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An Unpretentious View of Technical Drawings – Historic Evolution (Managerial Approach)

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Abstract

Since the very initial industrial activities along the past, industrial revolution, and until the contemporary technology level, the industrial objectives and resources roughly have being the same. The industry creates products to serve society, earning wherewithal and by using technological resources like, drawings, procedures, planning, machines, labor, tools, materials etc.… The drawing indeed is one of the most important creations of the mankind, and along the years, mainly since the industrial revolution, has become more and more important into this technological environment. Drawings per si; prescripts the technology of the company, mainly for being considered, along decades, the document which synthesize the company's identity. This paper aims to describe historically, empirically and uniquely by the author´s views, the impact on the drawing with the more intense application of new technologies. Understanding technology as the application of new intellectual tools, machines, methods and methodologies, (3D modeling, FMEA, DFSS, Six Sigma, etc…) associated with the industry, academies and producer.

Keywords: Industry; Technical drawing; Tolerances; FMEA; DFSS; Six sigma

Introduction

The human being has always felt the need to represent all that surrounds him, finding in drawing, the most interesting means to carry out this desire. The first drawings go back to the Superior Paleolithic, 35.000 years ago, when the Homo sapiens represented on the cave surfaces of the caves or on the skin of the coats, animals that he hunted. An example of this artistic manifestation can be found in the cave paintings of the caves of Altamira, in Cantabria (Spain) [1]. The history of civilization reveals many forms of design representation, from maps engraved in stone to physical models built to scale and based on the human imagination (Figure 1). Engineers, not differently, have always needed a technique to create and communicate their design ideas [2] and the drawing, therefore, belongs to their tools box. Historically speaking Albert Einstein stands for, with his phrase, "God does not play dice", a milestone on the understanding of logic, randomness and determinism.

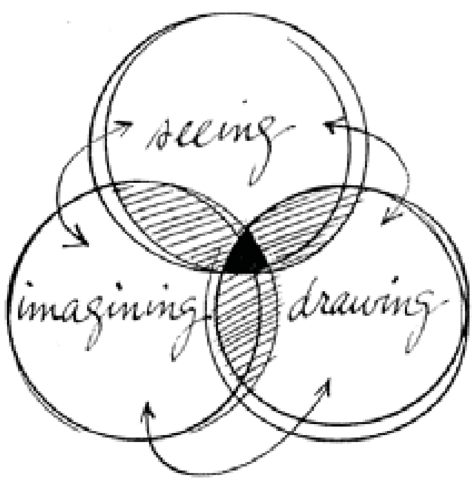

Figure 1: McKim's model for visual thinking underscores the need for creative sketching in the Engineering Design.

His phrase shook the intellectual minds from academy and industry [3]. Einstein´s speech ignited, even more, the development of quantum theory by physics theorists; on the same hand, there was, in parallel, the development of new intellectual tools at industries / academies. The statistics, for instance, was one of the great outputs (creations), bringing the engineers and technicians to a new and original scenario, considered a superior technical level. Scenario that allowed them to foresee tendencies and interpret results based on data. At this stage the regular drawings had its first impact in industry; the variability is known and must be onboard. With time there was a relevant second impact related to the "mass production" concept, developed by Taylor. Taylor brought the need of an important and new concept of interchangeability [4]. The drawings as a result passed through another impact and received an additional characteristic called "tolerance". Such tolerances (dimensional or shape and/or position), then required by the modern industry, contemplated limits to dimensions in such a way of permitting its assembly in any Set. Due to the high volume produced since then the tool or concept of tolerance had to be introduced in industries in order to guarantee the mass production continuity and success. This paper aims to describe historically and empirically by the author´s views, the impact on the drawing with the more intense application of new technologies. Understanding technology as being the application of new intellectual tools, machines, methods and methodology associated with the culture of the manufacturer.

Drawing

Drawing is a form of visual art that makes use of any number of

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drawing instruments to mark a two-dimensional medium. Technical drawing, also known as drafting or draughting, is the act and discipline of composing plans that visually communicate how something functions or has to be constructed [5]. Drafting is the visual language of industry and engineering. People who communicate with technical drawings, (those who design and those who are trades people), may use technical standards that define practical symbols, perspectives, units of measurement, notation systems, visual styles, or layout conventions. These enable a drafter to communicate more concisely by using a commonly-understood convention. Together, such conventions constitute a visual language, and help to ensure that the drawing is unambiguous and relatively easy to understand. Engineering drawing and artistic drawing are both types of drawing, and either may be called simply "drawing" when the context is implicit. Engineering drawing shares some traits with artistic drawing in that both create pictures. But whereas the purpose of artistic drawing is to convey emotion or artistic sensitivity in some way (subjective impressions), the purpose of engineering drawing is to convey information (objective facts) [6].

