Functional Dimensioning Based on a 3D Nominal Model

Esandi-Baztan M. Ángeles, Valin Ortega Antonio, and Brusola Simón Fernando

Abstract A part definition drawing must accurately assume the functional requirements of the mechanical system to which it belongs to enable correct functional dimensioning. This dimensioning is essential for the methods office to define its production and for metrology to define its verification. It should be noted that the functional dimensioning process we propose simulates a professional exercise in an academic environment. In this paper, a method that uses a 3D model of a mechanical system is adopted and the nominal models of the components. It also relies on analyzing the positioning of each part in the possible working states of the mechanical system. The part functional dimensioning requires mastery of the ISO-GPS language (International Organization for Standardization-Geometrical product specifications), and a precise analysis of the operation and positioning of each component. This analysis of the part positioning will allow the definition of the necessary datum systems and the definition of the initial GPS specifications of dimension, tolerance zone and pattern (maximum or least material requirement). Both analyses should provide us with the ISO-GPS functional dimensions in the functional definition drawings according to ISO 16792:2021 and other GPS standards.

Keywords ISO-GPS · Functional dimensioning · Part positioning · 3D nominal model

1 Introduction

The adoption of ISO-GPS dimensioning as a natural language in the industrial field for dimensioning parts and assemblies, both in manufacturing companies and in educational institutions, becomes complex. The many new features compared to

E.-B. M. Ángeles (✉) · V. O. Antonio
Valladolid University, Valladolid, Spain
e-mail: mariaangeles.esandi@uva.es

B. S. Fernando
Universitat Politècnica de València, , Camino de Vera, Valencia, Spain

C. Manchado del Val et al. (eds.), *Advances on Design Engineering V*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-032-08108-7_38

the traditional method of dimensioning that must be applied throughout the process cause this effect. However, the main difficulty is solved by broadening the notion of 'dimensioning' and consequently its approach.

The functional dimensioning of genuine mechanical systems means that the drawings must clearly indicate the technical functional requirements that each part must meet in order to function in each operating condition. Professional practice dictates that functional dimensioning should be limited to the strict minimum necessary and that tolerances should be as wide as possible [1]. A single element (usually a surface) will have several functions in one or more operating states of the assembly and therefore its functional dimensioning will require as many ISO-GPS specifications as there are functions. Functional dimensions are function dependent, not geometry dependent as in traditional nominal dimensioning.

Traditional teaching processes start with the geometric definition of individual parts. The next stage is usually the definition of assemblies. The aim of these exercises and problems is usually to produce definition drawings in which ISO fittings are defined, welding processes are shown, or exploded views are produced in which dimensional tolerances and surface finishes are defined. In the best case, some 'geometric tolerances' and 'tolerance stackups' are defined in the statement. The concept 'ISO dimension' is not often used and ISO 14405–2:2020 (Dimensional tolerancing—Part 2: Dimensions other than linear or angular sizes) is not usually applied.

This training sequence does not correspond to the way in which the process of defining mechanical systems takes place in professional engineering practice. It begins with the requirements defined in the project's Functional Specification Document and a preliminary design model in 3D format, and ends with the functional dimensioning of each component, by means of ISO-GPS specifications.

The didactic method under discussion [2] is predicated on the existence of a 3D model of the assembly, in addition to a working knowledge of the ISO-GPS dimensioning language, as defined mainly in the ISO 1101(Geometrical tolerancing—Tolerances of form, orientation, location and run-out) and ISO 5459 (Geometrical tolerancing—Datums and datum systems) standards. ISO functional dimensioning requires the adoption of engineering functional analysis methods to identify the minimum functional requirements to be met by the systems. The development and availability of a nominal 3D model in the early stages of a project is not uncommon, nor is it difficult to achieve, even in medium-level educational environments. Students frequently acquire basic knowledge of the ISO-GPS language in both professional and academic settings.

The utilization of technical functional analysis techniques as a subject within the domain of engineering graphics is an uncommon occurrence. By employing a series of basic kinematic diagrams, assembly areas and functional block or flow diagrams, we can direct the functional dimensioning towards the study of the positioning and fulfilment of the functional requirements of the assembly through the study of the positioning and tolerance stackups.

2 Materials and Methods

The functional dimensioning process we propose simulates a professional exercise in an academic environment. The procurement of a 3D model of a device, in our case CATIA V5 software (3D CAD Interactive Application), allows complete knowledge of each of the parts of a mechanism, their relationships and the expected functional requirements. The structure of an assembly in the V5 environment is presented, along with the general process of positioning parts in the context of their real-life behavior. Engineers, suppliers or clients exchange and demand technical information. The preliminary design study of a mechanical system usually started with an assembly drawing or a 3D model. In this phase, the mechanism is the constructive solution to a general service function agreed with the customer. Initially, the 3D model has only the main nominal dimensions of the assembly. At the end of this process, the specifications and tolerances that ensured operability with the parameters detailed in the project's functional requirements report will be achieved.

