# Proposal for a method for advanced search of information and standards in the field of Geometrical Product Specification

Ileana Bodini[1] [0000-0003-4904-2044], Gabriele Baronio[1][0000-0002-8521-4555], Diego Paderno[0000-0002-6001-2148], Valerio Villa[0000-0001-7737-499X] , Paolo Martinelli, Roberto Frizza[2], Alessandro Balsamo[3][0000-0003-1117-8501], Stefano Uberti[1][0000-0002-4831-7520]

[1] DIMI, Università degli studi di Brescia
[2] MG Marposs, Brescia
[3] INRIM, Torino
stefano.uberti@unibs.it

**Abstract.** The Geometrical Product Specification (GPS) is one of the most powerful tools available to link the "perfect" geometrical world of the models to the imperfect world of manufactured parts and assemblies. GPS aims to be an unambiguous common language between designers, process engineers, and Coordinate Measuring Machines operators (CMM) in the ISO (International Organization for Standardization) environment. GPS standards are 150 and further 26 are under development. The need to have a tool to search through the standards, to optimize the work of the designer and to minimize the design, production and control costs is great. A database and the structure for a search engine, called GPS Navigator, has been studied and developed, and the requirements for the following coding phase have also been defined, in order to realize a powerful, efficient, fast, robust and rigorous tool to navigate through the GPS standards. Final aim of this tool is to help and guide the designer to quickly consult the correct standard or the most appropriate set of standards.

**Keywords:** Geometrical Product Specifications (GPS), Database, Advanced Search Criteria, Design Methods.

## 1 Introduction

The Geometrical Product Specification (GPS) and the Geometrical Dimensioning and Tolerancing (GD&T) languages are the most powerful tools available to link the "perfect" geometrical world of the models to the imperfect world of manufactured parts and assemblies. GPS and GD&T should be unambiguous common languages between designers, process engineers, and Coordinate Measuring Machines operators (CMM) in the ISO (International Organization for Standardization) and ASME (American Society of Mechanical Engineers) environments, respectively [1].

This works only deals with GPS standards, because they are the ones adopted in Italy and in almost all Europe and because they are also the most numerous. Consequently, it is easier “to get lost” among them. The whole GPS standards set is under continuous development through the cooperation of 27 participating members and 26 observer , and currently includes 150 standards, while 25 others are currently being developed [2].

GPS standards have been considered in several works as an integral part of the production chain of a product, from its design to its final control, passing through production and processing. Their knowledge and correct application has often been considered as fundamental medium to reduce the overall cost of a certain product [3-6]. Even if GPS standards have been increasingly taught at engineering schools or in basic tolerancing classes, many circulating drawings are still prone to ambiguity of interpretation and do not communicate true functional requirements of the parts. Potential savings related to the correct implementation of GPS language are generated by eliminating these types of losses. All companies involved in designing or manufacturing mechanical parts can benefit from a correct usage of GPS, but advantages are greatest for those companies outsourcing the manufacturing of parts because these companies, more than any others, need their drawings to clearly communicate functional requirements, univocally, not ambiguously [4-7].

There have been many attempts in synthesizing these standards [4, 8-10], providing guidelines or simplifications [1, 3, 4, 7-10] or otherwise creating a new language [11]; in all cases, authors of these studies highlighted the need to provide guidance in choosing and applying standards, in order to reach the best communication level during the first phase of the product lifecycle. .

In this moving chain of information, designer is often the weakest link since he must formalize and express the desired prescriptions with clear terms and a proper language that can sometimes be cryptic. Whatever the complexity of a drawing, not all the 150 standards are needed to understand it, therefore having a tool that allows the designer to find the group of appropriate standards to reach the functional requirements of the component can be extremely useful.

Present work originates from all the aforementioned needs, first of which is the correct choice of the most appropriate set of rules to convert the functional requirement into an appropriate graphic sign on the drawing. This paper presents the development of an advanced search engine, named “GPS Navigator”, to help designers in untangling themselves among ISO GPS standards. The database and the structure of this system have been developed and made available, and the specifications for the coding of the GPS Navigator search engine were studied and provided as well.

The operational steps were the following: Database development, Technical specifications definition, and Implementation.

# 2 Methods

Whatever the complexity of a design, not all the 150 standards are needed to understand it. The aim of this work is to find a method to choose between the more suitable standards, starting from a simple keyword, e.g. the functional aim of the component, or the required form. In this regard, GPS Navigator is an advanced search engine that facilitates designers in their search for GPS information or standards.

