other anexxe.

As the geoemetry of the case it is not easy catia gives us the área and distance to calculate.For be in the worst situación ill estimate this as a rectangule of 0,4*0.4 as you can see is very close to that in the following figures.

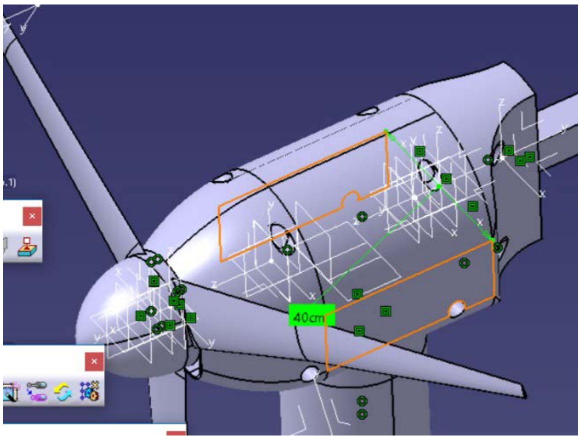


Figure A.7.1.-Distance in catia between lateral faces

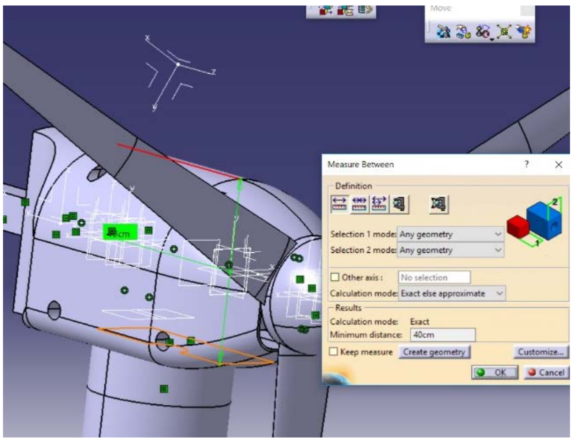


Figure A.7.2..- Distance in catia between vertical axis

We Will aproxximate the are of the case to a rectangule of 0,4*0,4 as we see in the figures before.

$$F_{aero} = 0.62*A*v^2 = 0.62*0.4*0.4*33.46^2 = 111\ N$$

Fcase=300*9.8= 2940N

The mass of the disc 2 kg by catia + the paddles (2.6 kg *3)=7.8 kg = 9,8 kg+nose 5 kg=14.8 kg

Fblade=14.8*9.8=145.04N

Knowing that forces and estimating the center of mass of the nacelle and the blades can be calculated the normal force that the screws support due to the flector moment.

Catia calculates the center of mass of the nacelle.

$$\mathrm{M1 = Faero * dg = 111 * 0.1 = 11.1\ Nm}$$

$$\mathrm{M2 = Fcase * dg = 2640 * 0.05 = 123\ \ Nm}$$

$$\mathrm{M3 = Fblade * dg = 145.04 * 0.1 = 14.504\ \ Nm}$$

$$\mathrm{Fnblade} = \frac{M1}{0.175} \rightarrow 63.42\ N$$

$$\mathrm{Fcase} = \frac{M2}{0.175} \rightarrow 702.85\ N$$

$$F_{ntotalmass} = 63.42 + 702.85 = 766.3N$$

$$\mathrm{Faero} = \frac{M3}{0.175} \rightarrow 82.88\ N$$

The worst case is the last one 766,3 N.

7.1.-Necessary force of assembly

The force that assures the join is the Fmin

$$F_{min} = \frac{F_t}{\mu * m * n}$$

-Ft is the separating tangential force that is the centrifugal force that supports every Screw it is taken as a hypothesis that every screw supports the same force.

-µ is the coefficient of rubbing, supposing the most unfavorable case, 0,15.

-m is the surface number in Contac.

-n is the number of screws.

Substituting the parameters we obtain:

$$F_{min} = \frac{\frac{766.3}{4}}{0.15 * 2 * 4} = 159.64\ N$$

Starting from the maximum force of assembly that admit the screws used in this union it is possible to determine that force of assembly that stays once has been considered Factor of tight and the accession of the union. For it it is necessary to know several information of the screws that next is detailed.

Part Number	M	L	D_1	L_1	B	L_2	Tension Rupture Load (N)*1	Qty per Pack	Mass (g)
SNST-M5-35	5	35	8.5	5	4	22	9080	1	3.6

Table A.7.1.- Parameters of the screw L2-22

To join the case we have 4 screws of M5

Knowing the maximum assembly force and the factor of tight it could be known the minimum assembly force, as is showed in the following equation

As before i obtain the Fmax and the ɑ directly from the company who sell us the screws

Fmax=9080 N; ɑ=1.6;

$$\alpha = \frac{F_{MAX}}{F_{MIN}} \rightarrow F_{MIN} = \frac{F_{max}}{\alpha} \rightarrow \frac{9080}{1.6} = 5675\ N$$

7.2.-Calculation of the rigidity of the screws

Before calculating the accession of the join it is needed to know the rigidity of the screws and the pieces that are in the join

For screws M5 there is in the **Figure A.6.1** obtain that the parameter At is 14,2

Knowing that MPa EC 210000 = and substituting the values there is the rigidity of the screws.

Going to the table A.7.1 we have all the parameters to solve the following equations.

$$K_d = \frac{A_d.E}{L_d}$$

Kd=(14,2*210000)/35=85200 N/mm

$$K_t = \frac{A_t.E}{L_t}.$$

Kt=((π/4*5^2))210000)/22=187424.56 N/mm

$$\frac{1}{K_d} = \frac{1}{K_t} + \frac{1}{K_d}$$

Kd=58573.5 N/mm

Rigidity of the joined pieces

There is the equivalent rigidity of the pieces in the following equation.

$$k_i = \frac{0.577\pi Ed}{\ln\left[\frac{(1.15t + D - d)(D + d)}{(1.15t + D + d)(D - d)}\right]}$$

When the elements has the same E are all elements are normalize D=1,5d.We can asume and convert in the following ecuation.

$$k_{unión=m} = \frac{0.577\pi Ed}{2\ln\left(5\frac{0.577l + 0.5d}{0.577l + 2.5d}\right)}$$

Substituting:

K1= 238694 N/mm

K2=3100 N/mm

K3=238694 N/mm

7.3.-Calculation of the accession of the union.

After the assembly of the pieces there is a loss of force produced for the accession of the union, that loss of force can be calculated by the equation.

$$\Delta \mathrm{Fm} = \delta \mathrm{x} * \mathrm{C} * \mathrm{Kp}$$

Δx is the accession and it is estimated addend the accession of each join including the coil

C is the factor that relates Kc and Kp

$$C = \frac{K_C}{K_C + K_P} = 0.99$$

In that join there is 4 accessions; 2 screw-piece and 2 piece-piece, then the accession is, equation.

$$\delta \mathrm{x} = 4.4\mu\mathrm{m} + 5\mu\mathrm{m}(\mathrm{coil}) = 21\mu\mathrm{m}$$

Substituting in the equation

$$\Delta \mathrm{Fm} = \delta \mathrm{x} * \mathrm{C} * \mathrm{Kp}$$

there is the loss of force produced for the accession, equation

$$\Delta \mathrm{Fm} = 21\mu * 0.15 * 3048 = 9.6\ N$$

7.4.-Checking of the assembly forcé

To know the assembly force after the accession it has to be reduced the force that is loosed during the accession

$$F_m' = F_{Min} - \Delta F_M = 5675 - 9.6 = 5665.4\ N$$

Now it can be calculated the safety coefficient

$$Cs = \frac{F_m'}{F_{m-necessary}} \rightarrow \frac{3908.57N}{159.64\ N} = 24.48 \geq 1$$

There will be any problem in the join because the safety coefficient in more than one.

7.5.-Checking of the screw

The checking of the screw must be in the worst case before the accession of the union.

Checking screws propierties in the table A6.3

We obtain:

-Re= 340 Mpa

-Rm=510 Mpa

Alter in the equation is calculated the σ_{adm} and the σ of the screw and the σ of the screw and the compared, if the $\sigma_{adm} > \sigma$ then there will be not breaking problems with the screws.

$$\sigma_{adm}=Re*0.9=0.9*340=306\ N/mm^2$$

$$\sigma_{adm}=Fm/At=9080/36.6=248,08\ N/mm^2$$

where the At is obtain from the **figure A.6.1**, as before

As we can see 248,08<306

There Will be not poblems.

