Contributions Regarding the Specific Approach on the Management of the Global Engineering Process in Aerospace Organization

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Abstract
In the aerospace industry, the documents most commonly encountered by industrial organizations describe expressed, unexpressed, measurable, and immeasurable requirements. Product requirements can influence the overall engineering process through the level of applicability within the component processes. The overall engineering process applies a high percentage of product control documentation requirements. The characteristics of the products as input elements in the global process have a direct influence on the process. The purpose of the requirements is to facilitate the approach to non-compliance management, involving technical knowledge from manufacturers, but also socio-economic knowledge. These requirements must be clearly stated by the customer to the manufacturer, in order not to give the possibility of interpretation and to facilitate clarification in the process of non-compliance management. Based on these requirements, industrial organizations can perform quantifications through records in databases, to perform analyzes of the quality of production systems. This paper addresses a global model for analyzing the requirements of metal structural products in aerospace. The contribution of this study starts from the component processes of the global process that have been developed and integrated into the quality management system based on product requirements and the capability of the aerospace organization, which is why each feature is used in the global process. It was argued the importance especially in the manufacturing processes of metal structural components, the verification of the characteristics of hardness and conductivity of the material. The global engineering process incorporates several interconnected processes and is tracked and measured in terms of capacity and deliverability. The basic indicator of this process is given by the number of finished products in terms of deliverables. Approaching the critical path in a system of processes is another important aspect of this research, since, regardless of the process and its complexity, there is always at least one path in the process to be followed, regardless of the time required. In project management, the method of establishing the critical path is mandatory, because in general, leadership functions within organizations tend to reduce the time of any process. Their motivation is given by the costs that are directly connected to the time taken to go through an engineering process in an industrial organization and this can be approached as a further direction of research.

Keywords
Aerospace manufacturing; quality management system; product requirements; product characteristics.

Introduction

Teixeira (2020) and Castro (2019) mention that the matrix analysis of structural product quality requirements helps any organization to visualize product requirements. The aim is to plan the activities of their implementation in manufacturing and to evaluate the possibilities of capacity development in terms of manufacturing processes (Daube, 1992, pp. 402-414).

Approaching requirements at various levels of detail, allows organizations to develop strategies for integrating requirements into internal processes, to ensure verification of all product requirements, without omitting certain generally applicable requirements (Li, 2018, pp. 17-34). Approaching the critical path, in a system of processes, is very important since, regardless of the process and its complexity, there is always at least one path in the process to be followed, regardless of the time required (Grendel, 2017, pp. 30-37).

In project management, the method of establishing the critical path is mandatory, because in general, leadership functions within organizations tend to reduce the time of any process (Brahmeswara, 2018, pp. 43-51). Their motivation is given by the costs that are directly connected with the time taken to complete a process (Tanaka, 2020, p. 14-30). In other words, the critical path is represented by a succession of activities within a process, or several interconnected processes, depending on their inputs and outputs. The critical path is associated with the risks of each activity and the influences on the others (Rojo, 2017, pp. 80-85).

Research methodology

In this paper, the research methodology involves the development of the component processes of the global process and their integration into the quality management system based on product requirements and the capability of an organization in the field of aeronautics. The first step in developing this methodology will be presented below.

Requirements expressed

The requirements expressed are those requirements that are transferred from the beneficiary to the producer in an obvious form. Thus, it can be mentioned that the technical documentation of a product represents requirements expressed in the form of documents that describe the shape and parameters of manufacturing (Wang, Kon, & Madnick, 1993, p. 670; Jacobs, 1999, p. 172).

In the aerospace industry, the documents most often encountered by industrial organizations, which describe these requirements are:

- Execution drawings - are drawings that represent the views of the product at scale and its dimensions. These drawings are the most obvious expressed requirements of product quality.

- Lists of materials / semi-finished products required for the manufacture of products - these lists contain information generated by the design process on the type of materials required, alloys, material conditions, dimensions and quantity of materials / semi-finished products needed to make products, materials manufacturing standards, specific class information safety, etc.
- Product approval note and use in aircraft - these documents are specific to aerospace. The reason is that they contain information on the approval of the manufacturing process by the design organizations, approval without which the product can only be manufactured as a test product.
- Process specifications - these documents are the standards developed by aircraft manufacturers to control the manufacturing parameters for the products to be installed in aircraft. The requirements in these specifications are defined in the form of suggested or mandatory requirements. Mandatory requirements are requirements that are used in the certification of conformity of each product. In this regard, the cutting parameters, the thickness of the surface protection layer of the products, the temperature and humidity of the environment in the process of applying the protection (paints) of the product surfaces can be mentioned.

The expressed requirements are used in product conformity certification, being very easy to address in the case of non-compliance management (Svensson, 2011, p. 69; Alsaqaf, 2017).