## 2.1 Database development

Currently, the database is essentially an Excel table whose rows contain ISO GPS standards identification numbers while the columns represent the attributes that will be exploited during the search process which define the standard from different points of view: (i) ISO codification; (ii) UNI codification; (iii) Title; (iv) Class (Fundamental, General, Complementary in accord to ISO 14638); (v) Relationship to matrix model (ISO 14638).
Each standard of the ISO GPS has been analysed so far, and consequently different attributes representing probable search criteria have been inserted in an Excel spreadsheet for each standard: (i) ISO coding; (ii) UNI coding; (iii) title; (iv) type; (v) position in the GPS matrix; (vi) 3 levels of topics from general to specific; (vii) keywords; (viii) index; (ix) purpose; (x) notes.

| GPS MATRIX | A Symbols and indications | B Feature requirements | C Feature properties | D Conformance and non-conformance | E Measurement | F Measurement equipment | G Calibrations |
|---|---|---|---|---|---|---|---|
| 1 Size | | | | | | | |
| 2 Distance | | | | | | | |
| 3 Form | | | | | | | |
| 4 Orientation | | | | | | | |
| 5 Location | | | | | | | |
| 6 Run-out | | | | | | | |
| 7 Profile surface texture | | | | | | | |
| 8 Areal surface texture | | | | | | | |
| 9 Surface imperfections | | | | | | | |

**Fig. 1.** GPS matrix structure.

**Fig. 1** shows the GPS matrix structure as defined in the ISO 14638:2015: the GPS Matrix is composed of 9 rows and 7 columns. The different geometric properties are arranged in the rows while the position of the product in the production chain is defined through the columns. This matrix is divided into three sections: specification (first 3 columns, continuous line in **Fig. 1**); comparison and decision rules (fourth column, dashed line **Fig. 1**); verification (remaining 3 columns, dotted line in **Fig. 1**)

| GPS MATRIX | A Symbols and indications | B Feature requirements | C Feature properties | D Conformance and non-conformance | E Measurement | F Measurement equipment | G Calibrations |
|---|---|---|---|---|---|---|---|
| 1 Size | • | • | • | • | • | • | • |
| 2 Distance | • | • | • | • | • | • | • |
| 3 Form | • | • | • | • | • | • | • |
| 4 Orientation | • | • | • | • | • | • | • |
| 5 Location | • | • | • | • | • | • | • |
| 6 Run-out | • | • | • | • | • | • | • |
| 7 Profile surface texture | • | • | • | • | • | • | • |
| 8 Areal surface texture | • | • | • | • | • | • | • |
| 9 Surface imperfections | • | • | • | • | • | • | • |

(a)

| GPS MATRIX | A Symbols and indications | B Feature requirements | C Feature properties | D Conformance and non-conformance | E Measurement | F Measurement equipment | G Calibrations |
|---|---|---|---|---|---|---|---|
| 1 Size | • | • | | | | | |
| 2 Distance | | | | | | | |
| 3 Form | | | | | | | |
| 4 Orientation | | | | | | | |
| 5 Location | | | | | | | |
| 6 Run-out | | | | | | | |
| 7 Profile surface texture | | | | | | | |
| 8 Areal surface texture | | | | | | | |
| 9 Surface imperfections | | | | | | | |

(b)

| GPS MATRIX | A Symbols and indications | B Feature requirements | C Feature properties | D Conformance and non-conformance | E Measurement | F Measurement equipment | G Calibrations |
|---|---|---|---|---|---|---|---|
| 1 Size | | | | | | | |
| 2 Distance | | | | | | | |
| 3 Form | | | | | | | |
| 4 Orientation | | | | | | | |
| 5 Location | | | | | | | |
| 6 Run-out | | | | | | | |
| 7 Profile surface texture | | | | | | | |
| 8 Areal surface texture | | | | | | | |
| 9 Surface imperfections | | | | | | | |
| Standards on mouldings | • | • | | | | | |

(c)

**Fig. 2.** (a) Relationship between ISO 1:2016 and matrix model. (b) Relationship between 286-1,2:2010 and matrix model. (c) Relationship between 286-1,2:2010 and matrix model

ISO 14638 specifies the classification of all the GPS International Standards into three categories, according with a matrix model:

- fundamental standards, which fill all boxes of the matrix model (**Fig. 2a**)
- general standards, which take up one or more boxes of the matrix model (**Fig. 2b**)
- complementary standards, which sit in one or more boxes of a row (**Fig. 2c**) occasionally added at the bottom of matrix model.

The position in the GPS matrix is one of the attributes listed in the database, and thus it is one of the possible search criteria.