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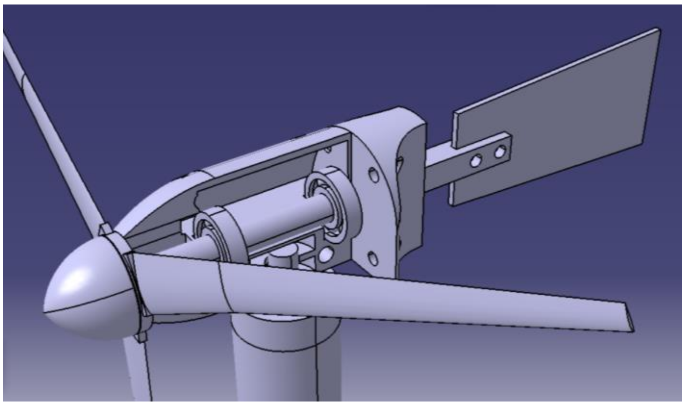
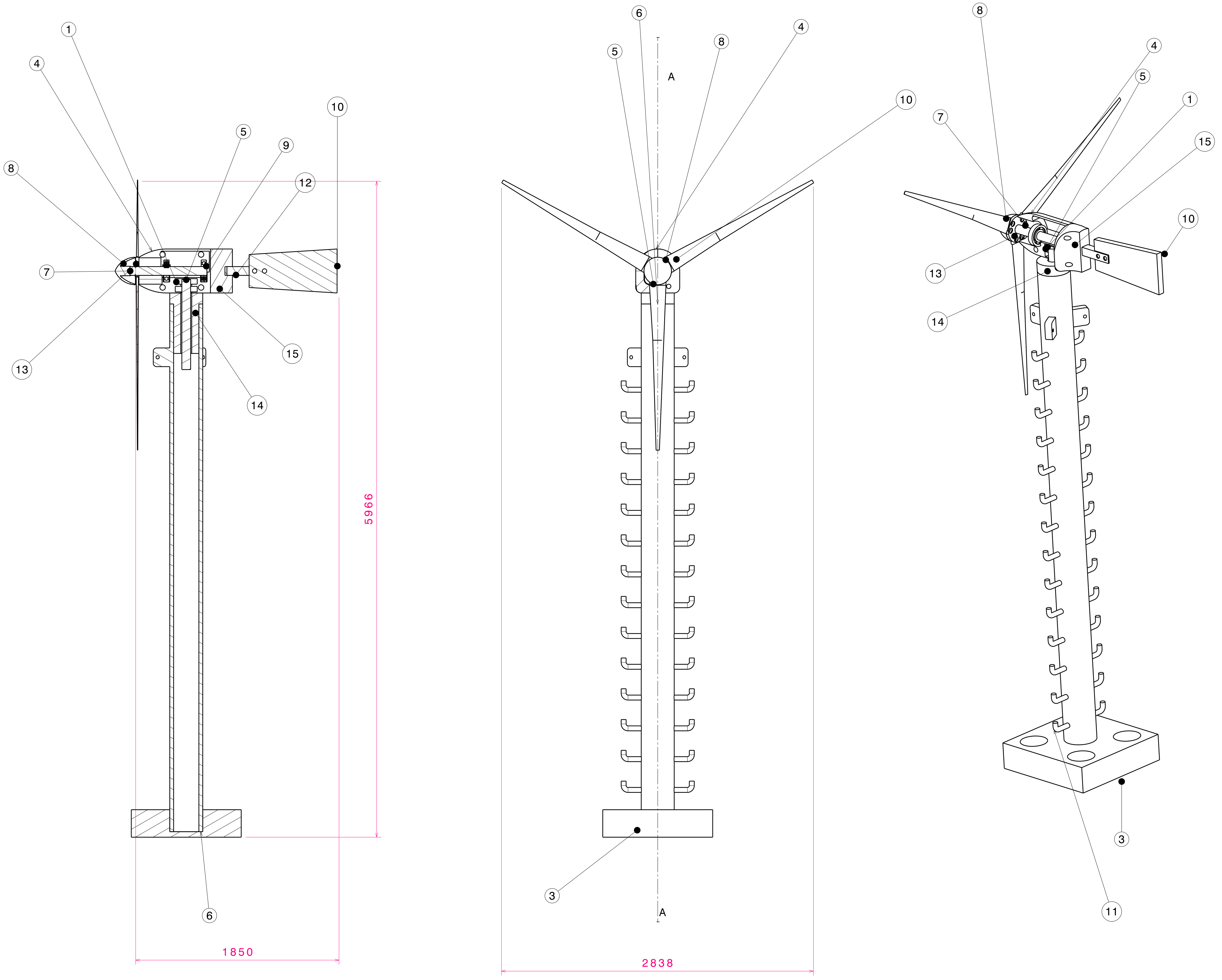


Design of a windmill for a romanian countryside home

ALVARO BARINAGA RODRIGUEZ

ANNEXES 2

DRAWINGS



Romanian Countryside Windmill			
Name	Mark	Quantity	Material
Right Side Case	1	1	Foundry
Naca 4412 Wings	2	3	E-Fiber Glass
Base	3	1	Steel
Left Side Case	4	1	Foundry
Shaft Top Side	5	1	Steel
Principal Shaft	6	1	Steel
Case Shaft	7	1	Steel
Nose	8	1	Foundry
Bearing 6416 SKF	9	4	Steel
Vane	10	1	Steel
Stair	11	28	Steel
Conexión Back Part	12	1	Steel
Conexión Nose	13	1	Steel
Top Cap	14	1	Steel
Vane Back Side	15	1	Foundry
Hex NuxSHNT-M5-F	-	10	Steel
Hex NuxSHNT-M4-F	-	7	Steel
Screw SNST-M4-20	-	7	Steel
Screw SNST-M5-30	-	10	Steel

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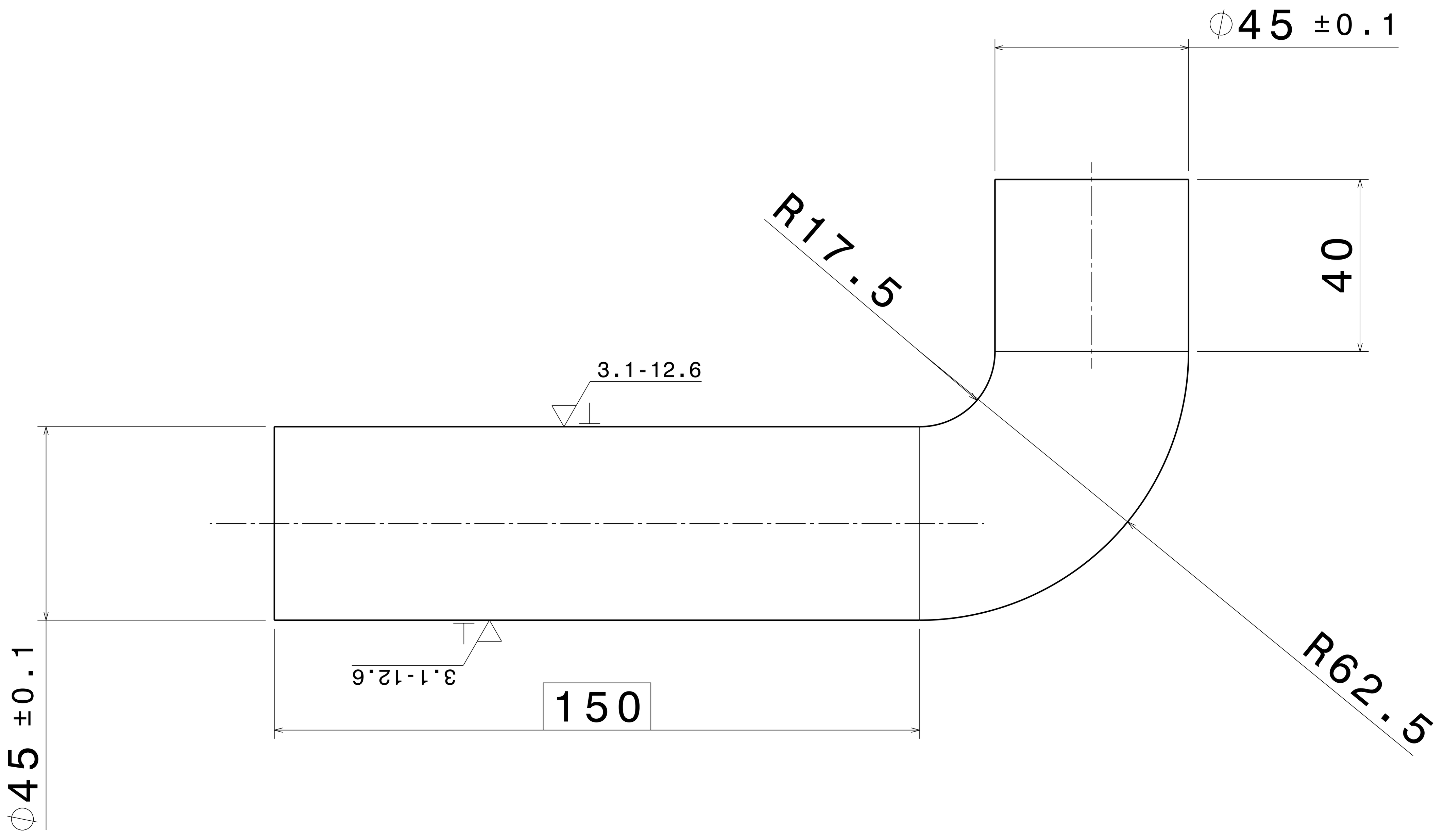
DRAWN BY Alvaro Barinaga	DATE 09/03/2018	DRAWING TITLE Assembly Drawing	
CHECKED BY	DATE	SIZE A1	DRAWING NUMBER 01
DESIGNED BY Alvaro Barinaga	DATE 10/03/2018	SCALE 1:20	MATERIAL