Unexpressed requirements

Unexpressed requirements are requirements that are not transmitted from the beneficiary to the manufacturer in a clear, explicit manner. In general, these requirements are set out in the collaboration between the customer and the manufacturer, in the form of "expectations".

For example, in the aerospace industry, and not only, it can be considered as an unexpressed requirement - the customer's requirement to manufacture products with deviations as small as possible from the dimensional values of the products expressed in the execution drawings (Alsaqaf, 2019, p. 39). Also, the quality of the products should be as high as possible, once the manufacturer is quoted on the market with a high quality of the products.

From the manufacturer's point of view, these requirements are difficult to manage, because they are requirements that are interpreted as the manufacturer considers them. Addressing unexpressed requirements is a topic that involves not only technical knowledge from producers but also socio-economic knowledge. These are necessary to be able to deduce those requirements that are not explicitly communicated.

Measurable requirements

The process of checking and validating product requirements can only be done by measuring the requirements in relation to their references.

Measurable requirements are those requirements that can be reported as numerical values. Measurable requirements are controlled by upper and lower limits, defining the limits in the compliance field of the requirement (s). Thus, a measured value of a requirement is considered to be compliant if its measured values fall between the two limits.
The field of conformity is defined as the tolerance field of the requirement. It can be symmetrical or asymmetrical in relation to the nominal value, or only positive or negative, being defined according to the functional role of the requirement on the product.

Measurable requirements are the requirements most clearly expressed by the customer to the manufacturer, and which do not allow interpretation. These requirements are also the easiest to clarify in the non-compliance management process.

Immeasurable requirements

Immeasurable requirements are those requirements that are given and verified by attributes or statements. The requirements of the structural components, in aerospace, fall largely into three categories of immeasurable requirements, were the statements "YES" or "NO", "COMPLETE" or "INCOMPLETE", "CORRECT" or "INCORRECT", validate compliance requirements achieved through the manufacturing process.

Although these requirements are considered immeasurable, industrial organizations quantify them through records in databases, to perform analyzes of the quality of production systems, with values 1 or 0. These requirements have a high level of complexity in terms of interpretation because the method of verifying compliance with the requirements is of a pronounced subjective nature. This subjective character has very high chances to differ from the client's point of view. For this reason, these requirements are difficult to manage in case of non-compliances.

A concrete example of immeasurable requirements is that to achieve a benchmark, the customer asks the production organizations to check whether the color of the paint is respected. In this case, even if the color code is observed, and all the paint manufacturing requirements are met, there may be differences in hue that can be interpreted differently by the inspection staff. These differences may occur even if samples received from customers are used, due to the subjectivity of the inspection method.

Requirements influence matrix

Product requirements can influence the overall engineering process through the level of applicability within the component processes. Using the requirements matrix presented in Table 1 of this study - more precisely the first 4 levels of requirements breakdown - in relation to the component processes of the global process, the influence of the requirements on the process can be identified.

Table 1. ***Influence matrix of product requirements on the overall engineering process***