2.1 Kinematic Diagram

The first step was to understand how the mechanism worked and its kinematic structure. The first step was identifying each of the kinematic equivalence classes (set of parts without relative motion to each other). The most straightforward method of identifying each equivalence class was to utilize a coloring technique, whereby the constituent parts of each class are distinguished by a distinct color (see Fig. 1).

To produce a schematic representation of machines and mechanisms in 2D or 3D, it was necessary to apply the ISO 3952 standard (from ISO 3952-1 to 4). In order to facilitate this process superimposition of the diagrams on the drawings of the complete assembly was recommended (see Fig. 2). However, it was imperative that the relative positions and orientations of the mechanism must be respected in the diagrams. It was also recommended to differentiate the kinematic units by means of colors in both diagrams and drawings, and in perspectives.

The problem solver was forced to frame the problem in such a manner as to enable a solution, and this required simplification and idealization of the problem. This approach aligned with the manner in which CAD considered parts and geometric constraints within the 3D model.

The contacts and degrees of freedom between each equivalence class identified in the kinematic diagrams facilitated the determination of the functional structure to impose on our 3D model and the identification and gathering of the constraints to be used in the 3D model of the assembly.

In the structure of the 3D model, each equivalence class corresponded to a 'logical' subset. That is to say, a component (Catia software terminology) or set of parts with internal links that behaves as a single element at an external level. The grouping of the positioning restrictions of each equivalence class and the definition of possible

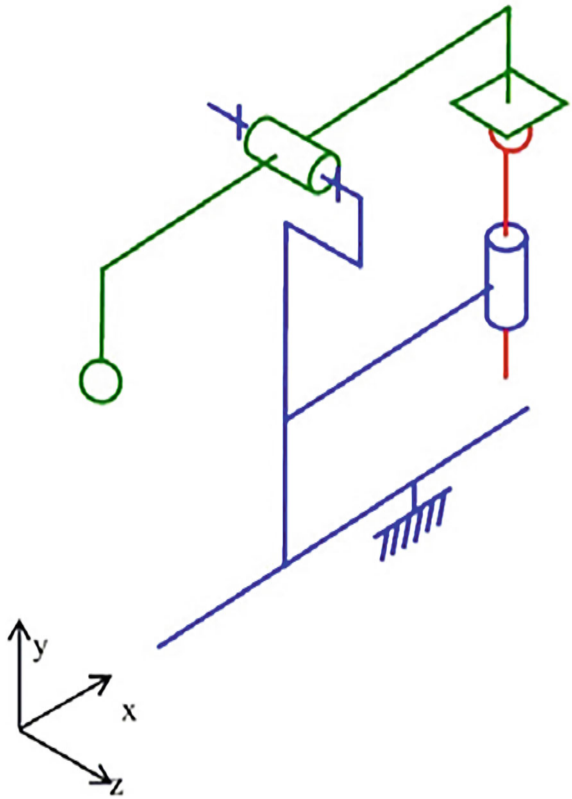


Fig. 1 Example of a 3D Kinematic diagram. Course on mechanical connections [3]

'functional blocks' inside the equivalence class had to be allowed as a consequence. The composition of these functional blocks or components may vary, with the number of groups of parts ranging from a single element to multiple combinations, contingent upon the assembly process employed.

Subsequently, were identified the fixed equivalence class or the one that behaves as the basis of the assembly. Furthermore, the identification of additional equivalence classes that were linked to the 'external environment' had to be conducted. The geometrical elements that characterize these links, and the degrees of freedom present within them, had also to be determined.

These contacts with the 'external environment' defined the so-called 'skeleton part' which was the virtual starting part of the 3D modelling of an assembly. This part had to be fully determinable from the requirement report of the assembly. This facilitated the design in the context of non-standard or non-commercial components.