FINISH N8 0.5-1.6 0.030 0.008

SHEET 1/1



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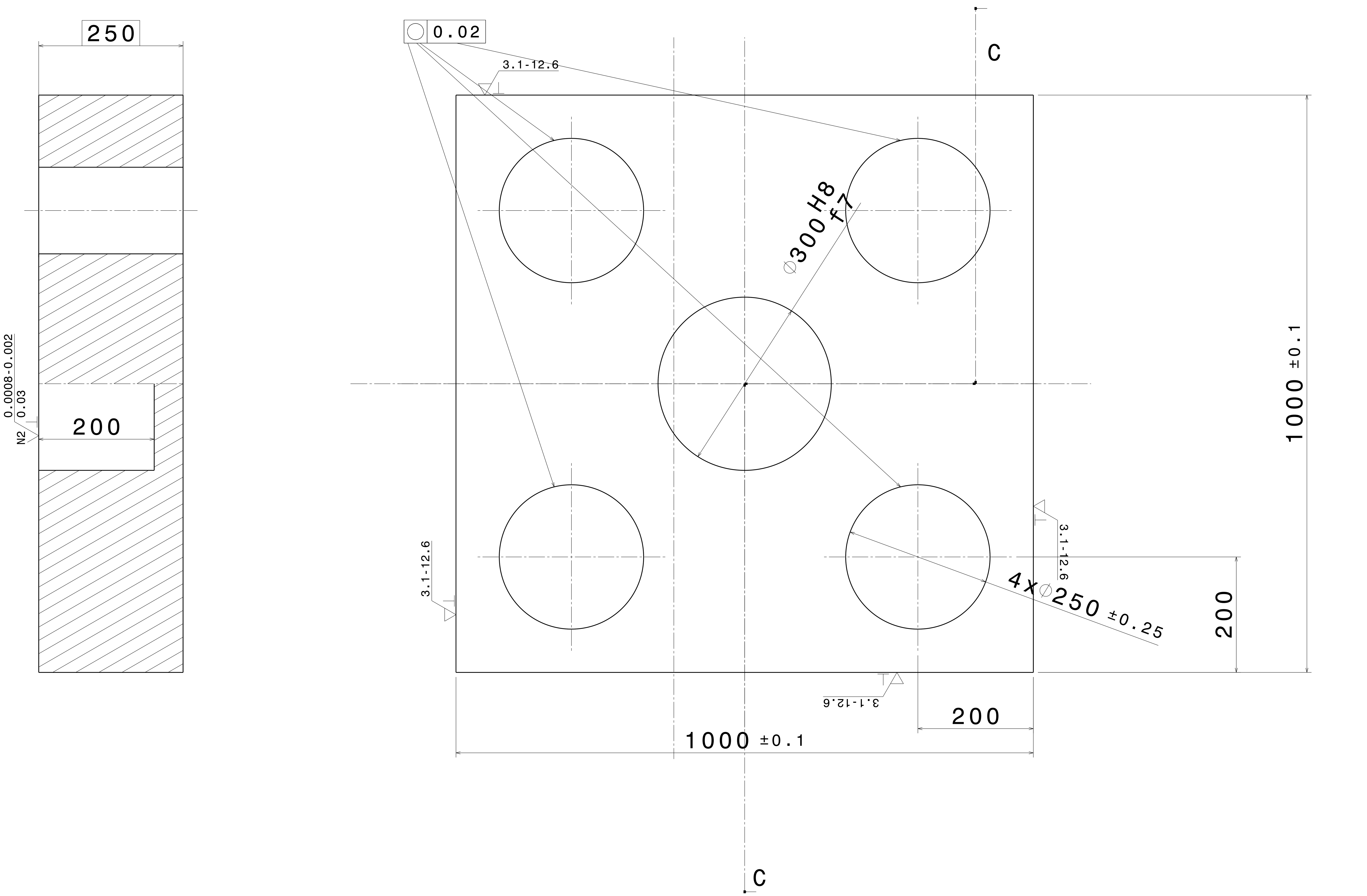
DRAWN BY Alvaro Barinaga	DATE 15/03/2018	DRAWING TITLE Stairs	
CHECKED BY	DATE	SIZE A1 / DRAWING NUMBER 02	FINISH N8 0.5-1.6 0.030 0.008
DESIGNED BY Alvaro Barinaga	DATE 15/03/2018	SCALE 1:1 / MATERIAL Steel	SHEET 1/1



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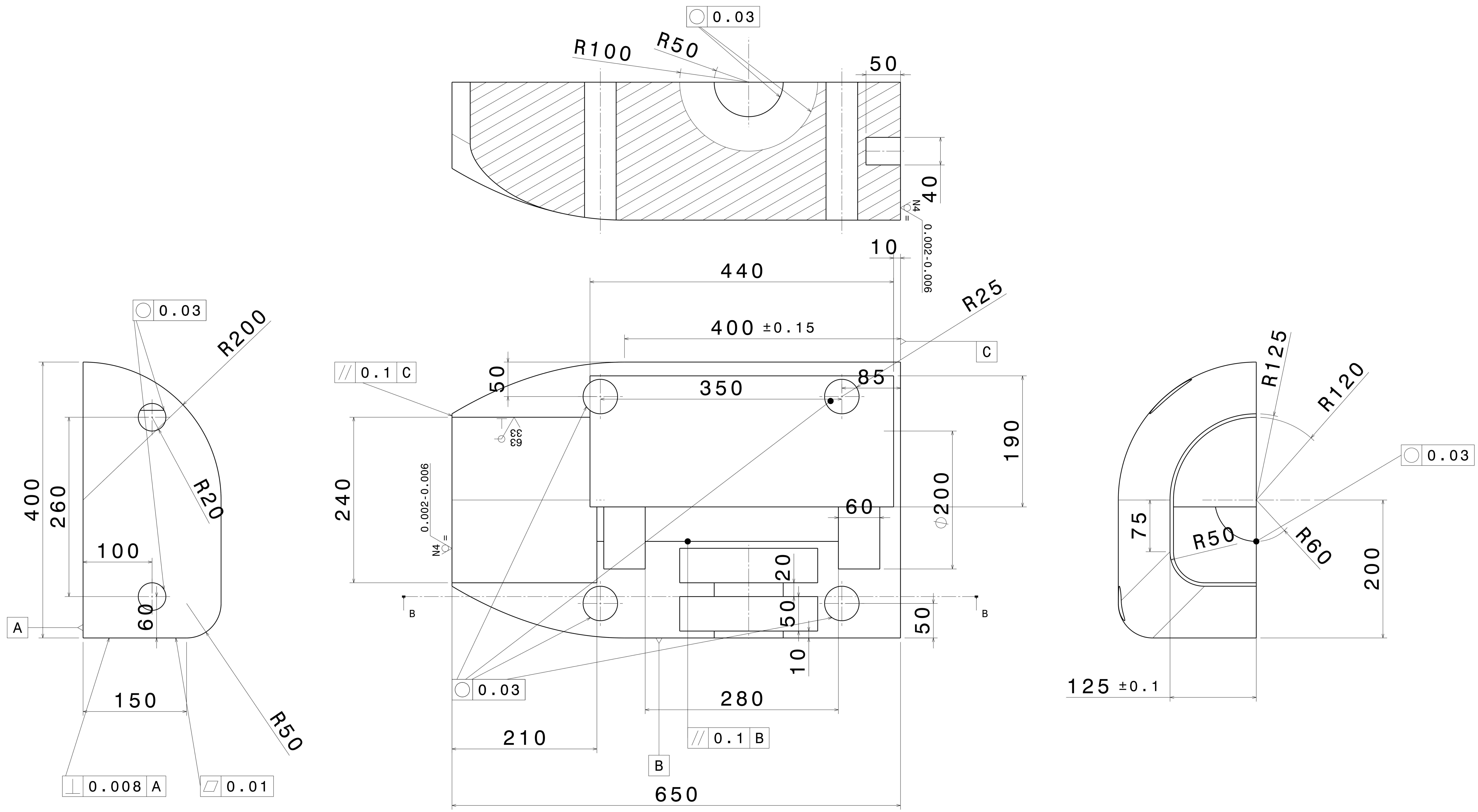
DRAWN BY Alvaro Barinaga	DATE 10/03/2018	DRAWING TITLE Base	
CHECKED BY	DATE	SIZE A1 / DRAWING NUMBER 03	FINISH N8 0.5-1.6 / 0.030 / 0.008
DESIGNED BY Alvaro Barinaga	DATE 10/03/2018	SCALE 1:4 / MATERIAL Steel	SHEET 1/1