Level I	Level II	Level III	Level IV	Characteristic Type	Influence percentage	Documentation review	ERP doc. Preparation	CAD doc. Preparation	NC Program	CMM Program	CNC Clamping Device	CMM clamping device	Design of forming tools	Clamping device manufacturing	Bill of Materials	Defining Manufacturing Route	Define ERP BOM	Define ERP BOO	Raw materials purchasing	Inspection Plan	Release in production
Designed requirements	Product Form characteristics	Dimensions	Respect all product dimension	Dimensions	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
			Relative position of all the geometric characteristics of the product	Form	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
			Manufacturing of all design characteristics	Holes	56%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✖	✖	✖	✖	✔	✖
				Bores	63%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
				Contour	69%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✖	✔	✔	✖
				Chamfers	56%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✖	✖	✖	✖	✔	✖
				Bends	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
		Materials	Material chemical composition	Chemical composition	81%	✔	✖	✔	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖
			Mechanical properties	Tensile strength	56%	✔	✖	✖	✔	✖	✔	✔	✔	✔	✔	✖	✖	✖	✔	✔	✖
			Material manufacturing process certification	Yield strength	56%	✔	✖	✖	✔	✖	✔	✔	✔	✔	✔	✖	✖	✖	✔	✔	✖
				Hardness and conductivity	88%	✔	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖
				NO cracks on surface	31%	✔	✖	✖	✖	✖	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✖
				No material defects	31%	✔	✖	✖	✖	✖	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✖
				Surface condition (corrosion free)	45%	✔	✖	✖		✖					✔	✔	✖	✖	✔	✔	✖
	Product functionality requirements	Tolerances	Manufacturing tolerances	Dimensional tolerances	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
			Assembly tolerances	Assembly Tolerances	63%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
		Form Tolerances	Product form tolerances as per manufacturing process requirements range	Form tolerances	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
				Positional deviations	63%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
			Functional tolerances	Functional deviation	63%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
		Surface condition	Surface roughness	Surface roughness	69%	✔	✖	✔	✔	✖	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
			Surface corrosion protection	No metallic powder	19%	✔	✖	✖	✖	✖	✖	✖	✖	✖	✖	✔	✖	✖	✖	✔	✖
				NO cracks on surface after machining	31%	✔	✖	✖	✖	✖	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✖
				Paint layer thickness	44%	✔	✖	✔	✖	✔	✖	✖	✖	✖	✖	✔	✔	✔	✖	✔	✖
				Paint type	44%	✔	✖	✔	✖	✔	✖	✖	✖	✖	✖	✔	✔	✔	✖	✔	✖
		Traceability		Manufacturing batch traceability	56%	✖	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✔	✔	✔	✔	✔
Aerospace product specific requirements	Document management requirements	Design data confidentiality requirements		Not using uncontrolled copy of documentations	93%	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔
		Design data control requirements	1:1 scale drawing requirements	1:1 drawings to be used in temperature control room	81%	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✔
			Digital Product Definition	3D Model	94%	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖
	Manufacturing process requirements	Product alloy specific manufacturing process	Manufacturing process parameters specific to the product alloy	Cutting regime	50%	✔	✖	✖	✔	✖	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
				Cooling material type	38%	✖	✖	✖	✔	✖	✔	✔	✔	✔	✖	✖	✖	✖	✖	✔	✖
				Special Cutting tools	44%	✖	✖	✖	✔	✖	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
	Process inspection requirements	Inspection process specific to the product type	Inspection levels corresponding to the product safety class	Inspection 100%	38%	✖	✖	✖	✖	✔	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✔
				Inspection only by certified inspector (ex. NADCAP)	44%	✖	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✔
		Preparation of inspection documentation		Full requirements inspection plans	100%	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Quality System requirements for qualifications	Quality System requirements for qualifications			Product certification according to the EN10204 2.1	63%	✔	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✔	✔	✔	✔	✔
	Design data control			Design data control	63%	✔	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✔	✔	✔	✔	✔
Regulation requirements in aerospace				Product certification using FORM 1, PART 21.G	63%	✔	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✔	✔	✔	✔	✔

Source: original contribution

From the perspective of the requirements of structural products in aerospace, the overall process is 100% influenced by the specific aerospace requirements and the safety requirements in this field, followed closely by the projected requirements.
The results of this analysis are based on the applicability of each requirement in each process of the overall process, and not on the importance or conformity of the product.

The result of this analysis also demonstrates the integration of these requirements in all procedures and work instructions at the organization level.

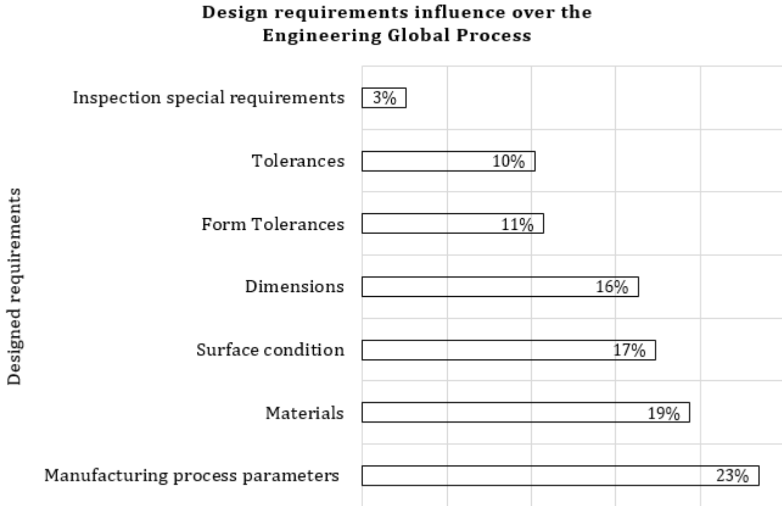

Figure 1. The level of influence of the projected requirements on the process
(original contribution)

As we go into the details of each category of requirements, we can see the influence of all requirements on the overall process (Figure 1). It can be seen that the requirements on manufacturing process parameters have the greatest influence because they apply to as many products as possible. These requirements are also introduced in the instructions specific to each process, to systematize the applicability of the requirements.