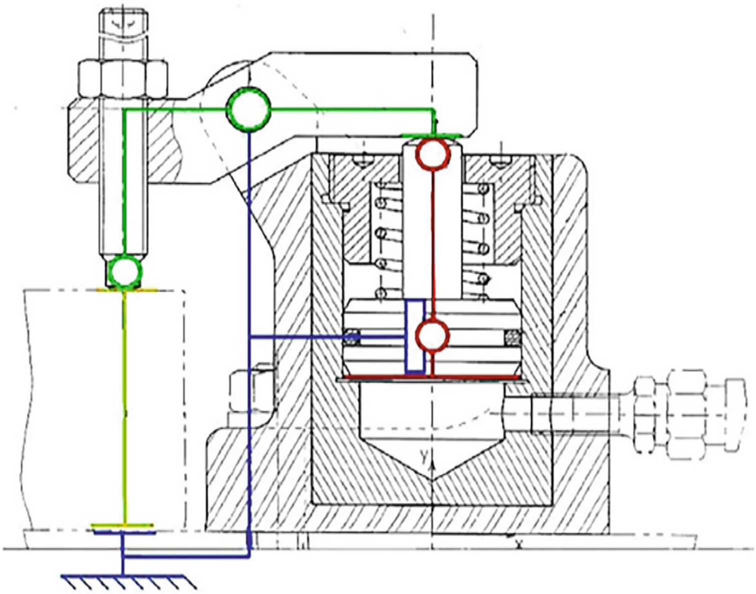


Fig. 2 Kinematic diagram superimposed on the drawings of the assembly example. Course on mechanical connections [3]

2.2 Technical Functional Analysis

The subsequent stage in the functional dimensioning process was to identify the main elementary technical functions of the assembly using technical functional analysis methods. The purpose of this study was to specify the areas to be investigated, to identify the service conditions and the geometric functional conditions of the mechanism. As the functional dimensioning aims to specify the conditions that ensure the functions, it was essential to identify each and every one of them. These tools facilitated the determination of dimensional requirements.

The most suitable functional analysis methods for defining the components of a mechanism were as follows: The following methodologies were employed: SADT (Structured Analysis and Design Technique) [4], failure analysis DFMEA (design failure mode and effect analysis or AMEDC *Analyse des Modes de Défaillance et l´Étude de leur Criticité* [1]) and TAFT (Technical Functional Analysis Tables) TAFT [1].

The utilization of flow and contact diagrams within the SADT facilitated the visualization of the multiple links and interfaces between each part of the system. It was asserted that the provided elements facilitated the comprehensive definition of both the Elementary Technical Functions (ETF) and the positioning of each constituent part. The contact diagram facilitated the grouping and differentiation of the geometrical positioning constraints, the degrees of freedom, the components utilized in the kinematic links (e.g. bearings, gears, threads, shafts), and the constraints characterizing each operating state. Initially, the internal constraints for each equivalence class had to be established. Conclusively, the constraints defining each operating state had to be determined.

Failure analysis (AMEDC) was the process of identifying the functional characteristics of excess or defective material, with the objective of avoiding unwanted contact or interference between parts. Furthermore, it facilitated the regulation of passive functions, including the directives 'let through' and 'not to contact with'.

The most straightforward AMEDC to execute is the simulation of the displacement of functional surfaces of each component, a process that is rendered uncomplicated by the utilization of a 3D model. In order to check for interferences with adjacent parts, it was sufficient to introduce a pattern (positive or negative) in significant directions, of a value slightly larger than the general tolerances (e.g. 0.5 mm).

The TAFT facilitated the capitalization of all pertinent information and the definition of the geometrical characteristics that components were required to fulfil in order to satisfy each ETF, i.e. the specifications. The aforementioned specifications had to be expressed in the form of ISO dimensions of a part. The requirements that each surface might meet were to be recorded in an Excel table or database. For this purpose, each surface of each component of the assembly should be identified by a code. This identification code should have consisted of one or more letters and a number, thus forming an alias for each part. This identification code should also have to be recorded in a drawing and in the 3D model of each component. In instances where a more precise identification was required for the utilization of CAT (computer aided tolerancing) applications, the code might conform to the STEP type.

2.3 Assembly Diagram

In the context of complex assemblies, it can be advantageous to prepare the assembly sequence of the device, since these are usually simple graphics that correspond to more intuitive operations and allow the surfaces in contact between the parts to be identified. The assembly sequence does not correspond exactly to the hierarchy of surfaces of the positioning, but in many cases, it coincides or is very close. Therefore, it is advisable to obtain the range as an exercise prior to the analysis of the positioning, which is what will actually serve to determine the ISO dimensioning process for each component.

In addition to defining the assembly sequence, assembly ranges enable the 'direction' of contacts and flows to be established (a capability that block diagrams do not possess) and it is possible to determine whether one part 'positions' or 'is positioned'.

2.4 States of Operation

The arrangement of components within a mechanism may be subject to variation depending on the operational state of the mechanism (open, closed, unloaded, loaded, etc.). For each operating state, a set of geometrical constraints (distances, orientations, overlaps, etc.) between parts of different equivalence classes will correspond to determine the specific relative position of the parts. Those constraints are grouped in the 3D model structure. Their management (activation or deactivation, modification of values, etc.) shall facilitate the transition from one configuration to another without altering the model. The identification of an operating state is to be made by a code in conjunction with one or more specific geometric constraints.