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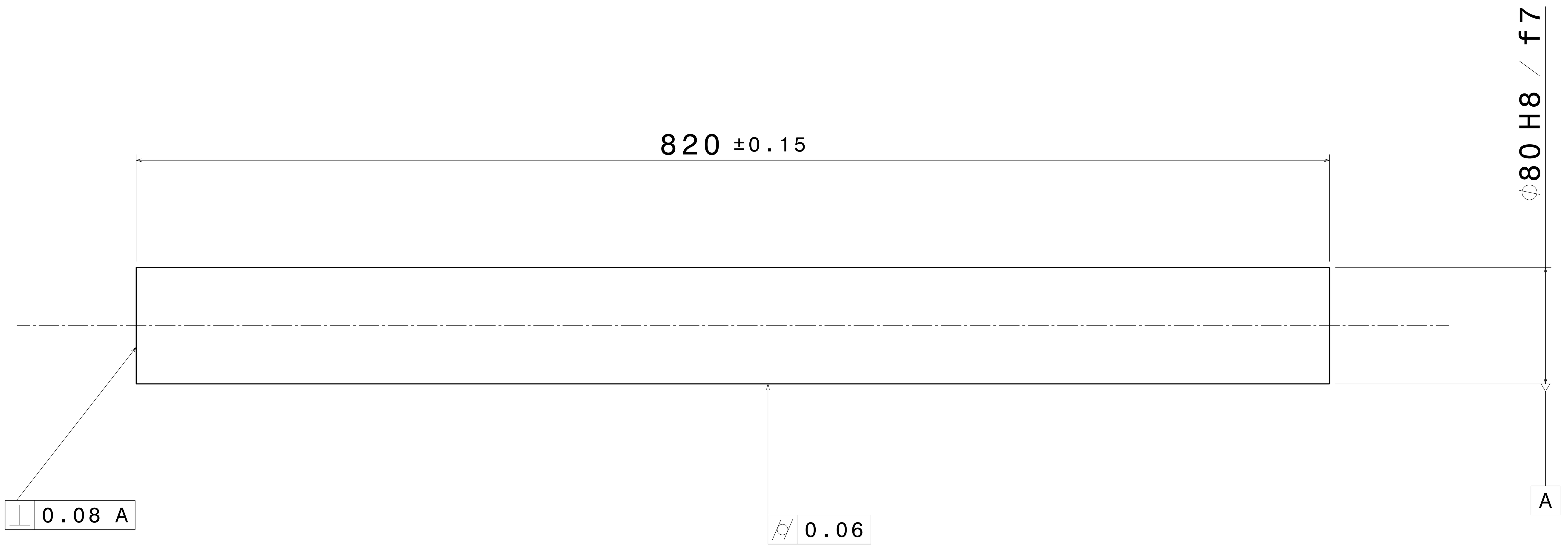
DRAWN BY: Alvaro Barinaga — DATE: 10/03/2018	DRAWING TITLE: Right Side Case
CHECKED BY — DATE	SIZE: A1 — DRAWING NUMBER: 04 — FINISH: N8 0.5-1.6 0.030 0.008
DESIGNED BY: Alvaro Barinaga — DATE: 10/03/2018	SCALE 1:3 — MATERIAL: Steel — SHEET 1/1



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DRAWN BY Alvaro Barinaga	DATE 10/03/2018	DRAWING TITLE	Shaft top side
CHECKED BY	DATE	SIZE A1	DRAWING NUMBER 05
DESIGNED BY Alvaro Barinaga	DATE 10/03/2018	SCALE 1:2	MATERIAL Steel
FINISH		SHEET 1/1	

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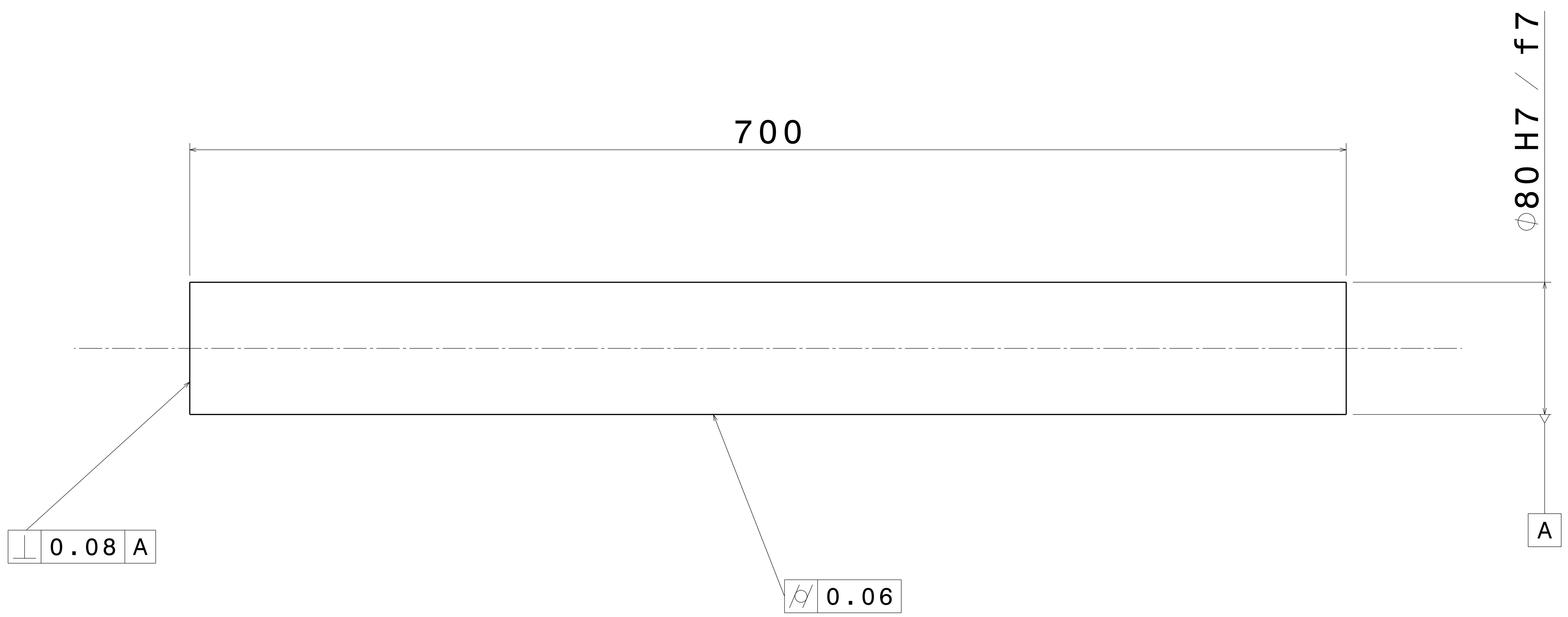
		DRAWING TITLE: Principal Shaft			
DRAWN BY: Alvaro Barinaga	DATE: 10/03/2018				
CHECKED BY	DATE	SIZE: A1	DRAWING NUMBER: 06	FINISH	N8 0.5-1.6 / 0.030 / 0.008
DESIGNED BY: Alvaro Barinaga	DATE: 10/03/2018	SCALE: 1:8	MATERIAL: Steel	SHEET 1/1	