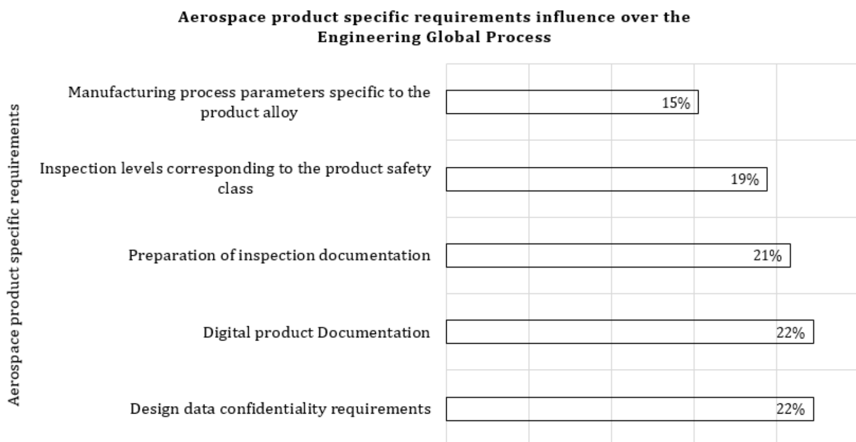

Figure 2. The level of influence of the aerospace requirements specific to the process
(original contribution)

The special inspection requirements, due to the type of requirement, i.e., a requirement to be implemented only in the process of preparing product inspection documentation, interact with the process very little. Instead, it has a high impact in terms of product quality (Wu, 2019, p. 243). From the perspective of the specific aerospace requirements, it can be seen (figure 2) that the requirement for data confidentiality control applies to the same extent as the requirements for the use of technical documentation - i.e., in all component processes of the overall process. The overall engineering process, as can be seen in the figure above, also applies a high percentage of product control documentation requirements. This requirement is applied not only in the processes specific to the preparation of product control documentation but also in all other processes. This requirement is also integrated into the internal documents (working procedures and instructions).

Characteristic influence matrix

Product characteristics (Alblawi, 2018, p. 1151) as input elements in the global process have a direct influence on the process, as shown in Figure 3.

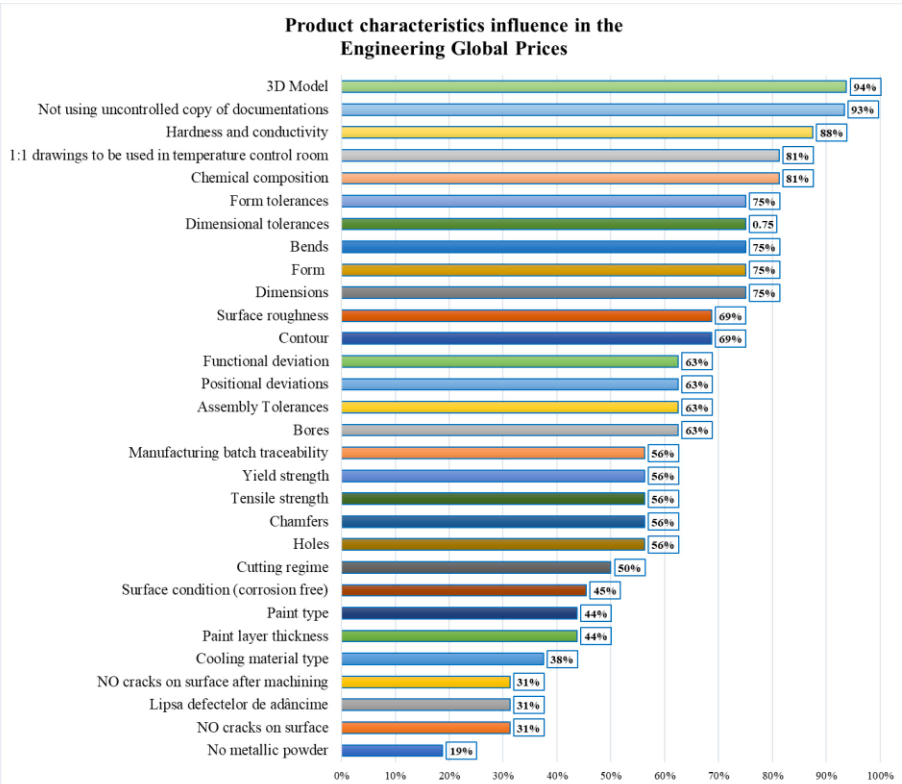

Figure 3. The influence of product characteristics on the overall engineering process
(original contribution)

The component processes of the global process have been developed and integrated into the quality management system based on the requirements of the products and the capability of the organization, which is why each feature is used in the global process. Just as product requirements are used in the working procedures and instructions of each process, product characteristics are addressed by one or more processes, depending on the deliverability they produce (Queiruga-Dios, 2018, p. 2052).

As can be seen in Table 2, the 3D model of the product, as a virtual feature of the final product, is the most used feature, with the greatest influence.

