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APPLICATION OF THE QUALITY FUNCTION DEPLOYMENT METHOD FOR DETERMINING TRIBOMETER DESIGN REQUIREMENTS 26th COBEM

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Abstract. *With the need for projects that present characteristics desired by customers, it is essential that there is a good progress during the development stage of the same and for that it is necessary the use tools that contribute in determining the tasks order and consequently in decision making. Among the techniques, the QFD (Deployment of the Quality Function), has the function of identifying the client's requirements, systematizing the project activities, in addition to guaranteeing the quality of the product. Failure to use this tool can lead to problems in the project schedule, low efficiency in the design phase and increased costs in the equipment development. This three stages method consists, the first being conducting a survey, aiming to collect the input data. The second stage refers to the information analysis obtained and definition of the project requirements. The third and final stage, on the other hand, is based on the application of the method itself. The article aims to establish the hierarchy of an equipment design requirements for tribological tests through the QFD. Initially, customer requirements were identified, based on patent data, being hierarchized by the MUDGE diagram. Then, the customer requirements were translated into project requirements, and then the QFD method was applied. Afterwards, the information analysis stage was carried out, considering the initial project requirements and finally the definition of the Quality House, that is, the application of the QFD method. With the application of the methodology, a series of engineering criteria were obtained for the development of the equipment in order to meet the customers requirement. In this way it is possible to verify that a product that meets the aspects desired by its users, as well as their satisfaction, will need efficient design methods and with that the QFD becomes a differential tool for the excellence in the generation of new equipment.*

Keywords: QFD, Tribometer, Product Development.

1. INTRODUCTION

The growing need to reduce costs related to the wear of mechanical components brings interest to the development of tribological testing equipment. Therefore, the complexities of product development such as time limitation, quality and interdisciplinary knowledge must be provided for good project planning to be executed and, for this, the use of tools that aid the design and execution phase tend to contribute to product quality (Romano, 2003).

Conforms Cheng et al. (2007) the product quality can be guaranteed through three perspectives that are part of the product's life, which include inspection, process control and product development. In order to avoid future problems with possible modifications, quality assurance through development perspective has proven effective and important in increasing competitiveness. Customer satisfaction is a key part of evidencing product quality and, for this, customer requirements must be considered and analyzed from the beginning of the product development phase.

One tool that can be used for quality assurance in the product development stage is Quality Function Deployment (QFD). Created in the mid-1960s by Professors Akao and Mizuno, the QFD method is able to confront the design requirements with each other and obtain a hierarchy of these same requirements and, with this, the definition of the design specifications. According to Akao (1996) the goal to be achieved is the planned quality, which can be obtained from the translation of the desires and customer's expectations for technical terms of design and the comparison between them by the QFD matrix.

Also, according to Akao (1996), the projected quality and planned quality are similar, but the initial entry of data in the table is due to the customer's desire and these are deployed in technical requirements of the technology world, that is, the desires and requirements are transformed into quantitative characteristics that must be prioritized from the relationships and conversions of the matrix. Finally, the design attributes that are based on projected quality are hierarchical based on their importance degree and compared to competing products.

In the planning, product design and production preparation stages this method has been widely used for process structuring and development. According to Ohfujii et al., (1997) the method is very efficient for developing products and services, such that it seeks to identify customers' desires and requirements and that later in the production and delivery of the product meet them satisfactorily.

The QFD methodology application can be used for the development of any product or service, being commonly used in product design in the mechanical industry (Kiran, 2017). Among the products to be developed, considering the use of the method, there are mechanical test products that must meet specific requirements desired by users, which are called by tribometers and, according to Maldaner et al. (2021), have the function of simulating laboratory scale analysis of engineering materials wear.

