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GEOMETRIC TOLERANCING EXPLAINED BY THE MEANS OF CONCEPT MAPS

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Abstract Knowledge plays a fundamental role inside the industrial reality, being closely connected to the efficiency of the entire lifecycle of a product. In this work the authors present the use of the Concept Map as a form of simplifying, storing and communicating the technical concepts that stand behind a normative. The normative of reference is the one related to the Geometric Dimensioning and Tolerancing (GD&T) that expresses a language to define tolerances in mechanical technical drawings. The objective of this work is to create a set of Concept Maps that permits to study and to communicate the rules defined in the GD&T, in order to support the designer during the process of defining geometric tolerances. The resulting Concept Map will be freely available over the Internet.

1 Introduction

Knowledge plays a fundamental role inside the industrial reality, being closely connected to the efficiency of the entire lifecycle of a product. A high level of knowledge organization, recorded both in a document and experience or ability gained by the experts, is the reference point to realize a knowledge-based system to support the design process (Torsun, 1995). The stage of knowledge acquisition and organization, held by a company, is fundamental and very complex: the difficulties arise at the very beginning of the process, when there is the need to identify the different kinds of knowledge distributed in the company departments, and arise at the end when a suitable method of filing and communicating the knowledge could be defined (Dutta, 1997). However the investment of time and resources needed to complete the process, leads to obtain many advantages for the entire lifecycle of the product, as improvement of time and quality and reduction of costs and errors (Hendriks, 1999).

Concept map (Novak, 2006, Akinsanya, 2004) has shown a wide diffusion in many different fields as a tool to gather and communicate knowledge and to teach different subjects.

Very few attempts (for instance Turns, Atman, Adams, 2000) have been conducted in using Concept Map for gathering the knowledge related to specialized technical fields as, for instance, mechanical engineering.

In this work the authors present the use of the Concept Maps as a form of simplifying, storing and communicating technical concepts that stand behind a normative.

Technical normative, or standards, are usually long and specific documents that explain and clarify to the designer aspects like how to design a machine or a component or how to make test or inspection on a new installed machine, or other engineering aspects, depending on the specificity of the normative itself.

The possibility offered by the Concept Maps to explain and to show the important concepts expressed in the normative can help the designer to study and to understand the normative faster and easier.

In this work the authors have analyzed the technical normatives ASME Y14.5M, ASME Y14.5.1M and the corresponding ISO 1101 and ISO 8015 that refer to a design subject called “Geometric dimensioning and Tolerancing” (GD&T) and have created a series of Concept Maps of the concepts gathered from the normatives.

The objective of this work is to create a set of Concept Maps that permit the study and the communication of the rules defined in the GD&T, in order to support the designer during the process of definition of the geometric tolerances.

2 Geometric dimensioning and Tolerancing

Technical drawings are a “way to communicate information” (Bertoline, 2002). An engineering drawing is a document that communicates a precise description of a part. This description consists of pictures, words, numbers and symbols (Krulikowski, 1997). These elements communicate part information to all the drawing users. Engineering drawing information includes: geometry (shape, size, and form of the part), critical functional relationships, tolerances allowed for proper function, material, heat treatments, surface coatings, part documentation information (part number, revision level). A designed component, in order to be assemblable, must keep the variations of its dimensions and of its geometric shape in a small range of variability. Since each component can have a small variability of its shape and dimension, a set of standards has been released to cope with this problem (**Figure1** Example of mechanical technical drawing with indication of geometric tolerances).

These standards define a graphical language to express concepts as the shape, the position, the orientation of a generic component. The language is called "Geometric Dimensioning and Tolerancing" because it defines which are the allowed boundaries of a generic shape, in term of its geometry and of the allowed dimensional values that can be accepted for a variation over the "exact" or nominal value expressed by the designer.

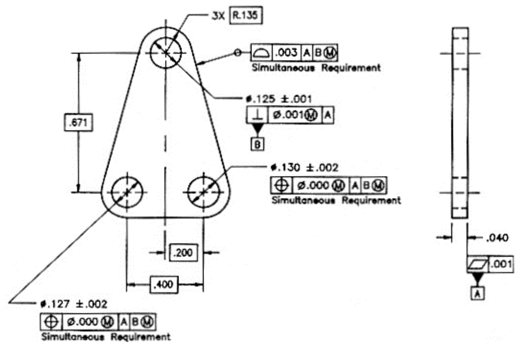

Figure1 Example of mechanical technical drawing with indication of geometric tolerances

3 Application of Concept Map to GD&T

The final objective of the work is to create a conceptual representation of all the rules that are expressed in the standards. Since the rules are quite complex, a graphical representation can easily show to the designer how to use the GD&T language and especially can prevent him from making mistakes in the way he uses such a language.
The difficulty of applying GD&T is that there are many available symbols and every symbol can be combined between each other in many different ways, with a series of constrains that depends on the geometry of the component and with many possible modifiers. The hypothesis behind this work is that if the designer has a graphical tool that he can use as a guide to insert the proper symbols and modifier to the proper geometric shape, the jobs of inserting tolerance in the drawing will be easier and less prone to mistakes.