Table 2. Matrix of influence of product characteristics on the global engineering process

Characteristic Type	Influence percentage	Documentation review	ERP doc. Preparation	CAD doc. Preparation	NC Program	CMM Program	CNC Clamping Device	CMM clamping device	Design of forming tools	Clamping device manufacturing	Bill of Materials	Defining Manufacturing Route	Define ERP BOM	Define ERP BOO	Raw materials purchasing	Inspection Plan	Release in production
Dimensions	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
Form	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
Holes	56%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✖	✖	✖	✖	✔	✖
Bores	63%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
Contour	69%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✖	✔	✔	✖
Chamfers	56%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✖	✖	✖	✖	✔	✖
Bends	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
Chemical composition	81%	✔	✖	✔	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖
Tensile strength	56%	✔	✖	✖	✔	✖	✔	✔	✔	✔	✔	✖	✖	✖	✔	✔	✖
Yield strength	56%	✔	✖	✖	✔	✖	✔	✔	✔	✔	✔	✖	✖	✖	✔	✔	✖
Hardness and conductivity	88%	✔	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖
NO cracks on surface	31%	✔	✖	✖	✖	✖	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✖
No material defects	31%	✔	✖	✖	✖	✖	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✖
Surface condition (corrosion free)	45%	✔	✖	✖		✖					✔	✔	✖	✖	✔	✔	✖
Dimensional tolerances	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
Assembly Tolerances	63%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
Form tolerances	75%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
Positional deviations	63%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
Functional deviation	63%	✔	✖	✔	✔	✔	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
Surface roughness	69%	✔	✖	✔	✔	✖	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✖
No metallic powder	19%	✔	✖	✖	✖	✖	✖	✖	✖	✖	✖	✔	✖	✖	✖	✔	✖
NO cracks on surface after machining	31%	✔	✖	✖	✖	✖	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✖
Paint layer thickness	44%	✔	✖	✔	✖	✔	✖	✖	✖	✖	✖	✔	✔	✔	✖	✔	✖
Paint type	44%	✔	✖	✔	✖	✔	✖	✖	✖	✖	✖	✔	✔	✔	✖	✔	✖
Manufacturing batch traceability	56%	✖	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✔	✔	✔	✔	✔
Not using uncontrolled copy of documentations	93%	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔
1:1 drawings to be used in temperature control room	81%	✖	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖	✖	✔	✔	✔
3D Model	94%	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✖
Cutting regime	50%	✔	✖	✖	✔	✖	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
Cooling material type	38%	✖	✖	✖	✔	✖	✔	✔	✔	✔	✖	✖	✖	✖	✖	✔	✖
Special Cutting tools	44%	✖	✖	✖	✔	✖	✔	✔	✔	✔	✖	✔	✖	✖	✖	✔	✖
Inspection 100%	38%	✖	✖	✖	✖	✔	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✔
Inspection only by certified inspector (ex. NADCAP)	44%	✖	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✖	✖	✔	✔	✔
Full requirements inspection plans	100%	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Product certification according to the EN10204 2.1	63%	✔	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✔	✔	✔	✔	✔
Design data control	63%	✔	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✔	✔	✔	✔	✔
Product certification using FORM 1, PART 21.G	63%	✔	✔	✖	✖	✔	✖	✖	✖	✖	✔	✔	✔	✔	✔	✔	✔
Influence level of requirements on each individual		84%	16%	61%	77%	61%	77%	77%	77%	77%	61%	81%	23%	23%	60%	100%	10%

Original contribution

In aerospace, especially in the manufacturing processes of metallic structural components, the verification of the hardness and conductivity characteristics of the material is very important (Goncharenko, 2018). The reason is that the identification of the type of alloy and its condition (level of hardening) is very important throughout the process, especially in the manufacturing processes of semi-finished products for their certification and in the manufacturing process of structural components, before being painted and marked to ensure traceability. This feature is used in 93% of the overall engineering process.

The influence matrix of the indicators

The global engineering process being a process that incorporates several processes, connected to each other, is monitored and measured in terms of capacity and ability to achieve deliverables (Sengupta & Manna, 2019, p. 2043).

The basic indicator of this process is given by the number of finished products in terms of deliverables (Alsaqaf, 2019, p. 39). The overall engineering process refers as a whole to the number of items for which all deliverables have been produced. These indicators are used to manage process capacity.

In terms of product quality, deliverables are measured as follows:

- Within each process, each deliverable goes through the process of creation, verification, and validation. The results of the verifiable verifications are considered quality indicators of the process.
- Once the products are made, the success rate of the products becomes a benchmark of the overall process.
- The overall process and at the same time, all the component processes, are also evaluated in relation to the number of non-conformities of the products generated by the process deliverables.

