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ISO GPS Changes- challenges for manufacturing industry

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Abstract
This paper is a short report on the way that manufacturing companies are affected by the latest updates of ISO GPS series (Geometrical Product Specification) since these standards affect their entire chain of activities being crucial for competitivity on the market. Although consistent and highly necessary modifications of tolerancing standards have a positive influence on companies after implementation, the process of adopting them is not simple, neither smooth, on the contrary, due to its' complexity is time consuming and involves significant effort and resources.

Keywords
Geometrical Product Specification (GPS), ISO standard, functioning tolerances, design tolerances, manufacturing tolerances

1. Introduction

Nowadays, rapid technological progress in manufacturing industry induces the necessity of ample changes in design, processes and control methods. Engineers have to integrate rapid pace changes in their work system that becomes more complex day by day. Last decades, one of the biggest problems encountered, both by companies and engineering education providers, is that many GPS standards have been updated with significant modifications. Due to the importance of these standards in manufacturing engineering, the international technical committee for "Dimensional and geometrical product specifications and verification" has stated as a goal to establish" a more precise method of expressing workpiece" in ISO/TC 213 Business Plan [[1]. GPS standards are used as communication language between design, production and quality control engineers, so one of the main objectives of modifications is to reduce uncertainty and ambiguity. Unfortunately, on practical level it is not simple at all to implement the new standards, on the contrary it takes considerably amount of time and effort. Training courses for the employees are generally required, some companies work with older standards, some with the new standards depending on their capacity to adapt and the process may take years. Another challenge is that GPS standard modification deepened the gap between industry and technical universities.

This paper provides some insights into challenges imposed by the new ISO GPS standards to the industry.

2. ISO GPS Standards Modification- Consequences for Industry

2.1. Brief Historical Background of ISO GPS Standards

The beginning of standardization originated in ancient times when mankind realized that trial and error method is no longer satisfactory. Among the first reports on a higher level of products' size and shape standardization stated that Carthage people were using standardized parts for ship building. A shipwreck discovered near Sicily – Marsala Punic shipwreck – showed evidence of assembly instructions, numbered and marked parts of the ships. This method allowed rapid and effective building and quick repairs of Punic fleet. Romans highly appreciated this naval standardization system and adopted it after capturing and disassembling one of the Punic ships [2]. Since then, all over the world there were significant efforts for uniformization has progressed to constructions, guns, coins and later to other products. The industrial revolutions and interchange increase generated the necessity to harmonize the features of manufactured products. Before GPS standards, comments and notes were used to annotate specifications on sketches or more advanced technical drawings. Then, national standards emerged and, for a long time, were used in the industry e.g. ASME (in US), BS (in UK), DIN (in

Germany), AFNOR (France), JIS (Japan). The need for an uniform and global technical language in manufacturing determined a great interest for internationalization and in 1996 it was created ISO/TC 2013 committee “responsible for creating, updating, and maintaining the ISO GPS standards for geometrical product specifications and verification” [3]. Nowadays, ISO/TC 2013 has members from North America, South America, China, Japan, Australia and Europe. This committee is collaborating with research institutions and with important industrial companies in manufacturing, automotive, aerospace, computers and metrology having as main goal to “facilitate international commerce by developing a complete set of internationally accepted technically valid standards in the field of mechanical engineering” [1].

2.2. Key ISO GPS Standards and the Benefits of their Improvement

Among the key factors that influences the quality of manufactured products is the conformity of final product to the specifications. That involves beside the use of appropriate materials, proper designs and technologies that ensure dimensional and shape accuracy, good surface finish that ca guarantee reliability, durability, safety and overall performance. There is a huge importance of GPS standards because they make possible the communication between designers, manufacturing engineers and quality engineers at any level. GPS standards are defining geometry, size, form, orientation and position of surfaces of manufactured parts so that they can be understood by anyone involved in their production without misinterpretation.

Considering the industry essential demands, the main objectives for continuous improvements of GPS standards specified by ISO/TC 213 committee in th6th version of “ISO/TC 2013 Business Plan” [1] are summarized as follows:

- developing tools to express correctly and completely necessary requirements;
- enriching GPS language, keeping it as simple as possible;
- reduce ambiguities and eliminate misinterpretations by setting clear default rules.