Tolerance

As mentioned previously, another important characteristic in the drawing is the tolerance. Tolerance, once included in most of the technical drawing has several definitions, being one of them "The allowance for a specific variation in the size and geometry of the part" or "Dimensions, properties, or conditions may vary within certain practical limits without significantly affecting functioning of equipment or a process". Tolerances are specified to allow reasonable leeway for imperfections and inherent variability without compromising performance [7-9]. The tolerance considered in the drawings aims to guarantee the interchangeability, like firstly conceptualized by Taylor [4], the lifetime and strength of products in the modern world of "mass production". At the beginning, the tolerances applied in the drawings were not accurate mainly due to the poor capability analysis available by the manufacturing. For this reason designers and engineers used estimated limits, which were considered representative of the processes, certainly under few measurements. With the introduction of statistics (covered in the item 4) and the commercialization of specialized software's, the responses analysis (based on data) became much easier, bringing with it the need of more quantitative data. Such easiness, brought by the software, revealed that, the prior estimation of the processes capability, practiced in the drawing in the tolerance way was not enough for the precision. The tolerances used till that time was known as inaccurate. Therefore the event of the data knowledge brought the consciousness of the need of revaluation of the tolerances in the drawings, being the previous tolerances in checkmate, or at least, under revaluation. With those movements in industry the determinism was better understood and the "cause – effect" logic used as a manner of foreseeing the requirements needed to the products utilization, by statistics usage, and avoiding future problems. The result of this gap of knowledge - old tolerances versus new one based in data - decreased the credibility of the prior tolerances adopted, and in parallel diminished the previous technical drawing credibility. Moreover there was the change of the document status from "document" to the "reference document" condition. This switch in the drawing (recognizing) jeopardized the interchangeability of the products, its lifetime and wearing. But reveal on the other hand the possibility of having a better and lean product with low cost of non-quality.

But maybe a question would rise in terms of how to stipulate tolerances in the drawing. There are basically three ways to input tolerances in a drawn part, as follow;

1– 1st way (scenario): When the product has the highest and new technology on board and the manufacturing processes and or machines are not capable to guarantee the product as drawn, investments must be done. At this particular case the product tolerance requirement is mandatory and investments are an exigency to move forward;

2– 2nd way (scenario): The available manufacturing shop in the company is capable to reach (deliver) the tolerances needed for the product and;

3– 3rd (scenario): The capability required by the product (based on tolerance) is not available in the company manufacturing shop but may be acquired by outsourcing.

Statistics (Six Sigma)

The statistics conception and application in industry introduced a great shift on the development of the products enhancements and new products creation in the last decades. Statistics is a mathematical science defined as the study of a collection and organized data where analysis, interpretation and presentation can be processed [10]. It covers all aspects including the planning of data collection in terms of the design of surveys and the proper experiments when applied [10]. The necessity of collecting data from a part in the production or prototyping those allowed the translation of data to a more logical and palpable picture in the industries. The necessity of revaluation of the design of "well known" products, which already had tolerances applied on it, became a need but in certain cases rejected or neglected. The advent of applying systematic methodologies using tools, training, and measurements to enable a better design of products, services, and processes in order to reach the customer expectations, has finally an allied. This allied is called Six Sigma Methodology. Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability (increasing capability) in manufacturing and business processes [11-13]. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Champions", "Black Belts", "Green Belts", "Orange Belts", etc.) who are experts in these very complex methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction and/or profit increase). The Design For Six Sigma (DFSS) or Design For Lean Enterprise Sigma (DFLES) optimizes the design process to achieve six sigma performance and integrates characteristics of Six Sigma at the outset of new product development with a wide set of tools [14]. This methodology allows the better knowledge of the way to design and manufacture products. The advent of the index PPM in industries (one defect or event per million of parts produced) has come from a grounded concept of Six Sigma. Actually the automakers phase is targeting the PPB index (one defect or event per billion of parts produced). The automotive industries have pulled the exigency of the products / processes capability up for the auto suppliers. The six sigma methodology gathered new techniques and tools to analyse the process sequences, interactions and capabilities. The Design for Lean Enterprise Sigma (DFLES) made the system more logic and postulate that the drawing must be based on the processes capabilities and initial prototyping and samples. Most of products therefore might be leaner, cost effective and highly reliable when this intellectual concept and its associated tools are used. The drawing then reached its more important stage as being a dynamic instrument (document) which represent and bring the technology of a company and the reliability of its products.