For each operating state, the positioning of each component and the tolerance stackups corresponding to the functional requirements must be studied. It is therefore helpful to obtain the 2D (or 3D) representation of the mechanism to facilitate the establishment and analysis of the tolerance stackup for each functional requirement.

2.5 Positioning

After structuring the 3D model and determining the requirements, functional dimensioning for each non-standard part proceeds. The manufacturer provides the commercial or standard parts, with documentation on the functional dimensions and the tolerances that can be assigned to them. Therefore, the first part of the ISO functional dimensioning corresponds to the geometrical specifications for positioning.

Parts may have several operating arrangements if there are several operating states of the mechanism. The positioning of a part can be defined as the arrangement of a part in relation to adjacent parts when the part is in service, i.e. is performing a function.

Positioning is performed by contacts between geometric positioning entities, usually surfaces. Positioning entities are of two types: surface positioning entities and bilateral positioning entities (with adjustment). When positioning entities make up the positioning of a part, they are hierarchized according to their preponderance and define, for each part, their ISO dimensioning reference system, which is unique for each part. Consequently, the positioning of the part under consideration constitutes the basis and preliminary step for the ISO dimensioning of said part.

The positioning of a part is defined in relation to another part, the 'positioning partv. The datum system of the positioned part will be matched by another datum system of the 'positioning part'. The same applies to the specifications of the integral datum elements. Several parts may be positioned on a part and there may be as many secondary datum systems as there are parts positioned on it, but only one main datum system. The system of the 'positioned part' is designated the main datum system, is denoted ABC and is unique for each part. The system of the 'positioning part' is called secondary datum system, it is denoted by DEF or successive and there will be

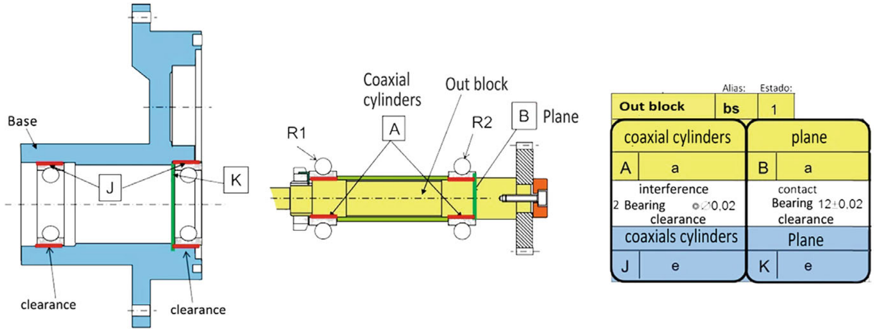


Fig. 3 Example of a positioning table with primary and secondary datum identification

as many as the number of parts positioned on it. The system of the 'positioning part' is referred to as the secondary datum system.

The datum system comprises derived elements, yet the specifications of the integral datum elements must be determined. That is to say, the ISO dimensions of the true datum elements must be ascertained according to their hierarchy. Consequently, the positioning of a part will define the datum system of that part and the specifications between each of the 'true' elements that constitute that datum system.

Anselmetti's CLIC method [5] facilitates the documentation of the ISO dimensioning process, corresponding to the positioning and the ISO specifications for each operating entity, as well as the potential alternatives or variants in its dimensioning. Its positioning card allows us to record the nature of each positioning entity, the hierarchy of each contact and the ISO dimensioning required both for the positioned part and the necessary dimensioning of the part or parts on which it is positioned (see Fig. 3).

As each part shall have a positioning file, the collective sum of these files will constitute a mechanical assembly positioning file. Each card is to be accompanied by a positioning table and a drawing. The drawing is to show the positioned part and the 'positioning' part, and it is to identify each positioning entity and its alias. In addition, on each tab there shall be a drawing with the corresponding ISO specifications of both the positioned part and the 'positioning' part (main and secondary systems and specifications between reference elements).

Ideally, the identification of the reference system for each part should be carried out in accordance with the ISO standard directly on the 3D model. This approach enables the automation of 2D dimensioning and the completion of positioning tables. However, to avoid 'gaps', it is advisable to apply a systematic procedure or protocol. This is more easily achieved by means of a positioning card for each part, even if the ISO specifications have to be transferred to the functional drawing of the parts.

2.6 Tolerance Stackup

A functional requirement is a condition on a pair of geometric elements that belong to different parts, but are connected by intermediate contacts through intermediate parts that form a ‘dimensioning chain’. This is known as a tolerance stackup and can be 1D, 2D or 3D. Each of the intervening parts in the tolerance stackup provides a functional dimension and is referred to as a link-dimension.