The structure of a GD&T representation on a drawing is composed by a feature control frame, made of different boxes, and a set on number or letter in the box (**Figure1** Example of mechanical technical drawing with indication of geometric tolerances).
The possible tolerances are as follow:

- Straightness: the axis of an item of revolution or element of a surface is a straight line
- Flatness: all the elements of a surface are in one plane.
- Roundness: all points of a surface of revolution are equidistant from an axis that is intersected by a plane perpendicular to that axis.
- Cylindricity: all points of a surface of revolution are equidistant from a common axis.
- Profile of Line: a 3D element is projected onto a plane.
- Profile of Surface: a 3D surface is projected onto a plane.
- Angularity: an axis or surface is at a specified angle from another axis or datum plane.
- Perpendicularity: an axis or planar surface is at a right angle to a datum axis or datum plane.
- Parallelism: an axis or planar surface is equidistant along its length to a datum axis or datum plane.
- True Position: a zone of tolerance exists for a center axis or center plane.
- Concentricity: the axis of all elements in a cross-section shares a common datum axis.
- Symmetry: the location of a feature relative to a center plane.
- Circular Runout: circular elements of a surface of revolution associated with a datum axis.
- Total Runout: all elements of a surface of revolution associated with a datum axis.

It is not interesting now entering the details of all the rules involved in GT&D because it is out of the scope of this article. But it is interesting to note the different possible options that the designer may choose when he wants to express a generic tolerance. Moreover there is a multiplicity of combination between feature control frame, geometric surfaces, modifier and indications on the drawing.

The main Concept Map, as in **Figure 2** Main Concept Map, is an introductory and high level Concept Map; its main use is to show the different types of possible geometric tolerances and all the subtypes of each one.

Each subtype of geometric tolerance, as shown in **Figure 2** Main Concept Map, is linked to a different Concept Map that expresses the details of the selected geometric tolerance.

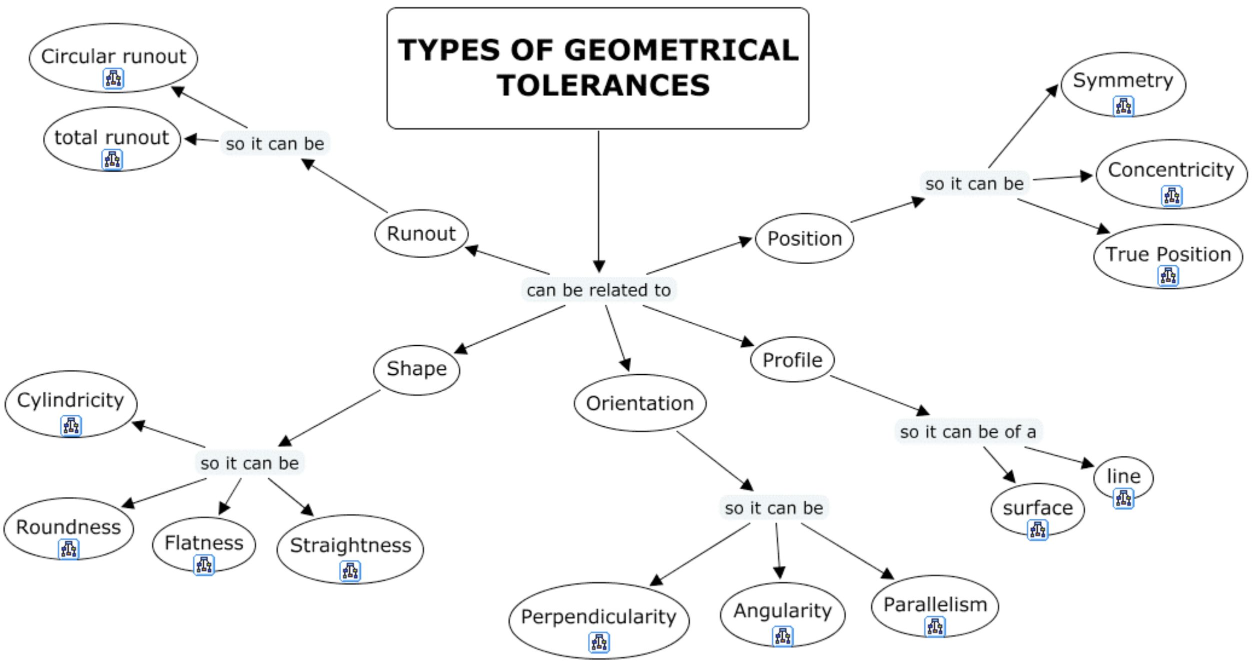

Figure 2 Main Concept Map

For instance, **Figure 3** Concept Map for Straightness tolerance , shows the details of the Concept Map for the Straightness type of geometric tolerance. The user can understand from this map if it is possible to set a datum reference (a plane or an axis), an example of the feature control frame for the selected tolerance, the different types of geometric feature to which the tolerance is applicable and the details of the way of representing the intention of the designer. Every interesting item is linked to a new file in which there is a description of the concept expressed in brief in the Concept Map.