The Actual Drawings Consistency (Deviation Culture)

In logic, a consistent theory is one that does not contain a contradiction. The new generation of drawings is going to bring more credibility in the industries with the application, as described, of new concepts like, DFSS, Prototyping Kaizen, FMEA [12,13,15-17] and Statistical Tools in sampling and production. This is definitely the actual and most advanced tendency/generation in industries. The application of those methodologies and intellectual tools in the design should pull the system up to a new generation of highest quality products. But in order to follow this path the production must reestablish the drawings credibility in order to avoid the culture of deviation. The deviation culture, due to the historical facts mentioned, may bring the document (drawing) back to manufacturing poor capabilities and uncertainty. The culture of deviation is very risky and depending on the product involved may bring catastrophic results for society. The management must be aware and actuating on this tendency. Mainly the manufacturers must be disciplined enough to follow the drawing, or at least, to communicate previously the possibility of deviation and its benefits associated. The statistical tools can be used in order to map (monitor and control) the status of the drawing versus manufacturing consistency, bringing higher results on the company metrics.

The Management and Culture Style

Management is the process of reaching organizational goals by working with and through people and other organizational resources. Management has the following 3 characteristics:

1. It is a process or series of continuing and related activities
2. It involves and concentrates on reaching organizational goals
3. It reaches these goals by working with and through people and other organizational resources.

The four basic management functions that make up the management process are described as follow: Planning, Organizing, Influencing, and Controlling [15,16]. In the drawings context, the managerial team therefore must be alert with this preconception due to historical facts and press their team in order to question the drawing but never neglect it or have it as a pure reference as before. The questions are a right and may bring improvement to the processes but the deviation, whether not eliminated, is a thread in the corporation as a whole. Misunderstanding of the representativeness of the drawing, for example, as being the identity of a company, questioning its status from technology and knowledgeable to reference is definitely very disastrous. In this direction, the top management must be aware of tendencies and the costs of non qualities present in the company metrics.

Technical Drawings Evolution

The technical drawings passed through a long journey and are still under a dynamical change (Figure 2) promoted for the wider tools available. At the beginning this intellectual tool had several formats and ways, which, with the time required certain standardization based on an exigency of international communication. Ahead and even more impacting was the "mass production" as described previously. Contemporarily the challenge is its adequacy in the world of data, statistics, efficiency and cost. This phase is built worthy whether the actual methodologies and intellectual tools are duly applied, like Lean Enterprise, DFLES, FMEA, Six Sigma, Prototyping, etc… All the possibilities are feasible when the context is designing the right product. The choice is based on the product design, for what it serves, and in the evaluation of the technology to be applied. The DFLES serves as design tool to prior analyse the processes and to compare the outputs from the process with the product usage.[18] The FMEA, another important tool to the drawing dynamic, brings the reliability of the product based on the project and manufacturing disciplines (experience and data) in a preventive manner. The constant study by the process engineering of the machines and processes capabilities save time and contribute to the initial design based on FMEA and DFLES. Despite of the superior advantage of these tools the integration of both product and process engineering is the must to bring superior benefits when appropriate tools and palpable data are used. The most contemporary tools able to promote the best product and or service can be detailed as follow:

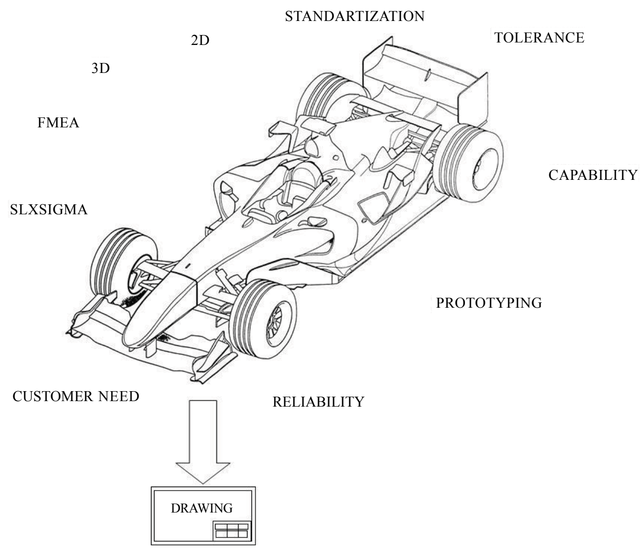

Figure 2: Characteristics interacting with the drawing [18].

1– 3D modeling: change the way of conceptualizes the product by tridimensional building. The benefits are associated to the interferences avoiding between the parts, eliminating mistakes due to spatial misinterpretations, getting productivity increase and afterwards marketing appeal.

2– Standardization: create a global way of drawing, with templates, standards, configuration, etc… The benefit is associated with a global way of communicating without misunderstandings.