The identification of the surfaces that condition the magnitude (termed ‘end surfaces’) and the contact surfaces of each part with the rest of the parts involved in the formation of the functional condition (contact surfaces) is imperative. For each component, the distance or magnitude between the contact surfaces determines a functional dimension and is affected by tolerance. It is important to note that, since each link dimension is subject to a tolerance, the condition dimension is also subject to a tolerance. The condition dimension is a functional dimension of the assembly, and the link dimensions are functional dimensions of the individual parts involved.

The following procedure will be employed to locate (specify their location) these surfaces with respect to each other. This will be achieved by means of one or more ISO specifications. In general, the specification will be of position, but it is possible to use specifications of symmetry, coaxiality or any surface profile. It is important to note that only the orienting reference (1st reference of the auxiliary reference system) will be essential; the rest of the references are positional and (2nd and 3rd references of the auxiliary reference system) will only be necessary in some cases.

In cases, it is necessary to introduce orientation tolerances. These cases are identified by the introduction of the ‘analysis straight line´ artifice. In the event that the line of analysis does not intersect the first reference of the main reference system of the link part under study, it will be necessary to add an orientation tolerance (often perpendicularity or parallelism) to the position tolerance.

The tolerance stackup analysis will provide us with the ISO dimensions corresponding to each functional requirement. As we explained [6], there are different types of tolerance stackups depending on whether the base part contains an end surface or not. If the base part contains an end surface of the tolerance stackups (it is an end part), the stackup will be simple or single path. If the base part does not support an end surface, the stackup will have two branches and will be called a contact loop. This differentiation is due to the fact that it is necessary to form reference systems on the positioning surfaces of the link parts starting from the base part in order to control the angular effect of the deviations from the nominal part.

The main functional requirements (service conditions) will be easy to identify after the functional analysis has been carried out and recorded in a TAFT. Each of them implies the existence of a tolerance stackups and a dimensional condition expressing it over the whole. Each functional requirement is expressed by at least one position specification and, if the straight line of analysis does not cut the primary reference, by another orientation specification.

For each tolerance stackup, we shall draw up an Excel file or table and an analysis figure where the tolerance stackup is graphically represented. In the tolerance stackup file, the nominal value and the tolerance width of each dimension-link shall be defined. In most cases (stackups up to five links) the tolerance synthesis procedure shall be the 'worst-case' scenario [7]. In the case of longer stackups or extended production runs, the probabilistic synthesis method is widely regarded as the most advisable approach.

Every operating condition gave rise to specific functional requirements, and each functional requirement had its own tolerance stackup and its own tolerance stackup file. Together they formed a tolerance stackup dossier organized by operating condition. Each file contained a drawing of each link, with the ISO specifications corresponding to each link. As for positioning, the dimensioning of the requirements was ideally done directly on the 3D model.

2.7 General Tolerances

To complete the functional dimensioning, it was necessary to specify the general tolerances that will controlled interferences with other blocks or adjacent parts, as well as the excess or lack of material in accordance with ISO 22081:2021(General geometrical specifications and general size specifications). General tolerances were known to exhibit three distinct levels of appreciation categorized from the widest to the narrowest: firstly, those that are intended to avoid interferences with neighboring parts; secondly, those that are intended to control part thicknesses; and thirdly, those that are intended to control local appearance characteristics.

The ISO dimensioning needed the surface quality specifications by both the profile method (ISO 13715:2017) and the area method (ISO 25178:2016). Furthermore, it was essential to differentiate at least functional, supporting and non-functional surface qualities. The same applied to the hierarchization of requirements according to ISO 24096:2024, as the TAFT allowed identification of customer, product, functional, feature and parameter requirements according to severity and susceptibility.

2.8 Clarifying Specifications

Considering the exhaustive nature of the proposed functional dimensioning, we judge that it is highly probable that there will be multiple specifications for the same element. Consequently, it became necessary to refine the multiple dimensioning obtained and eliminate unnecessary specifications. The principle of dimensioning the minimum required to ensure functionality was a fundamental aspect of professional applications, given the costly manufacturing and verification of ISO-GPS specifications. In instances where specifications of different types were present, location specifications were given priority over orientation and form. In the event of equal values, the location or orientation specifications should be maintained and the form specifications eliminated.

2.9 ISO Dimensioning on the 3D Model

There were tools for ISO dimensioning of 3D models of isolated parts with grammatical support (e.g. Catia's FTA module) that associated the specifications with the 3D model as if they were another parameter or variable of the model, ensuring that the 3D model is fully linked to its 2D representation.

There are also tools for automatic ISO dimensioning on 3D models of assemblies (3DExperience app), which can indicate the functional and positioning requirements of each component. This facilitates the dimensioning of each component, but does not make it possible to carry out a prior technical functional analysis that would provide the app with the functional requirements and the main and auxiliary datum systems for each part to be positioned. These App's avoided the elaboration of dossiers of tolerance stackups and positioning, yet they did not eliminate the requirement for understanding, structuring and functional analysis of the device under scrutiny. Absent such analysis, it was not possible to ensure compliance with all the technical functional requirements. It could de hypothesized in the future AI tools would facilitate automatic ISO dimensioning; however, at present 3D CAT tools still require user expertise in ISO-GPS.