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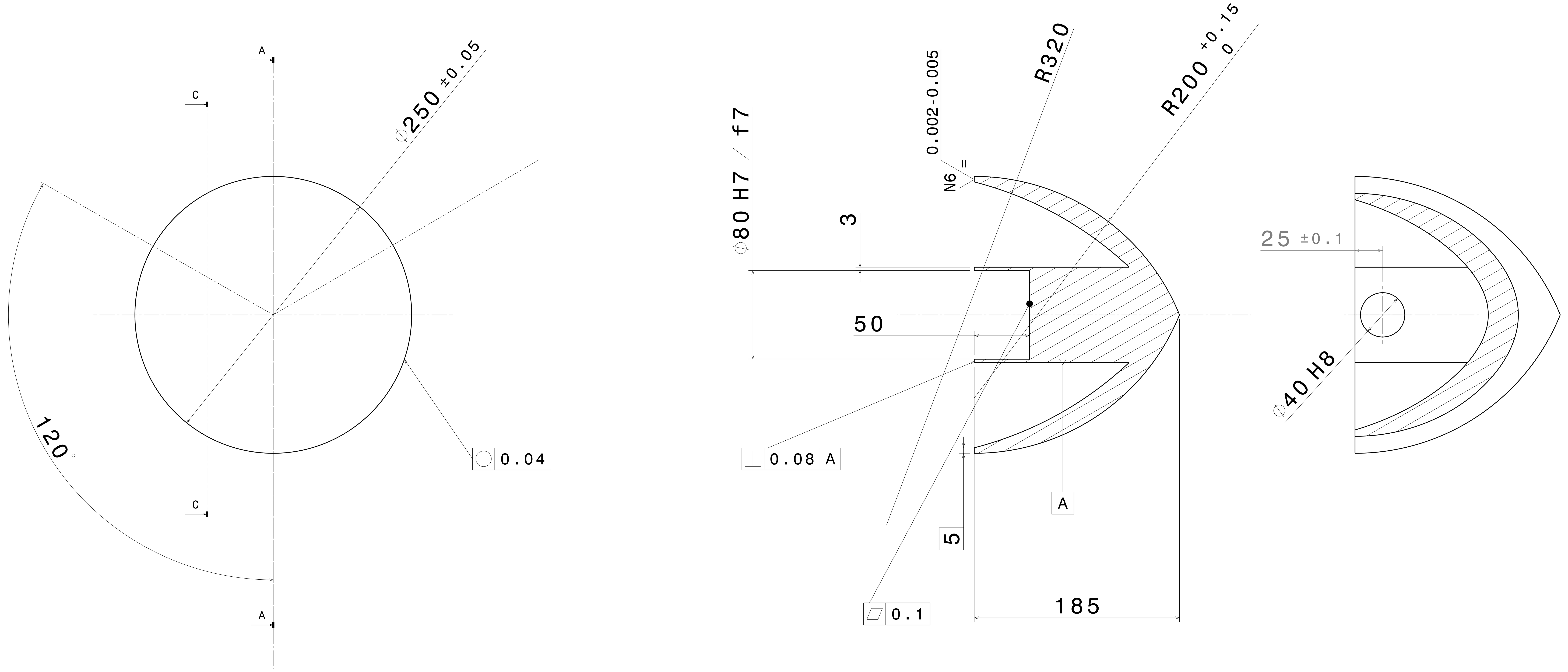
DRAWN BY Alvaro Barinaga	DATE 10/03/2018	DRAWING TITLE	Case shaft
CHECKED BY	DATE	SIZE A1	DRAWING NUMBER 07
DESIGNED BY Alvaro Barinaga	DATE 10/03/2018	SCALE 1:2	MATERIAL Steel

FINISH

SHEET 1/1



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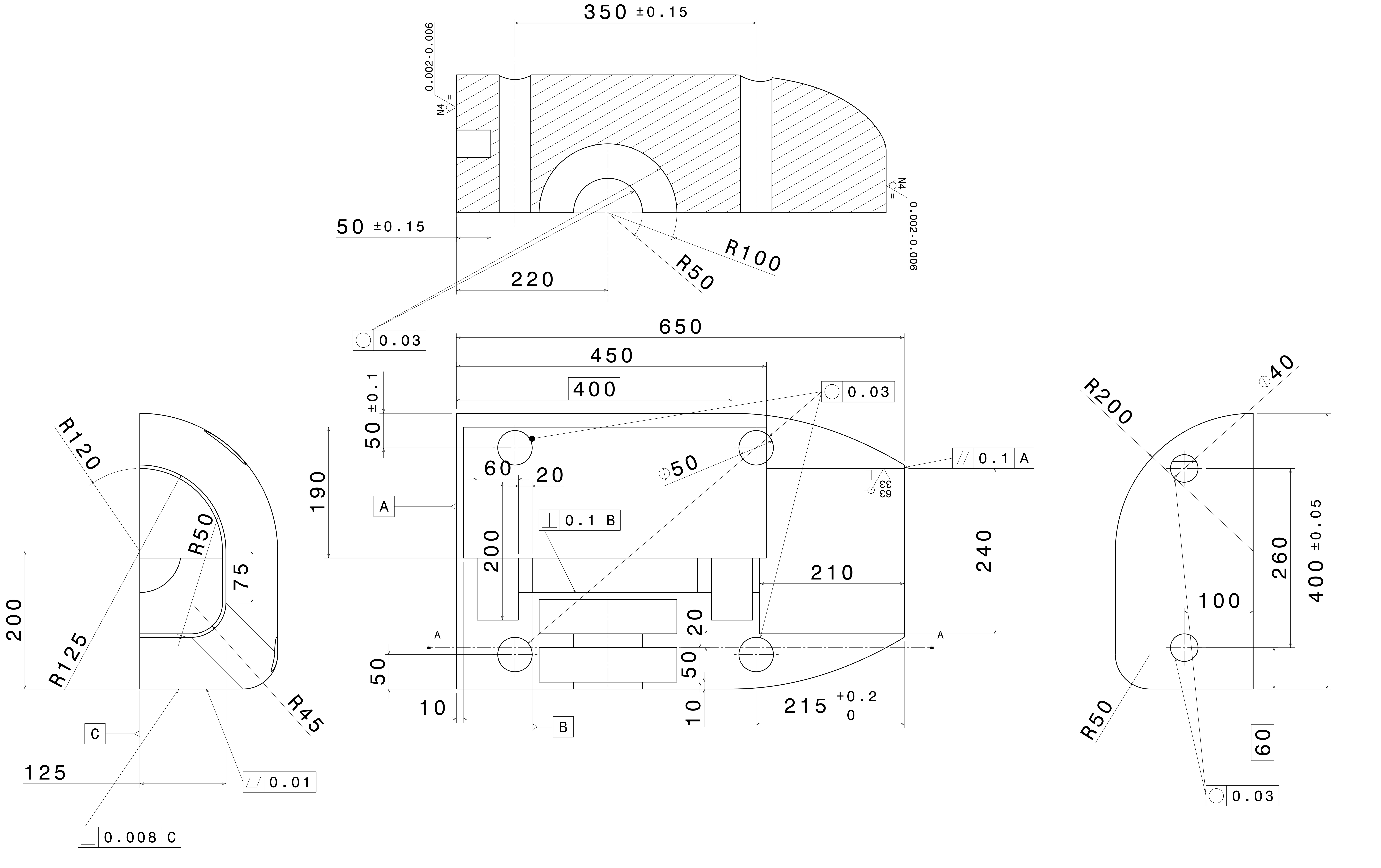
DRAWN BY: ALvaro Barinaga	DATE: 10/03/2018	DRAWING TITLE: Nose	
CHECKED BY	DATE	SIZE: A1	DRAWING NUMBER: 08
DESIGNED BY: Alvaro Barinaga	DATE: 10/03/2018	SCALE: 1:2	MATERIAL: Steel