The key ISO GPS standards created or modified over last 15 years, with their actual and previous versions are listed in tables 1, 2 and 3 [4]:

Table 1. ISO GPS standards for size and shape

Title	Actual version	Previous withdrawn version
ISO 286-1: Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 1: Basis of tolerances, deviations and fits	2010	ISO 286-1:1988
ISO 286-2: Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts	2010	ISO 286-2:1988
ISO 8015: Geometrical product specifications (GPS) — Fundamentals — Concepts, principles and rules	2011	ISO 8015:1985
ISO 1101: Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out	2017	ISO 1101:2012
ISO 5459: Geometrical product specifications (GPS) — Geometrical tolerancing — Datums and datum systems	2024	ISO 5459:2011
ISO 14638: Geometrical product specifications (GPS) — Matrix model	2015	ISO 14638:1995
ISO 14405-1: Geometrical product specifications (GPS) — Dimensional tolerancing — Part 1: Linear sizes	2025	ISO 14405-1: 2016
ISO 14405-2: Geometrical product specifications (GPS) — Dimensional tolerancing- Part 2: Dimensions other than linear or angular sizes	2018	ISO 14405-2: 2011
ISO 14405-3: Geometrical product specifications (GPS) — Dimensional tolerancing-Part 3: Angular sizes	2016	None

Table 2. ISO GPS standards for surface texture

Title	Actual version	Previous withdrawn version
ISO 21920-1: Geometrical product specifications (GPS) — Surface texture: Profile, Part 1: Indication of surface texture	2021	ISO 1302:2002
ISO 21920-2: Geometrical product specifications (GPS) — Surface texture: Profile, Part 2: Terms, definitions and surface texture parameters	2021	ISO 4287:1997
ISO 21920-3: Geometrical product specifications (GPS) — Surface texture: Profile, Part 3: Specification operators	2021	ISO 4288:1996 (withdrawn)

Beside the standards related to design and manufacturing presented in tables 1 and 2, of crucial importance are the standards specifying norms for verification, testing methods and instruments that are shown in table 3 [4].

Table 3 ISO GPS standards for measuring

Title	Actual version	Previous withdrawn version
ISO 14253-1: Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment. Part 1: Decision rules for verifying conformity or nonconformity with specifications	2017	ISO 5459:2011 (withdrawn)
ISO 14253-2: Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment. Part 2: Guidance for the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification	2011	ISO/TS 14253-2:1999 (withdrawn)
ISO 14253-3: Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment. Part 3: Guidelines for achieving agreements on measurement uncertainty statements	2011	ISO/TS 14253-3:2002 (withdrawn)
ISO/TS 14253-4: Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment. Part 4: Background on functional limits and specification limits in decision rules	2010	None
ISO 14253-5: Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment. Part 5: Uncertainty in verification testing of indicating measuring instruments	2015	None
ISO/TR 14253-6: Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment. Part 6: Generalized decision rules for the acceptance and rejection of instruments and workpieces	2012	None

As it is stated in ISO/TC 2013 Business plan the "aim of international standardization is to facilitate the exchange of goods and services through the elimination of technical barriers to trade" [1]. In the same document it is declared that the implementation of modified GPS standards in a company could reduce costs by estimated 10% to 20% due to less rework or waste as consequence of incomplete specifications. Other benefits are quality improvement, reduced time to market, better allocation of resources, all ensuring the "surviving in global competition" [1].

Due to the importance of GPS standards, there are a lot of studies regarding industry changes and their implications on tolerance standards. Maltauro et al. [5] present a dynamic evolution of ISO GPS standards, analysing information in four different areas: functional, manufacturing, verification and contractual specifications, considering that those specifications influence the product during entire lifecycle. Also, it is highlighted the importance of standards adaptation to be used in Computer-Aided Design (CAD), Computer-Aided Process Planning (CAPP) and Computer-Aided Manufacturing (CAM) and Computer-Aided Quality (CAQ). Other studies also detected important lines that need to be followed in tolerance standards development such as: meeting industry 4.0 requirements (real-time monitoring, adaptive control, and predictive maintenance), allow automated and intelligent tolerance optimization (AI and machine learning) and redesign standards according to new technologies and materials [6-9].

2.3. Time Frame for Adopting Updated Standards in Industry

As seen in tables 1 and 2, most of outdated standards are long lasting standards and changing them may require many years. Important international companies are expected to invest in training, implement necessary changes and introduce the new standards in a rapid pace. On the contrary, for small and medium companies may take even decades to abandon well established routines and adopt updated standards. Training is complex and extensive from designers, production engineers, quality engineers, quality inspectors, operators. For a while, both old and new versions may be used simultaneously in the same company depending on what standards are used by the clients and the suppliers.

Corroborating well-known Everett Rogers' categories -innovators, early adopters, early majority, late majority and laggards- for change adopters [10] with various surveys European and Asian on manufacturing companies [7, 9, 11-14] a timeline extended from a few years to more than a decade is developed and presented in Figure 1.