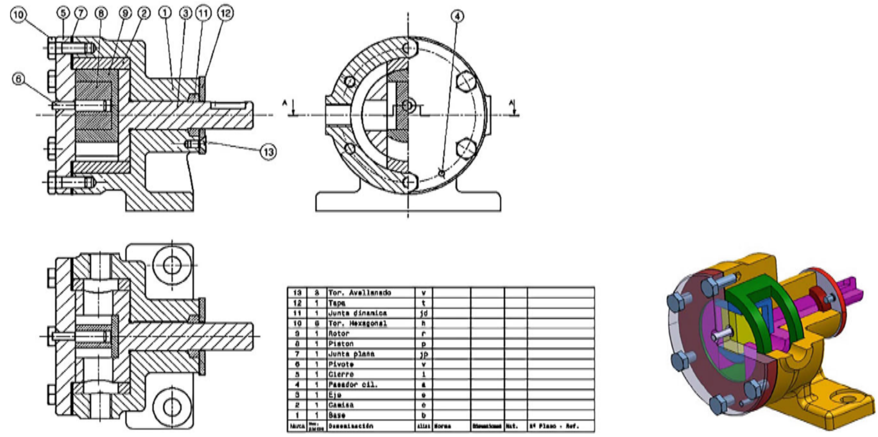
3 Obtaining ISO Positioning Dimensions

A practical example illustrates the method described above for obtaining ISO positioning dimensions of two parts from an Eccentric Pump. The selection and sequence of figures and technical drawings employed in this study constitutes the most efficacious and precise means of conveying the process under investigation incorporating graphic elements and graphic results (see Figs. 4, 5, 6, 7, 8, 9 and 10).

As a subsequent step to obtaining these ISO dimensions, it would be necessary to obtain the functional requirements dimensions. This process was detailed in a preceding publication by the authors of the present paper [6].

4 Discussion

Figure 10 illustrate two components that have been precisely defined in terms of shape and dimensions. Additionally, through the integration of ISO dimensioning, these components ensure not only aesthetic compatibility but also ensure optimal functionality within the device to which they are affixed.



13	8	Tor. Avellanado	v				
12	1	Tapa	t				
11	1	Junta dinamica	jd				
10	6	Tor. Hexagonal	h				
9	1	Rotor	r				
8	1	Piston	p				
7	1	Junta plana	jp				
6	1	Pivote	v				
5	1	Cierre	i				
4	1	Pasador cil.	a				
3	1	Eje	e				
2	1	Camisa	c				
1	1	Base	b				
Marca	[illegible]	Denominación	Alias	Norma	[illegible]	Mat.	Nº Plano - Ref.

Fig. 4 Eccentric pump assembly drawing and preliminary project model

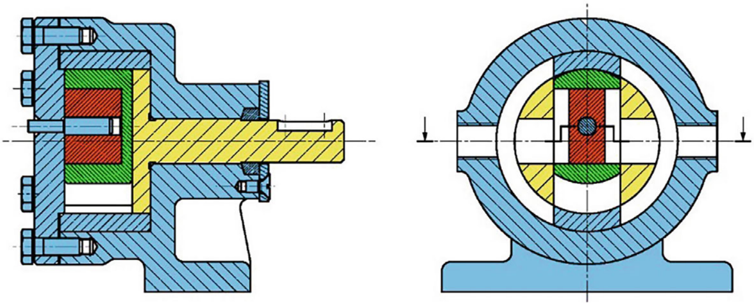


Fig. 5 Utilization of color-coding as a means of distinguishing between equivalence classes on a two-dimensional plane

The creation of a 3D model of a mechanism facilitates the establishment of a design intention, ensuring that the structure of the model of the assembly and the definition of the components correspond to the operation. This, in turn, facilitates the determination of the ISO dimensions of functional parts.

This process facilitates the application of ISO-GPS dimensioning in a logical way, starting from a functionally structured 3D model as the simplest way to understand that the necessary ISO dimensions are due to two types of requirements: positioning and service functions. These requirements must be expressed in ISO-GPS specifications.