FINISH: N8 0.5-1.6 / 0.030 / 0.008

SHEET 1/1



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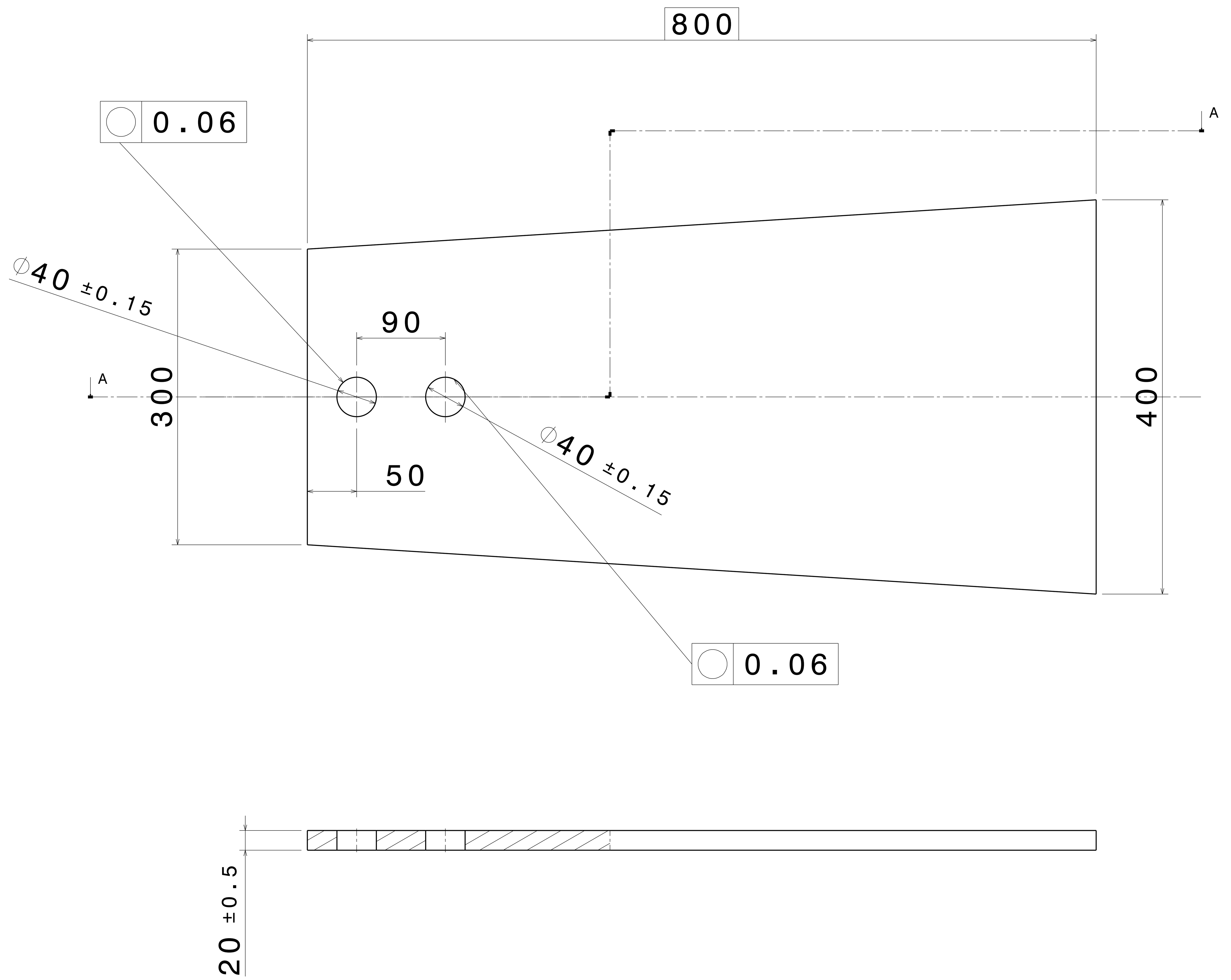
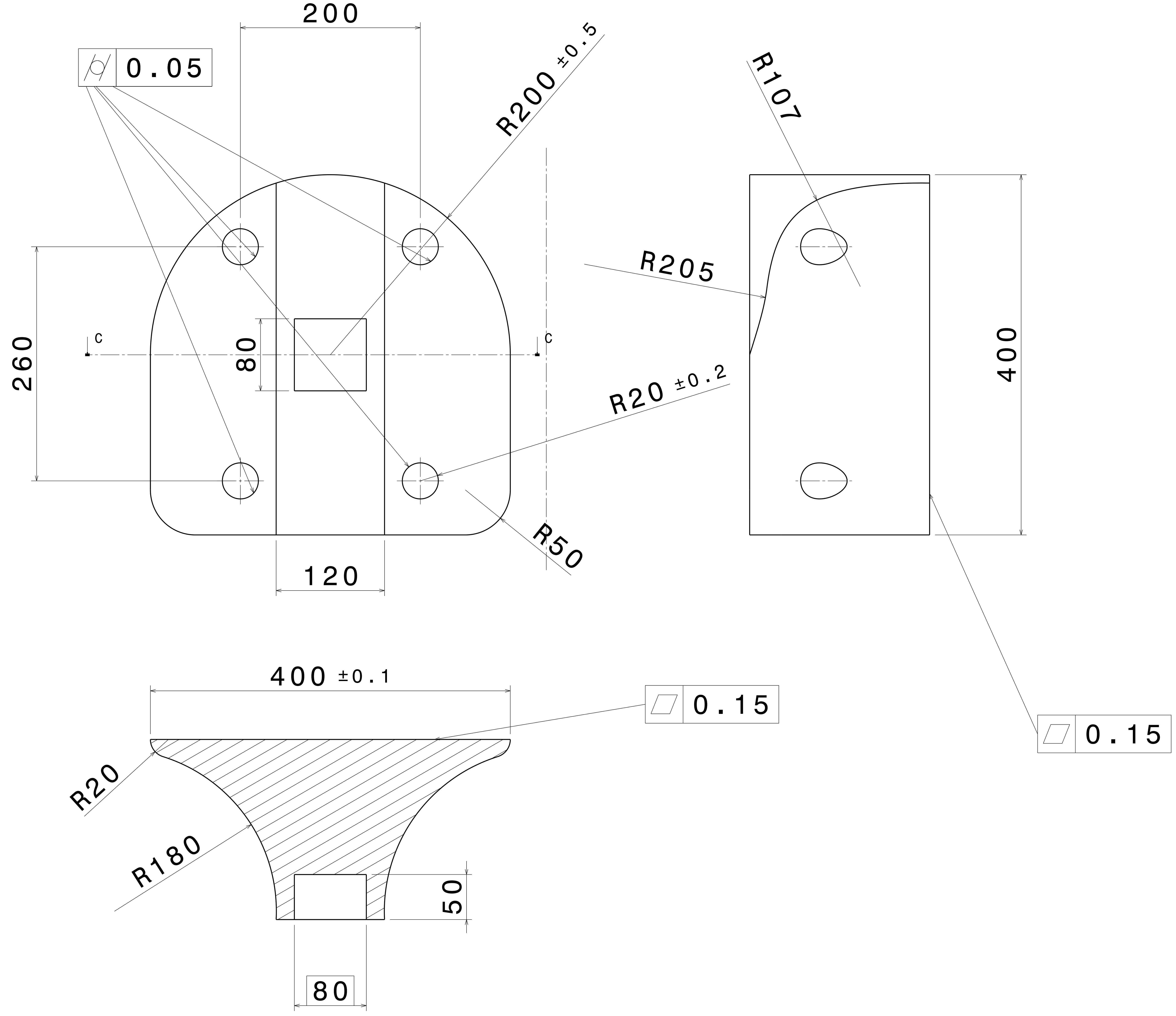
DRAWN BY Alvaro Barinaga	DATE 10/03/2018	DRAWING TITLE Left Side Case	
CHECKED BY	DATE	SIZE A1 / DRAWING NUMBER 09	FINISH N8 0.5-1.6 0.030 0.008
DESIGNED BY Alvaro Barinaga	DATE 10/03/2018	SCALE 1:3 / MATERIAL Steel	SHEET 1/1



DRAWN BY: Alvaro Barinaga	DATE: 23/03/2018	Gheorge Asachi Technical University		
		DRAWING TITLE: Vane		
CHECKED BY	DATE	SIZE: A1	DRAWING NUMBER: 10	FINISH: N8 0.5-1.6 0.030 0.008
DESIGNED BY: Alvaro Barinaga	DATE: 23/03/2018	SCALE 1:3	MATERIAL: Steel	SHEET 1/1