3– FMEA: require a better visualization on how to design the product avoiding previous bad experiences. Benefits are associated with historical enhancements avoiding recurrent mistakes in design and production.

4– Tolerances: created interchangeability between the products. Benefits are the guarantee of usage to high production volumes.

5– Statistics: brings a palpable way to get and study data in the product conceptualization as well as in the production.

6– Six Sigma: powerful methodology which include several tools, including statistical, to define a better product and or process. The benefit is to have a more lean and functional product.

7– Prototyping: worth methodology to create small samples which may represent the mass production afterwards. Benefit is to avoid surprises during production;

8– Customer need: the deep analysis of the customer need, being toward surveys, interviews or specification is the first step to succeed. The benefit of a good study and closer to the customer is to gain its loyalty in the market.

9– DFSS or DFLES: a powerful and associated tool with Six Sigma to better understand the capabilities associated with the right product since its conception. It also gathers the shop floor capability to a better product understanding / development. Benefit is to get a better relationship with the customer by delivering the better product which could be bought.

10– Reliability: a concept of guiding the project and the production to deliver product under the lower variation and maximum success possible. The benefit is to reach a stable product by reliability behavior along the phases.

Design Management and the Future of Design

In term of the of design management the application of management platform like Vault is a strong tendency. Autodesk Vault data management software, for instance, not only enables design and engineering users to collaborate on better designs with fewer errors, but also automates the product or project lifecycle. With features to facilitate team collaboration, data search and reuse, and revision management, Vault products help teams make better use of their design data throughout the process [19]. The software allows the designers and engineers to collaborate mutually and globally even having teams located in different parts of the world. Each engineering hub, for example, may design part of the equipment or machine involved in the project and uploads the conception of its part in the Assembling located at the Cloud (Vault). It means a very powerful global team, represented by the gathering of engineering hubs, engaged to converge to the same final product, (Figure 3) [20]. As known, the accuracy of the revisions control and traceability are already supported by such robust software. The future of the design passed through a break on the current paradigms where the designs are done in two dimensions. The advance on 3D modeling brings a new way to build parts, equipments and machines shifting the designers and engineer´s capability. The simple fact of seeing the parts in three axes requires more expertise on multi-axis imagination which is completely different of the usual close past two dimensional models. The close future advance in design is a totally virtual world where the concept developed can be interacted with the designer, engineer and user. Testing sled, for example, is a complex platform that's able to match the physical dimensions of nearly any vehicle. Once the physical properties are set, a tester sits in the sled wearing a head-mounted virtual reality display equipped with reflective spheres to enable 1-1 movement mapping. A pair of gloves with the same IR-visible balls helps complete the illusion (Figure 4). The goal here is to allow designers and engineers the ability to test out their designs without building a full-scale working model like the Cave Virtual Environment (Figure 5). Nearly everything from seating position to steering wheel position to blind spots can be evaluated and worked out [20].

Figure 3: Car modeled 3D by meshing geometrical (power wall of ideas exchanges) [18].

Figure 4: Virtual world when designing [20].

Figure 5: Cave Automated Virtual Environment [20].

Conclusions

The determinism questioning was one of the drivers to the actual evolution in technology. The changes in the level of knowledge of processes capabilities checkmated the forecast previous tolerances present in the drawings. New technologies brought new thoughts on how to produce the best product. Technologies like DFLES, 3D modeling, FMEA and Prototyping, make the engineering more accurate and with minor errors. The products challenge and at the same time tendency, is to reach a quality level where the reliability can beat PPB, as the market in the near future will require. The companies which do not look closer to the processes of design and manufacturing and do not apply the contemporary tools will certainly, in parallel, be in deep troubles. The top management, in parallel, should be aware of the natural rejection of those new technologies and bring an assertive approach where the company metrics are the main drivers to succeed. The drawing is the key to the companies succeed. The application of new technologies improves the projects understanding and consequently its accuracy, which aims to exceed the customer´s expectance. The design and the drawing walks together and define the enterprise technology level despite of being considered an old "tool" it must be treated as the right place where the company knowledge is contained. The top management must increase the importance of new technologies on design, drawings and concepts to enhance the products fitting with the customer expectance and in agreement with the increase on the design productivity. The company life is directly related with its designs and drawing, it means that a very simple misalignment with the company strategy is the disrespect of its designs and drawings. A good way to manage this situation is by using metrics (KPI´s) in accordance with the company strategy. One example of assertive KPI´s addressed to design / drawing can be the quantity of deviations requested in the shop-floor. Actually in order to guarantee the lead-time of the products some minor deviations are practiced. The risk is that these minor deviations become bigger and bigger and consequently being able to jeopardize a whole business.

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