In the following, an example of how UNI EN ISO 286:2010 standard have been classified within the database:

- UNI Codification: UNI EN ISO 286:2010.
- Class: General.
- Relationship to the GPS matrix model as in **Fig. 2(b).**
- 1st level topic: ISO code system for tolerances on linear sizes.
- 2nd level topic: Basics of tolerances, deviations, and fits.
- 3rd level topic: Establishes the ISO code system for tolerances to be used for linear sizes of features of the following types: cylinder, two parallel opposite surfaces.
- Keywords: dimensional tolerancing, IT tolerance grades, upper tolerance limit, lower tolerance limit, fundamental deviations, tolerance interval, hole, shaft, diameter, size, fit.
- Scope: This document establishes ISO code system for tolerances which define linear sizes of features of the following types: cylinder, two parallel opposite surfaces. It defines the basic concepts and the related terminology for this code system, and provides a standardized selection of tolerance classes for general purposes

### 2.2 Definition of the search criteria

User's interest in a specific subject, according to GPS “philosophy”, could have two prevailing connotations that lead to aspects related to: (i) the specification and (ii) the verification. In the classification phase, GPS system splits the standards into this couple of categories adding a third one, less populated, concerning the issue of establishing rules to define conformity/non-conformity. This classification will be exploited as one of the possible means of search the database.
The output of the search activity could be essentially a standard or a list of standards presented to the user with a configurable list of the attributes stored in the database.
The following search modalities have been hypothesized: (i) free search; (ii) simple guided search; (iii) advanced guided search.

**Free search.** This search is the simplest one and can be accomplished in two ways: (i) free keywords search, aimed to having an overview on all the standards containing the required word in the title, in the scope, or in the other "attributes" of the database; (ii) ISO codification search, directly targeting the standard of an already known ISO code.

**Simple guided search.** Different types of searches are possible in the following modality: (i) guided keywords search, in which the alphabetic list of keywords are showed as suggestion to help the user; (ii) search through symbols, where the list of symbols found in the various standards is shown to the user; (iii) Macro-topics, macro-topics have been assigned to attributes through each standard with the aim of summarize covered arguments. There are 3 level of topics, from 1st to 3rd, which gradually detail more deeply the theme of a standard; (iv) GPS standards classification search, in which user can browse into three lists of standards, subdivided according to the hierarchical structure of the GPS standards (fundamental, general, complementary); (v) search through the relationship to GPS matrix.

**Advanced guided search.** The intent is to guide the user through different routes or collections of standards with a pre-established order, which should enable a specific subject to be dealt with. The suggested order should consent a didactic approach to the user, who gradually is introduces to the standards of the collection, looking at each topic with the necessary preliminary knowledge. Different types of search are possible: (i) the "preparatory route" aims to enable the user to gain access to the introductory knowledge to understand how GPS system is structured with the specific content of each standards; (ii) the "drawing comprehensive route" aims to enable the user to be able to decode the requirements expressed in  blueprints; (iii) the "form errors" route aims to guide the user in deepening form errors comprehension, considering both specification and verification aspects; (iv) the "location errors route" aims to show the user the available standards to comprehend location errors considering both specification and verification aspects; (v) the "surface micro-geometric errors" route aims to show the user the available standards to understand surface texture errors considering both specification and verification aspects, through two possible strategies (the profile method and the areal method).

## 3 Results and discussion

In the following, examples of possible research methods are detailed.

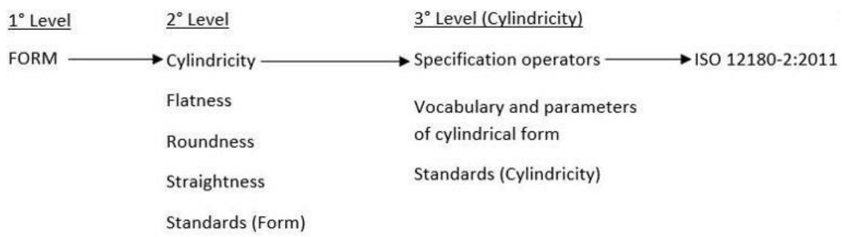


**Fig. 3.** Example of a complete topic search.

**Fig. 3** shows a complete topic search, included in the simple guided search mode. This research flows through three different levels. The 1st level topic sums up the main search argument in less of a line, and a list of alphabetically ordered 1st level topics are presented to the user. In the presented case the user chooses "FORM", as 1st level topic, then a list of 2nd level topics related to the chosen ones is shown. The user chooses "Cylindricity", then a list of 3$^{rd}$ level topics appears. The user chooses "Specification operators" and finally the related standard is retrieved