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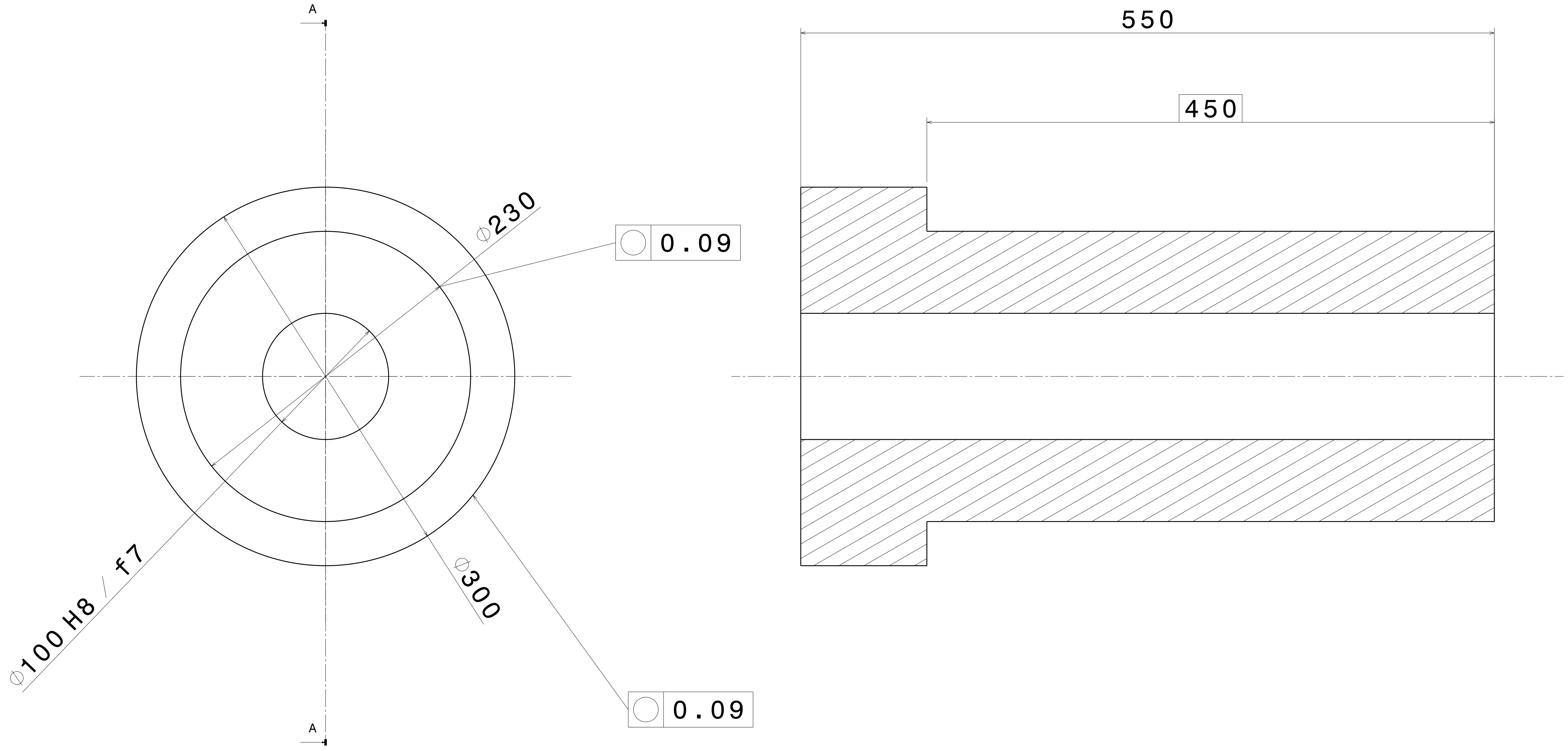
DRAWN BY Alvaro Barinaga	DATE 23/03/2018	DRAWING TITLE	Vane Back side
CHECKED BY	DATE	SIZE A1	DRAWING NUMBER 11
DESIGNED BY Alvaro Barinaga	DATE 23/03/2018	SCALE 1:3	Material Steel

FINISH N8 0.5-1.6 / 0.030 / 0.008

SHEET 1/1



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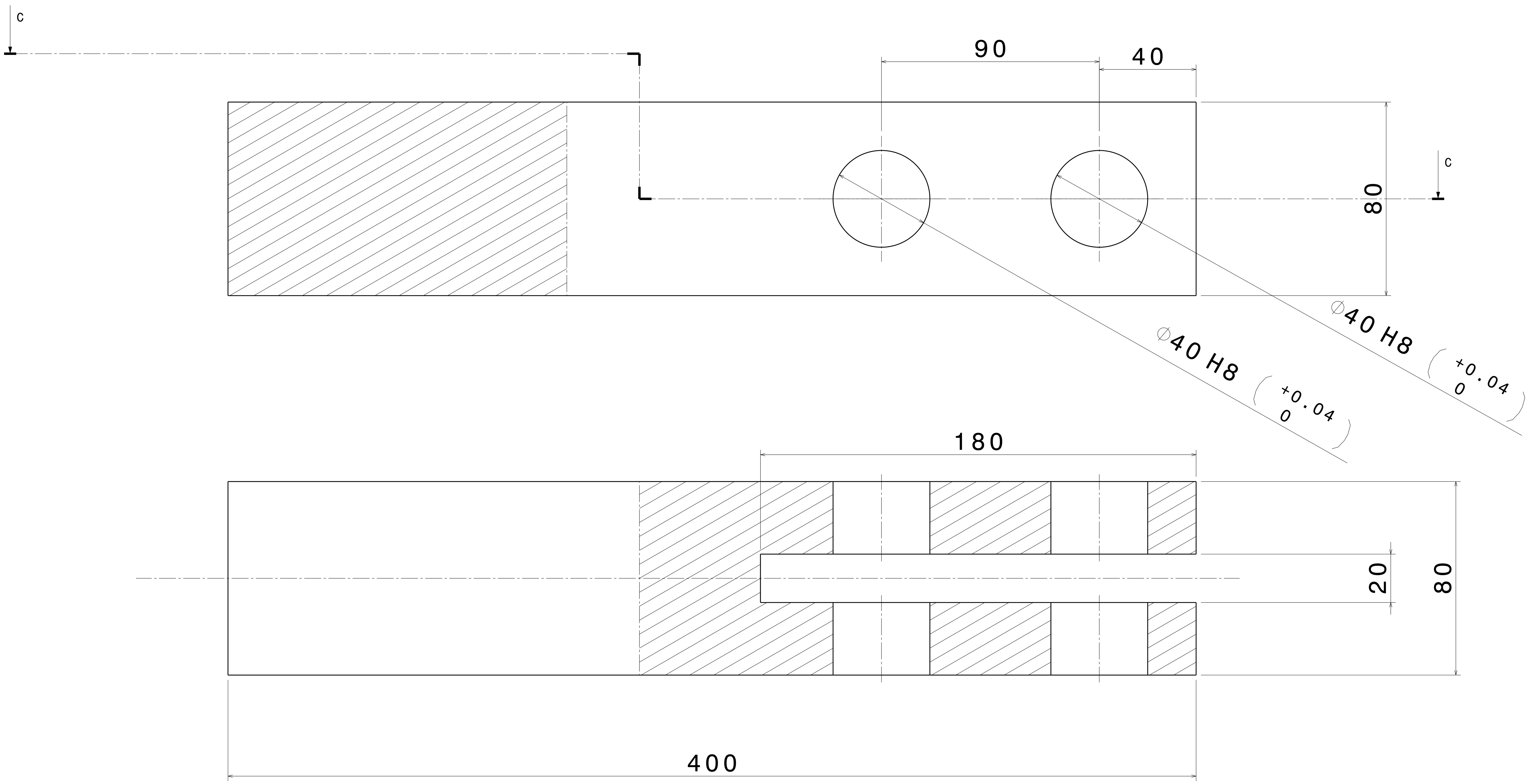
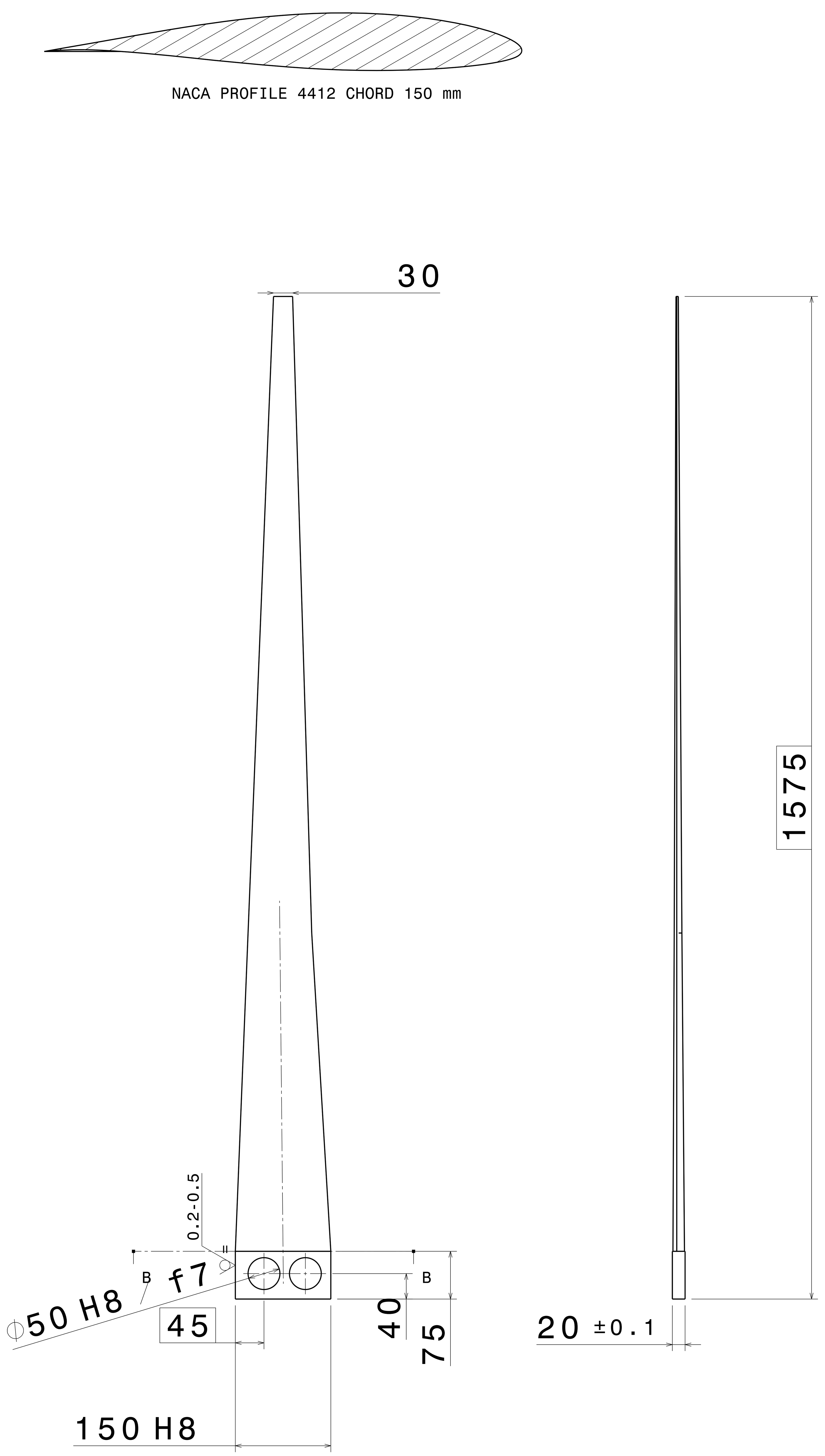
DRAWING TITLE: Top Cap