Still, according to Maldaner et al. (2021), there are several configurations of tribometers, which can be seen by the numerous amounts of existing patents, however to develop a new product it is necessary to evaluate the innovations not yet commercially available in conjunction with the customer's desire. Therefore, the proposal of this work aims to use the QFD method to determine design requirements for the development of a tribological testing equipment so that its configuration can meet customer requirements obtained through patent registrations in force.

2. METHODS AND MATERIALS

In this study, a product was used as a product for tribological testing, also usually referred to as a tribometer, which has the function of simulating on a laboratory scale the damage promoted by wear and estimating the friction coefficient in engineering materials. The methodological steps are described in the diagram represented in Figure 1.

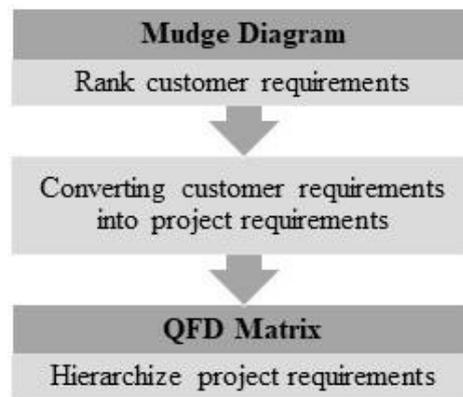


Figure 1. Study steps flowchart.

For the proper development of this item, the QFD matrix was applied. The method depends on obtaining a customer requirements list about the product to be developed, which were acquired from the patent analysis carried out by Maldaner et al. (2021). The patents of the tribometers used to elaborate the list of customer requirements were: Patent IN331165, Patent DE202020100572 and Patent WO201969322, which are characterized by the pin type on the disc. These patents were chosen for comparison because they have more detailed information about the product, according to the analysis performed by the authors. Figure 2 presents the equipment adopted in this study.