| | A | B | C | D | E | F | | G |
|---|---|---|---|---|---|---|---|---|
| 1 | 286-1,2<br>1119<br>2538-1,2<br>2692<br>3040<br>5459<br>14405-1,3<br>17863 | 286-1,2<br>1119<br>2538-1,2<br>2692<br>3040<br>5459<br>14405-1,3<br>17863 | 2538-2<br>2692<br>5459<br>14253-4<br>14405-1,3<br>14406<br>16610-series<br>17863 | 14253-1,2,3,4<br>16015 | 1938-1<br>14253-2,3,4,6<br>16015 | 463<br>1938-1,2<br>3611<br>9493<br>10360<br>13102<br>13225<br>13385-1,2 | 14253-2,3,4,5,6<br>14406<br>14978<br>16015<br>16610*<br>17865<br>23165 | 1938-1,2<br>3650<br>13385-1<br>14253-2,3,4,6<br>14978<br>15530-1,3,4<br>16015<br>16610-1 |

**Fig. 4.** Example of a research through the relationship to GPS matrix.

**Fig. 4** shows an example of search through GPS matrix, included in the “simple guided search” mode. The columns and rows are indexed with letters from A to G and numbers from 1 to 9, respectively, and user can request standards indicating bidimensional coordinates. In the example, the two-dimensional coordinate A1, provides the list of standards dealing with "Symbols and Indications" on the subject "Size".

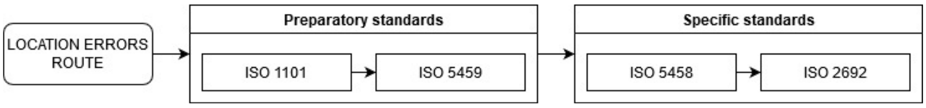


**Fig. 5.** Path for location errors.

**Fig. 5** shows an example of “advanced guided search”, in particular the path for location errors is presented. User chooses the path “LOCATION ERRORS ROUTE”, as a consequence the propaedeutic standard ISO 1101 (Geometric tolerances) and ISO 5459 (Datum) are shown, both including general concepts and definitions; then, specific standards are presented, to deepen the knowledge about the topic. So, ISO 5458 is about location tolerances and ISO 2692 is about maximum material, least material, reciprocity requirements concepts.

## 4 Conclusions

The created database contains attributes to characterize each GPS Standard. Thanks to this it is possible to create an indexing strategy to cover the various searching methods of the GPS Navigator. The illustrated coding strategies (flowchart of search strategies) can create an environment where users can perform different searches according to the needs, from the simplest to the most structured one.

Current work results can be exploited for: (i) updating information about new standards or updated standards; (ii) data enrichment, especially the section of key-words and symbols; (iii) vocabulary enlargement, for example with the translation into other technical languages about product specifications.

The final result will be soon online as a search engine supporting users in orientating themselves in GPS system to find and apply the standards of interest.

## References

1. Tornincasa, S.: Technical Drawing for Product Design. Springer, Cham (2021)

2. ISO/TC 213 Dimensional and geometrical product specifications and verification Home Page, https://www.iso.org/committee/54924.html, last accessed 2021/03/17.
3. Dantan, J.Y., Ballu, A., Mathieu, L.: Geometrical product Specifications – model for product life cycle. Computer-Aided Design 40, 493-501 (2008).
4. Bennich, P., Nielsen H.: An overview of GPS – A cost saving tool. 1st edn. Institute for Geometrical Product Specifications, Vaerloese (2005).
5. Mandolini, M., Campi, F., Favi, C., Germani, M., Raffaeli, R.: A framework for analytical cost estimation of mechanical components based on manufacturing knowledge representation. The International Journal of Advanced Manufacturing Technology 107, 1131-1151 (2020).
6. Vezzetti, E., Violante, M.G., Alemanni, M.: An integrated approach to support the Requirement Management (RM) tool customization for a collaborative scenario. International Journal on interactive Design and Manufacturing 11, 191-204 (2017).
7. Schuldt, J., Hofmann, R., Gröger, S.: Introduction of a maturity model for assessment of the integration of the GPS system in companies. In: Procedia CIRP 92, pp. 129-133 (2020).
8. Nielsen, H.S.: The ISO Geometrical Product Specification Handbook. Find your way in GPS. 1st edn. ISO/Danish Standards, Denmark (2012).
9. Qi, Q., Scott, P.J., Jiang, X., Lu, W.: A hierarchical category model for geometrical product specification (GPS). In: Procedia CIRP 43, pp. 214-219 (2016).
10. Humlenny, Z.: State of art in standardization in GPS area. CIRP Journal of Manufacturing Science and Technology 2, 1-7 (2009).
11. Loureiro, G.B., Espindola Ferreira, J.C., Messerschmidt, P.H.Z.: Design structure network (DSN): a method to make explicit the product design specification process for mass customization. Research in Engineering Design 31, 197-220 (2020).