DRAWN BY: Alvaro Barinaga	DATE: 23/03/2018	SIZE: A1	DRAWING NUMBER: 12
CHECKED BY	DATE	FINISH	N8 0.5-1.6 0.030 0.008
DESIGNED BY: Alvaro Barinaga	DATE: 23/03/2018	SCALE: 1:1	MATERIAL: Steel
		SHEET	1/1



DRAWN BY Alvaro Barinaga	DATE 23/03/2018	Gheorge Asachi Technical University	
CHECKED BY	DATE	DRAWING TITLE Conexion back part	
DESIGNED BY Alvaro Barinaga	DATE 23/03/2018	SIZE A1	DRAWING NUMBER 13
		SCALE 1:1	MATERIAL Steel
		FINISH	SHEET 1/1



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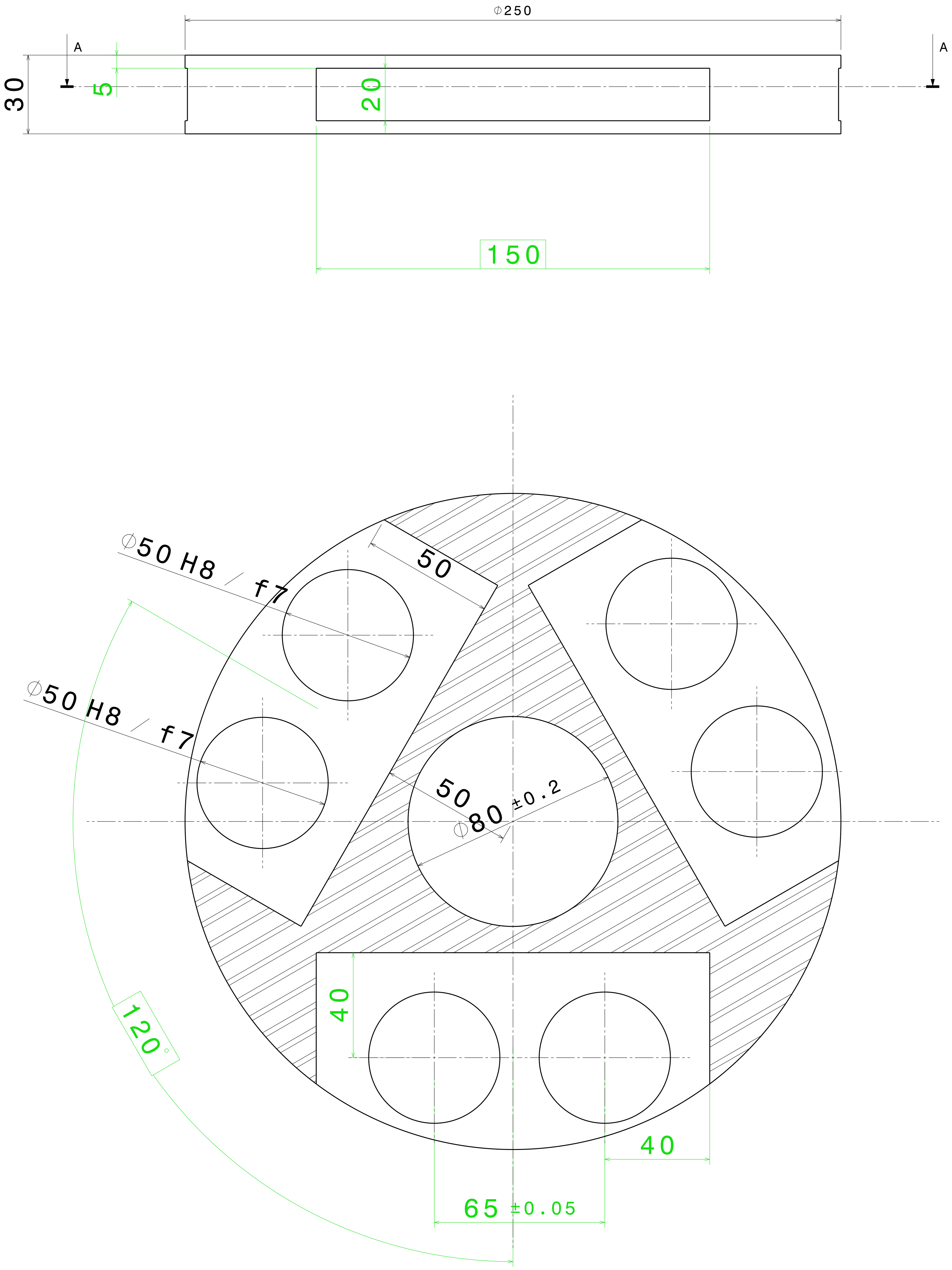
DRAWN BY Alvaro Barinaga	DATE 02/05/2018	DRAWING TITLE Naca 4412 Wings	
CHECKED BY	DATE	SIZE A1 / DRAWING NUMBER 14	FINISH N8 0.5-1.6 / 0.030 / 0.008
DESIGNED BY Alvaro Barinaga	DATE 02/05/2018	SCALE 1:5 / Material E-Fiber Glass	SHEET 1/1



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DRAWN BY Alvaro Barinaga — DATE 02/05/2018	DRAWING TITLE Conexion nose
CHECKED BY — DATE	SIZE A1 — DRAWING NUMBER 15 — FINISH N8 0.5-1.6 / 0.030 / 0.008
DESIGNED BY Alvaro Barinaga — DATE 02/05/2018	SCALE 1:1 — MATERIAL Steel — SHEET 1/1