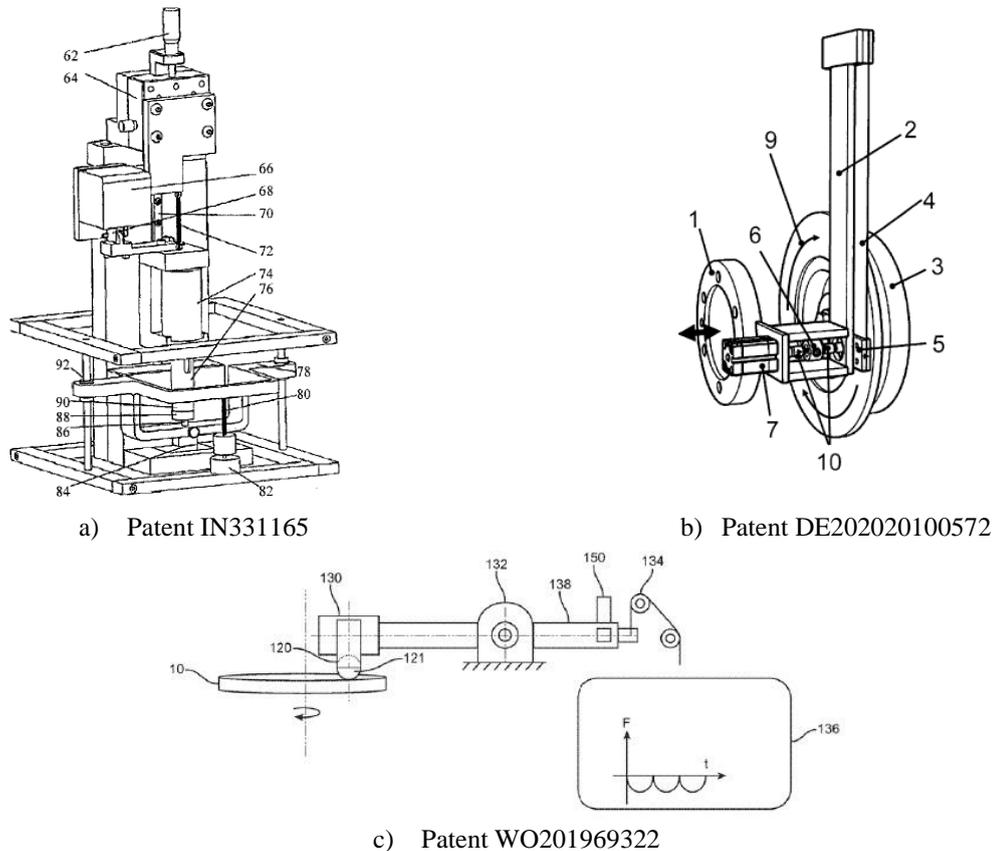


Figure 2. Patents classified for analysis (Maldaner et al., 2021).

In addition, it is necessary to value and hierarchize each requirement, and this step is performed from the use of the Mudge diagram. The diagram is a tool that allows you to compare customer requirements with each other and generate a hierarchy according to the relevance of each item. The client requirements considered in this study were inserted in the diagram and then a combination was made through numbers and letters in which the items are evaluated every two. Each number indicates the requirement that prevails over the other and the letter, likewise, its importance. In this work, 3 importance levels (A, B and C) were used, which are organized in ascending order, being (A) equivalent to one, (B) equal to three and (C) equal to five. After the comparison of the requirements and designated their relevance was carried out the accounting of their so important, which resulted in the requirements hierarchy.

The QFD (Quality House) matrix used is shown in Figure 3. To start the analysis in the matrix, the customer requirements (represented by "Room 1" in Figure 5) were converted to measurable design requirements ("Room 4"). Then, the list of valued and hierarchical customer requirements ("Room 3") was inserted into the matrix in conjunction with the technical specifications. With this, all requirements and specifications were correlated and defined their relationships ("Room 5"), which can be classified into three affinity degrees (strong, medium or weak). The matrix provides as a result the importance of each specification ("Room 7") and the comparison between competing products ("Room 2"), and the one with the highest score is used as a mirror product. The tribometers patents used to compare products are the same as mentioned above (patent IN331165, patent DE202020100572 and patent WO201969322).