Proposing a global model for analyzing the requirements of structural products in aerospace

In the industrial field, the quality of products is approached and evaluated, from different perspectives, generated by the possibility of interpreting the quality of a product due to immeasurable and unexpressed requirements (Luna, 2018, p. 26), (López Pascual, 2021). That is why the proposal of a global model for the analysis and quantification of requirements, respectively product quality, opens up opportunities to improve product quality and, indirectly, customer satisfaction.

The quantification of product quality is directly related to the measured values of its requirements (Sengupta & Manna, 2019, p. 2043). The approach of the manufacturing process regarding the realization of the products according to the requirements and the methods of their verification, directly influences the level of the product quality. Thus, a “zero defect” approach should be adopted by industrial organizations and not only (Liang, 2017, p. 1225). However, industrial organizations with large series of product, plan, even through quality policies, the realization of compliant products in percentages of 95-99%. This approach is generated by factors such as lack of a solid control system of manufacturing processes, methodologies to reduce unstable nonconformities, product developments, etc.

Approaching the quantification of the quality of structural products in aerospace, it is considered that each requirement of the product represents a part of the cumulation of all the requirements of that product (Roberson, 2020). To reach the maximum product quality level of 100%, each requirement is allocated a percentage of the total of 100%. The rationale for this approach is that a product is declared non-compliant even if a single requirement is not met, regardless of its type. Even if some requirements are met very precisely and only one requirement is not met, the product is still considered non-compliant.

Figure 4 shows its approach to the importance of structural product quality requirements in the aerospace industry, highlighting various perspectives generated by different types of requirements and their levels of breakdown.

Based on the detailing of the requirements at different levels, percentage distribution of each requirement can be obtained. In Figure 4, it can be seen that, for each product, the general requirements for the quality management system and the legal requirements for aviation safety occupy 50% of the total product requirements. Thus, it can be stated that with the design of a product and its approval for use in an aircraft, the volume of requirements increases considerably.

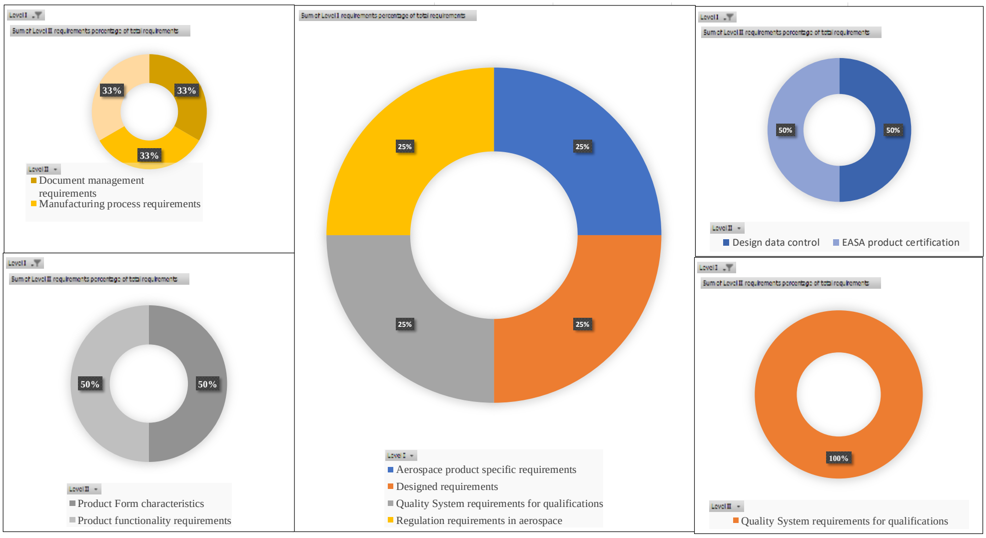

Figure 4. Percentage distribution of structural products requirements in aerospace industry level I and II
(original contribution)

In practice, industrial organizations are oriented on the functional role of products, which is why non-functional requirements are considered as additional requirements (Goncharenko, 2018; Boeing: 787, 2016; AIRBUS, 2016). Thus, in the event that a product is declared non-compliant in terms of additional requirements, organizations access the process by which concessions are issued to customers to accept non-compliant products. This approach is not a customer-driven approach, which is why very high costs are charged for each breach of compliance (Quintiere, 2007, pp. 8-72).

The designed requirements and the requirements specific to aerospace have several levels, of detail, common to all structural products, reason for which the development of the distribution of the requirements within these categories of requirements can be analyzed.

In Figure 5, the requirements that define the shape of the product with respect to the dimensional and those of the material used, occupy about 35% of the designed requirements. The justification is that 65% of the product functionality requirements common to structural products with the distribution shown in Figure 5 have been identified. This result is largely influenced by the common purpose of the products or in other words, their common function. - to ensure the strong structure of the aircraft.