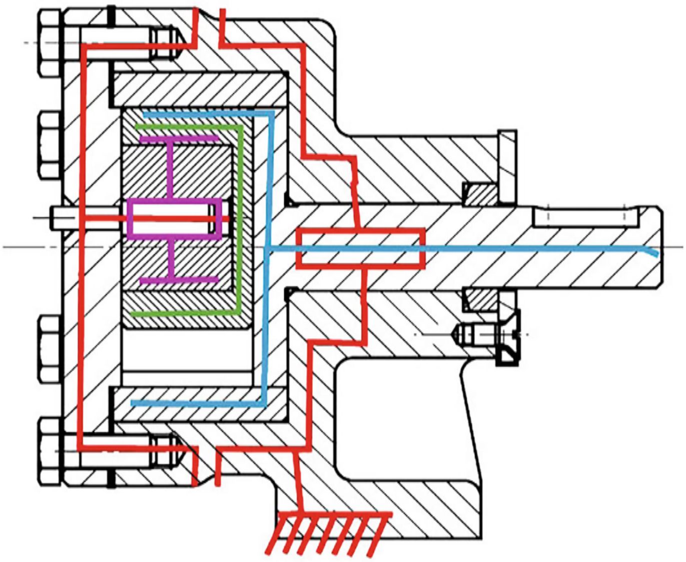
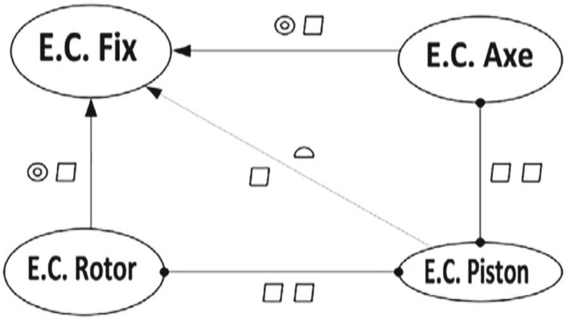


Fig. 6 Kinematic diagram superimposed on the drawing

Fig. 7 The block diagram illustrates the contacts between equivalence classes



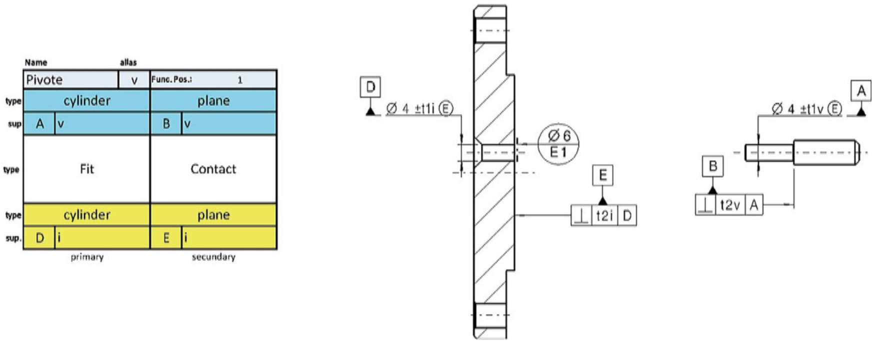


Fig. 8 CLIC table for positioning the pivot (V) with its corresponding ISO dimensioning

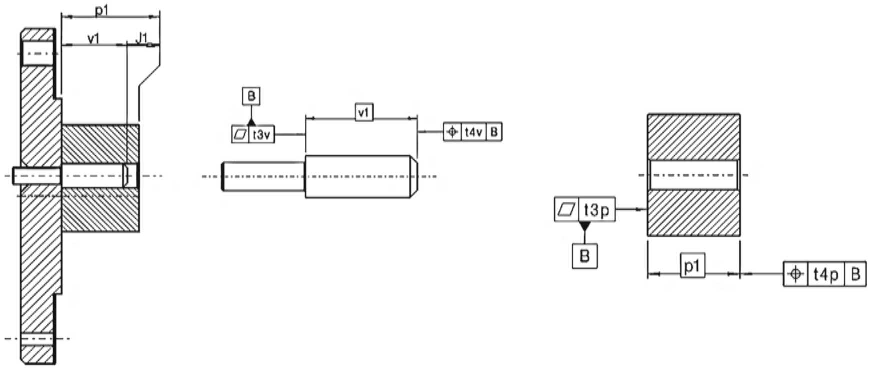


Fig. 9 Tolerance stackup graphical representation of functional requirement J1 and ISO dimensioning of the constituent parts involved in this requirement

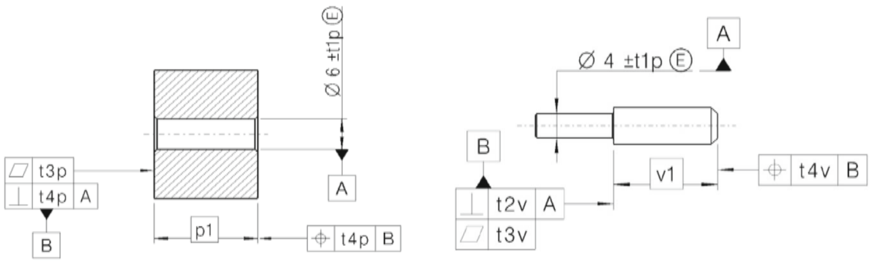


Fig. 10 ISO dimensioning of the positioning and functional requirement J1, Piston y Pivot part

5 Conclusions

The procedure presented is based on the application of professional engineering tools but simplified so that it can be applied in a teaching environment, without modifying the professional approach to the design of mechanical devices and the functional dimensioning of each of the parts that make them up. The training proposal under consideration is a teaching initiative that has been in application for several years, with a proven track record in successfully welcoming students of the ISO-GPS.

