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A compilation of patents related to mechanical metrology standards and high-precision measurement of mechanical quantities

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ABSTRACT

The paper aims to provide a source of information regarding the measurement of physical quantities, specifically those related to mechanical metrology. Since there is a lack of literature reviews referencing patents as a way of gathering useful information, we performed a systematic search for patents that could solve practical problems in this field. The methodology used focused on one of the most comprehensive patent database, Orbit.com, covering about 70,000,000 documents. This text gives a quick look at the fundamentals of the measurement literature and then points out the state-of-the-art concerning patents in the area of study. Additionally, data analysis shows the trends in the last five decades of patents about the subject. In total, 5686 documents are found and we compiled 10 examples of relevant patents for the quantities Length, Temperature and Mass, making this article a source of information for both scientific and non-scientific metrology community.

Contents

1. Introduction

The measurement of physical quantities is present in all human activities. The uncertainty of a measurement depends on the evaluation process itself, but also on the uncertainty derived from the measurement equipment [1]. In modern science there is a specific need to know the value of some quantity with high level of confidence. In this matter, metrological standards are equipment capable of providing reference values of specific quantities and they are used to calibrate other equipment [2] or to measure directly a quantity. The traceability of such quantity to the SI units is done through the hierarchization (chain) of those measurements, where better devices (in terms of metrological characteristics and measuring uncertainty) calibrate inferior instruments.

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When reviewing the literature about science and technological subjects, including metrology [3], it is evident that patents represent only a small part of the scenario. Some authors are concerned with the relation between science and technology [4,5]. There is a growing idea that even basic science must convey into industry relevance. Specifically, in the case of metrology, this relation is well established and measurement theory is hardly exempted of experimental validation.

Many studies are dedicated to analyze the presence of scientific scitation in patent documents [5]. The reverse scenario, where scholars use patents as bibliografic references is much less explored. Nevertheless, this kind of relation is covered by Glanzel and Meyer [6]. They show that Chemistry-related contributions tend to cite patents more than other scientific or technological area.

It is common that the scientific community uses academic papers as primary sources of information, but patents provide practical solutions to technical problems that should not be ignored. Therefore, the main goal of this work is to gather bibliographic information about patents that deal with the design of measurement standards and high-precision equipment or apparatus.

2. Subject

Each country, by means of their own patent office, may contribute with patent solutions. Patents might be published internationally, through the Patent Cooperation Treaty – PCT [7]. However, as the concept of priority is universal, we did not restrict the search to PCT applications, but included Intellectual Property Offices all around the globe.

In this paper we did not restrict the search conditioned to whether the patents where granted or not, because of some factors: a patent application, despite the country of registration, generally takes several years to be fully revised (in some countries, the process of granting or refusing a filed patent takes an average of more than eight years). Since the results of this paper include the present year, it didn't make sense to count for their acceptance. Besides, international patents are subjected by national or regional laws and may be granted or rejected in each jurisdiction in which a patent is desired. Also, what is widely accepted, including by the Organization for Economic Co-operation and Development - OECD is the number of patents filed, rather than the efficiency or quality (for example, measured by # IP granted/# IPs filed) of IPs owned by a given organization.

Since the adoption of the SI – *Système International d'Unités* by the 11th General Conference on Weights and Measures, the realization of physical quantities changed [8,9], in most cases, from physical realizations to their definition based upon fundamental constants [10,11].

The systematic review started with the choice of the quantities that would be explored. Among what we call physical quantities, four fields of measurement can be distinguished [12]: temperature, length, mass and time. In this study the objective was to review the low-uncertainty measurements of mechanical quantities, and then we investigated standards that might be used to measure temperature, length or mass. These are fundamental quantities and result in the definition of other units, as in the case of mass giving origin to force, torque, hardness and pressure, or length giving rise to roughness.

Several papers have been dealing with the measurement of those quantities ([13–45] for temperature, length, roughness, mass, force, torque, pressure and hardness, respectively). As stated previously, the literature about metrology is replete of academic papers regarding metrological standards and/or high-precision measurement of physical quantities, and state-of-the-art surveys and reviews are normally restricted to scientific journals as bibliographic references.

The keywords used in the search, besides the noun of the quantity, were combinations or variations of the words "standard", "reference", "measurement", "metrology", "calibration", "precision", "accuracy", "generation" and "uncertainty". More details about the search strategy will be given at the next section. The search was limited to the title, abstract and independent claims fields of the search mechanism [46], since, generally, the restricted search in those fields bring the most relevant patents for the searched keywords. We distinguished, then, three main groups of mechanical quantities to perform the search: length, temperature and mass. Each group correspond to the basic quantity itself plus derived quantities that correlates more with them.

3. Methods

To perform an exaustive search, the first step was the adoption of a patent database with wide coverage of databases of national authorities and patent offices around the world, and a strong analysis module to handle the data obtained. The following table shows a comparison between the main databases available, in terms of coverage [47] (see Table 1):

The selected database for this article was Orbit.com. This database provides a strong analysis module and covers INPADOC bibliographic and patent data. INPADOC covers 90 countries, almost 100 patent authorities, and contains intellectual property legal status from around 60 patent authorities. All databases that provide support to INPADOC can be recognized as a database with good data coverage. Orbit.com reaches more than 100 patent databases of national intellectual property offices and provide access to FamPat, PlusPat and INPADOC collections. Orbit contains 73.5 million documents, among which 49.5 million are original (considering the main patent only, not the foreign phases of the same application) [46]. For comparison effects, in terms of number of documents, the database with wider scope in number of documents available, Espacenet, have around 90 milion patents. Orbit.com is the database that represent the best compromise between completeness and analysis tool flexibility. These characteristics justify its choice for this study, compared to free tools and databases.

A primary standard is a measurement standard established using a primary reference measurement procedure, or created as an artifact, chosen by convention [49]. A measurement standard is the realization of the definition of a given quantity, with stated quantity value and associated measurement uncertainty, used as a reference. Besides, some other standards or instruments can be considered as reference standards because of their high precision character. From these definitions, some keyworks and synonyms [50] were strategically selected to filter results from the database. In addition, the International Patent Classification – IPC provides a regulamentory classification that can be used to distinguish between documents [51]. The classification areas include a class called "measurement" and some subclasses. Table 2 comprehend the keyworks used, in combination with the IPC codes used in the search.

The IPC provides a hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they pertain [52]. The IPCs used are shown as follows.

- G01B: measuring length, thickness or similar linear dimensions; measuring angles; measuring areas; measuring irregularities of surfaces or contours;
- G01C: measuring distances, levels or bearings; surveying; navigation; gyroscopic instruments; photogrammetry or videogrammetry;