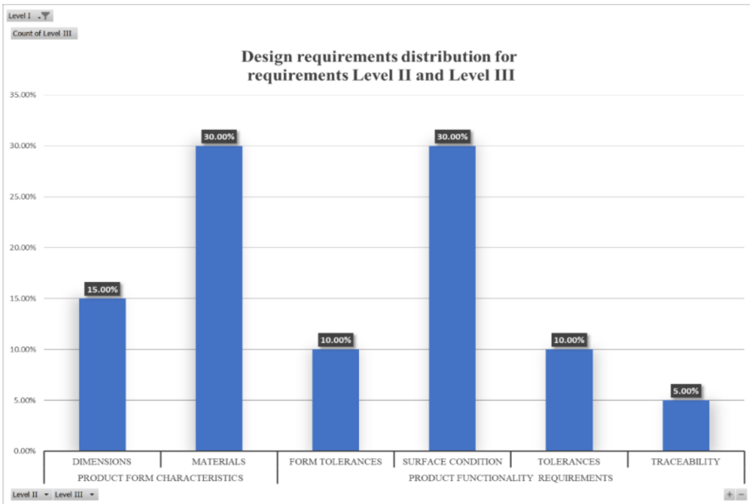

Figure 5. Percentage distribution of projected requirements from level II to level III of detail
(original contribution)

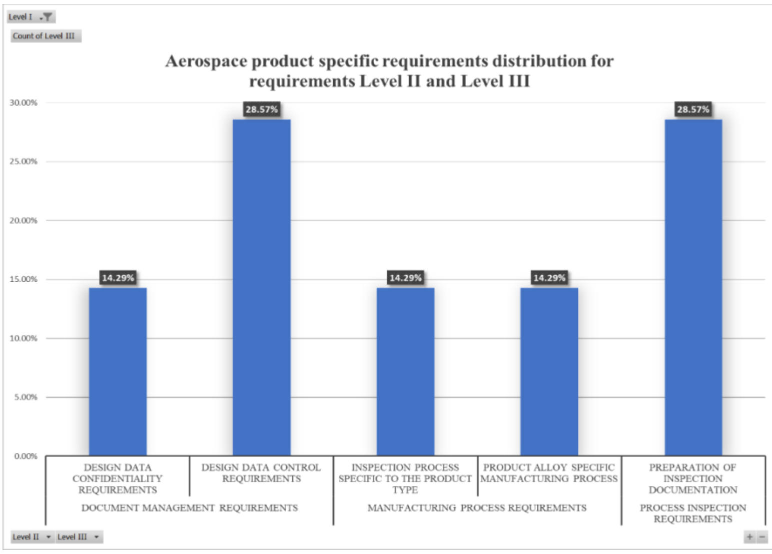

Figure 6. Percentage distribution of projected requirements from level II to level III of detail
(original contribution)

In Figure 6 analyzing the specific aerospace requirements, at levels II and III of detail, it can be seen that the requirements for control of technical documentation, at this level III, occupy a higher percentage of this category, due to the control of technical documentation representing those requirements, based on which the expressed requirements of the products are accessed, requirements that are found in all structural products and not only.

In conclusion, we can say that by approaching the method of allocating a percentage of the total to each quality requirement, the possibility is created for industrial organizations to implement the "zero defects" methodology. Thus, the importance of each requirement is highlighted quite clearly, as part of the quality of the final product. Approaching the quantification of the quality of structural products in the aeronautical field, each product requirement is considered to be part of the cumulation of all the requirements of that product. To reach the maximum product quality level of 100%, each requirement is allocated a percentage of the total of 100%. The rationale for this approach is that a product is declared non-compliant even if a single requirement is not met, regardless of its type. Even if some requirements are met very precisely and only one requirement is not met, the product is still considered non-compliant.

Establishing the critical path in the process system within the global engineering process

The influence matrix of deliverables in the global engineering process is the basis for identifying the critical path. In figure 7, we represented the global engineering process, in an industrial organization in aerospace, from the perspective of the critical path, using the Microsoft Project application.