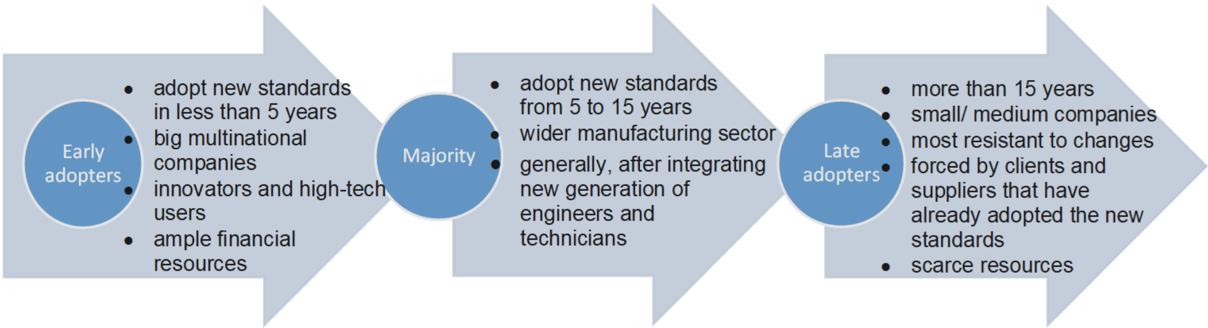

Fig. 1. Timeline for adopting new standards by the industry

3. ISO GPS Standards Modification- Consequences for Academia

The ISO GPS standards are covering a vast knowledge area specifying requirements from drawing to manufactured workpieces concerning size, location, distance, run-out, orientation, waviness, roughness, etc. In addition to macro and microgeometry clear definition, verification methods, measuring instruments and all the software involved are also affected by standard modifications. Therefore, a lot of employees from different departments- design, manufacturing, maintenance, quality assurance, metrology- are affected by ISO standards modification and need training.

It is obvious that all the transformations in ISO GPS standards oblige engineering education actors to redesign related courses content and adapt the teaching strategies. For future generations of engineers Sorgatz et al. propose a learning platform that uses a virtual tutor as tolerances teaching tool [15] with interactive activities, modular content and progress monitoring. Other studies emphasize the complexity and the importance of digitalization and interdisciplinarity in teaching ISO GPS standards [14, 16, 17]. An other example of good practise is a software developed in Poland for students that use animations to allow students to visualize tolerance zones and better understand previously learned ISO GPS rules [18].

It is a difficult task for teachers to have updated teaching materials for teaching subjects that include tolerancing standards, considering their complexity and the permanent evolution and frequent publication of changes in many of them. For example, at Transylvania University of Brasov, in the study program "Manufacturing Engineering" about 40% of the subjects of last two years – years 3 and 4 – of bachelor studies are using ISO GPS standards [19]. Because the local companies are using either one of actualized and previous versions of ISO GPS standards or both versions, it is difficult for students to understand and use tolerance requirements in their work.

3. Conclusion

The frequent modifications of ISO GPS standards are definitively meant to improve communication language of technical drawings and reduce misinterpretations or uncomplete definition of specifications. However, unified practise is still lacking among professionals and software integration of new algorithms is still in progress. New technologies, new materials, artificial intelligence and machine learning will very probably lead to further changes in ISO GPS standards.

Regarding engineering education, for a better understanding and use of ISO GPS standards it must be strengthen the partnership between universities and companies, especially to those that have already integrated updated standards. Modern teaching tools, more digitalized and more project-base orientated could ease students' transition to labour market. For already working professionals, short courses targeting ISO GPS modifications should be part of continuous learning.

It may be a little discouraging to consider the long duration of implementing new standards in the companies and the fact that there is always a gap of academy behind industry. It can be assumed that for many years to come a double system of standards will coexist and professionals and educators will have to manage this situation. In addition, there are currently fifteen ISO GPS standards under development [20] related to surface texture and imperfections, profile determination, testing methods, measuring topography, coordinate measuring systems, software measurement standards, mathematical concepts, characteristics of non-contact instruments, etc.

To sum up, there is no doubt that suitable, complete and clearly specified tolerance requirements in technical drawings are essential for taking the best decisions and choosing the most appropriate manufacturing processes and the right verification methods and tools. In the end, the result should be an increased efficiency and reduced production costs. On the other hand, significant changes carried out in ISO GPS collection of standards are difficult to implement and difficult to teach. In perspective, there are still many issues to be addressed that will determine more modifications.

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