It is proposed that the initial training in graphic expression for engineering students be modified to align with the professional requirements of future engineers and the utilization of 3D models. The challenges inherent in comprehending ISO specifications are mitigated when considering that these deficiencies are attributable to prior training that is not commensurate with the present circumstances. The remarkable pedagogical process presented proposes an enhancement to the comprehension and utilization of ISO language integrating it with several disciplines of industrial design methodology and mechanical engineering. It is hypothesized that an understanding of the ISO language, derived from the application of case studies in a manner consistent with its utilization in mechanical engineering, could serve as an optimal foundation for the progression of training in design engineering, characterized by a professional orientation.

We have not addressed it in this paper, but another interesting aspect is the fact that the identification of the function of a part or assembly is helpful because it provides insights into possible failure modes.

References

1. Dufailly, J., Poss, M.: Cotation fonctionnelle, chaîne de cotes, optimisation des tolérances: analyse fonctionnelle technique. Ellipses (2017)
2. Anselmetti, B.: Méthode de cotation fonctionnelle. Éditions HERMES–LAVOISIER (2003)
3. Course on mechanical connections and Kinematic diagram Homepage: http://www.lycee-ferry-versailles.fr/si-new/index.php?rubrique=6_1_liaisons. Last accessed 22 April 2025
4. Marca, D.A., McGowan, C.L.: SADT: Structured Analysis and Design Technique. McGraw-Hill, Inc. (1987)
5. Anselmetti, B.: Generation of functional tolerancing based on positioning features. Comput. Aided Des. **38**(8), 902–919 (2006)
6. Esandi-Baztan, M.Á., Valin-Ortega, A.: Method for analysing the positioning of components in mechanical assemblies. In: Manchado del Val, C., Miralbes Buil, R., Peris Fajarnés, G., Moncho Santonja, M., Rizzi, C., Roucoules, L. (eds.) Advances on Mechanics, Design Engineering and Manufacturing V. JCM 2024. Lecture Notes in Mechanical Engineering. Springer, Cham (2025). https://doi.org/10.1007/978-3-031-72829-7_92
7. Fischer, B.R.: Mechanical Tolerance Stackup and Analysis, 2nd edn. CRC Press, Boca Raton (2011)

Application of Generative Artificial Intelligence in Intersection Design: A Case Study in Road Design

Rubén Abad Ortiz, Irene Sentana Gadea, and Juan Marcos Llorca Schenk

Abstract This study presents the development and implementation of a personalized Generative Artificial Intelligence (GAI) model, based on the ChatGPT architecture, oriented to technical teaching in the field of road intersection design. The tool has been specifically adapted for the subject 'Intersection Design' of the Master's Degree in Civil Engineering of the University of Alicante, through its training with current technical standards (Standard 3.1-IC, Road Junction Guide, among others). The model allows the structured introduction of geometric and traffic parameters by the user and performs analytical calculations in accordance with the established normative criteria, providing results related to crossing distances, lengths of acceleration and deceleration lanes, turning radii, and other road design elements. Validation has been carried out through practical applications in the classroom, comparing results generated with manual solutions and specialized software. Findings indicate some positive aspects in efficiency and preliminary guidance, alongside limitations in technical accuracy and inability to produce valid graphic outputs. It is concluded that, under teaching supervision, the GAI model can support the delivery of regulated content in civil engineering, but it cannot replace traditional methods or expert analysis.

Keywords ChatGPT · Artificial intelligence · Learning support · Civil engineering

1 Introduction

In recent years, Artificial Intelligence (AI) has led to a paradigm shift in how teaching and technical calculations are approached within the scientific domain. The development of multiple tools in this field, such as ChatGPT, Google Gemini, or Microsoft Copilot [1, 2], has sparked growing interest within the educational community, particularly in the field of engineering, to explore how this technology can be applied to

R. A. Ortiz (✉) · I. S. Gadea · J. M. L. Schenk
Universidad de Alicante, Alicante, Spain
e-mail: ruben.abad@ua.es

C. Manchado del Val et al. (eds.), *Advances on Design Engineering V*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-032-08108-7_39