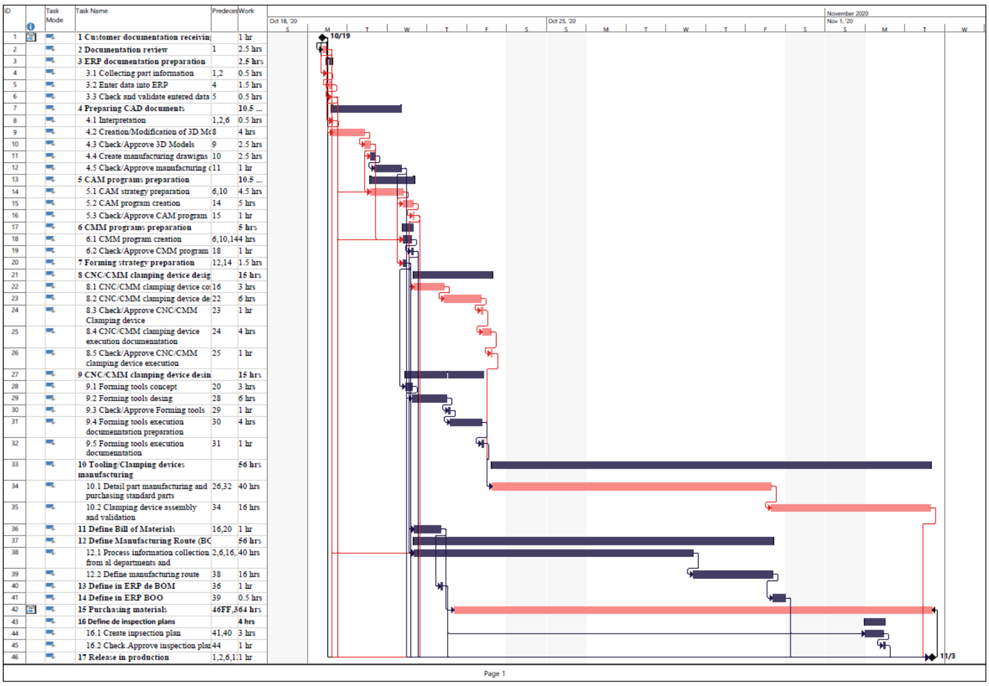

Figure 7. Gantt-type graphical representation of the critical path in the global engineering process, from the Microsoft Project application
(original contribution)

The establishment of the critical path was achieved by establishing the links between the activities of the processes and their succession. Also, the time required to achieve them is considered the basic criterion. In this process, the times associated with each activity are average estimated times for a product. This method of graphical representation using estimated times for products is a method used in project management, allowing industrial organizations to plan activities and resources. In addition, the critical path method highlights those activities in project planning, where special attention must be paid to their resources and capability.

Conclusions

The development and application of a methodology of structured analysis of requirements can influence organizations in the manufacture of high-quality products, by ensuring the analysis and interpretation of all product requirements, having the same perspective on them as the customer.

In aerospace, metal structural products occupy most of the entire structure of aircraft - about 80%. This research paper is aimed at this category to identify methods of analysis of product quality requirements and use them in improving the processes within the industrial organizations that deal with their manufacture.

Quantification of product quality is only possible if each requirement is individually quantified. Thus, depending on the type of requirements, both expressed and unexpressed can be identified as their unit of measurement.

The transfer of requirements within the industrial organizations in aerospace is done through a global process of preparation of the execution documentation, a process that we named in the report as a global engineering process.

Understanding all the requirements of the products depends on the level of knowledge available in industrial organizations. The development and attainment of a level of knowledge within organizations must be based on a target level. This target level can be set by the organization based on management decisions or customer demand. Verification of this level of knowledge can be done using information generally applicable in the industrial field or direct relation to the requirements of the products.

The entire research was conducted based on their views by identifying the need to analyze the requirements of structural products in aerospace. The aim was to identify opportunities to improve engineering processes within industrial organizations, by establishing the link between quality requirements, knowledge, and processes.

Our perspective on the possibility of quantifying the quality requirements of structural products is a first original contribution. It highlights the method of addressing the requirements of structural products in aerospace and at the same time for any industrial field.

Concerning the quality requirements applicable to all structural metal products, in this context, each requirement has been classified as expressed or unexpressed and measurable or immeasurable. At the same time, the limits of compliance with these requirements have been defined.

The approach of quantifying product quality requirements for a limited range of products, to identify the need and the type of very specific knowledge needed in the engineering process in an industrial organization, can be considered as a further direction of research.

By developing the matrices of influence of the requirements on the global engineering process, the requirements with the greatest impact on the process can be identified. Once these requirements are identified, the development of specific knowledge on the type of requirements leads to an improvement of the process with the greatest impact.

Establishing the critical path in process analysis is a complementary approach to identify those critical activities in the process that can most influence the process. The identification of the critical path in this report - for the global engineering process - is based on the dependencies of the processes and activities within the process and the estimated times for each activity to achieve a product.

All this process of identifying the influencing factors from different perspectives resulted in developing different perspectives on the processes and the level of influence of various factors.

These results allow any industry organization to develop a requirements management system, complementary to all standards and working methodologies, before making the products. Modeling methods and techniques allow analysts and process managers in industry organizations to view the information needed to make decisions or identify opportunities for improvement.

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