A total of 14 detailed Concept Maps have been generated to gather and communicate the use of all the types of geometric tolerances expressed in the normative.

4 Conclusion

This work is one of the first attempt to collect very specific engineering knowledge by the means of Concept Maps. After having created the Concept Maps, the authors have worked to create a web site to publish the results of this work. This work had been conducted in collaboration with an Italian industry. For the moment the result of the work, the online Concept Maps, is available online in an internal server of the industry. This work is also considered an initial gathering of specifications for creating a procedure to better implement GD&T inside CAD systems. CAD systems simply let the user insert whatever combination of tolerance symbols and apply them to whatever geometry of the components. Studying the subject and explaining it by the means of Concept Maps permits to analyze the difficulty of the subject and help the future development of a procedure for guiding the user and checking his actions, related to the insertion of tolerance symbols, directly inside a CAD system.

5 Acknowledgements

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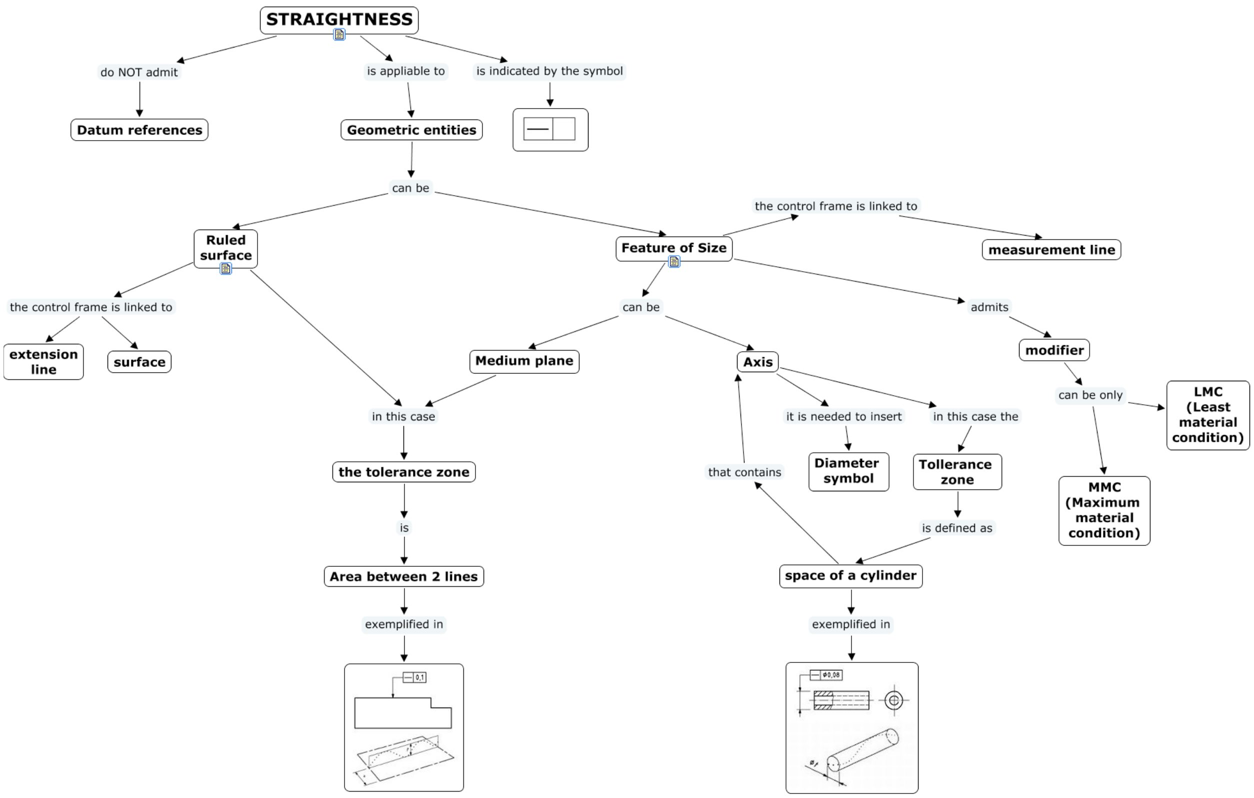

Figure 3 Concept Map for Straightness tolerance

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