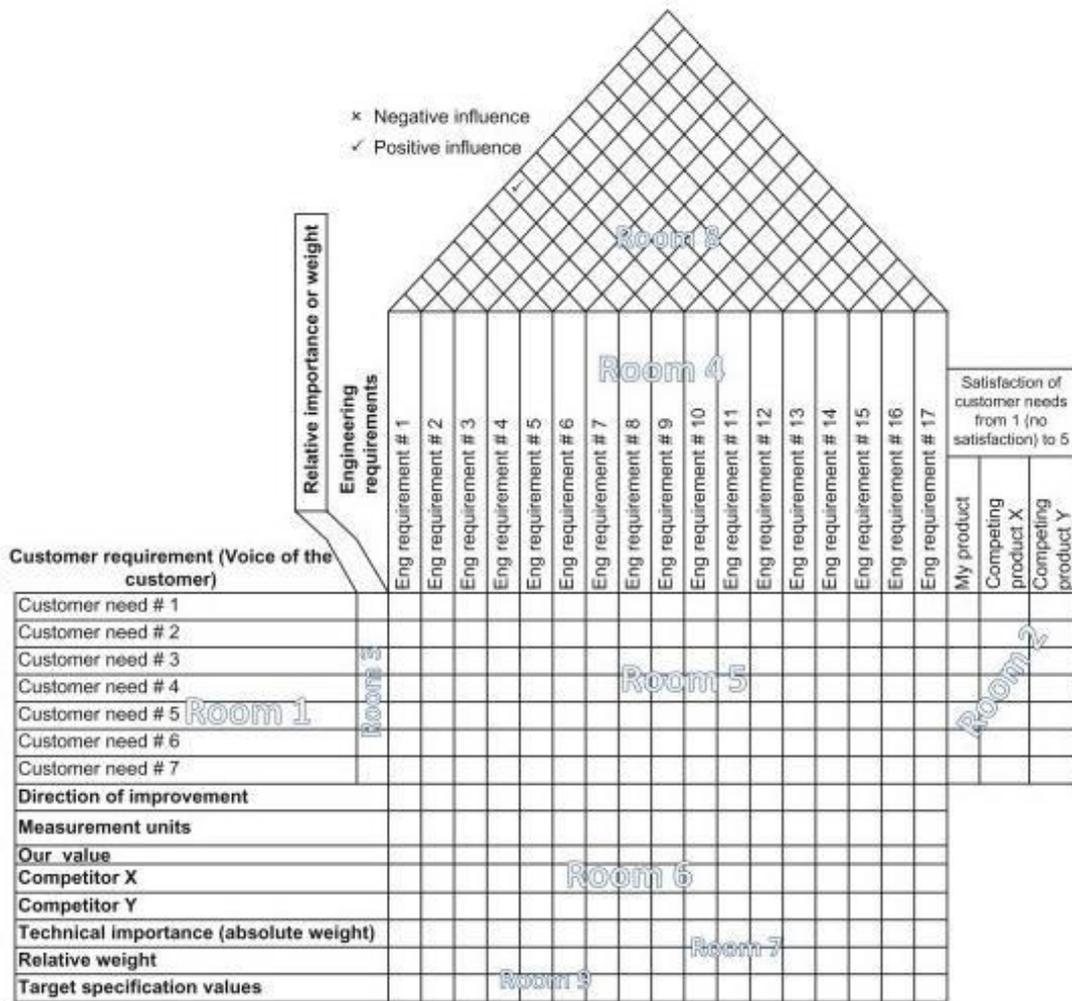


Figure 3. Quality house (Jahan, Edwards and Bahraminasab, 2016).

3. RESULTS

From the analysis of tribometers patents existing in the market carried out by Maldaner et al. (2021) and considering the classification of pin or sphere on disk, 10 customer requirements were determined, these being: Security; Low cost; Good finish; Avoid vibrations; Possess bench leveling; Have connectivity with microcomputer; Load application; Allow different usage settings; Have load/temperature sensors; (e) allow cyclical testing. Considering the application of the Mudge diagram, the value of each requirement was obtained, according to Figure 4, and the ordering by relevance according to Figure 5.

		2	3	4	5	6	7	8	9	10
Security	1	1C	1C	1B	1A	1C	1A	1C	1B	1C
Low Cost	2		2B	4A	5B	6B	7A	8B	9B	10A
Good Finish	3			4A	5C	6C	7B	3C	9C	10C
Avoid vibrations	4				4B	6C	4A	4B	4B	10C
Bench Leveling	5					6A	7B	5C	9A	10B
Microcomputer Connectivity	6						7A	6B	9C	6A
Load Application	7							7B	9B	7A
Allow Different Usage Settings	8								9A	10A
Have load/temperature sensors	9									9B
Allow the performance of Cyclic Tests	10									

Importance	Punctuation
Low (A)	1
Medium (B)	3
High (C)	5

Figure 4. Mudge diagram application.

REQUIREMENTS	TOTAL	%	RANKING
1	33	20,12	1
2	3	1,83	9
3	10	6,10	8
4	13	7,93	7
5	18	10,98	5
6	23	14,02	3
7	15	9,15	6
8	3	1,83	9
9	26	15,85	2
10	20	12,20	4
TOTAL	164		

Figure 5. Mudge diagram application.

It is observed that the item with the highest score was the safety requirement (33 points), since the equipment cannot present risks to the user, while the lower ones were low cost and allow different usage settings, which presented the same score (3 points). The lower value for the low cost item is due to the fact that it is not possible to have security and technology requirement without a minimum investment. Regarding the different usage configurations, it is noted that requirements such as measurements and load application are more important related to the testing of materials.

Customer requirements have been converted into technical specifications which can be measured (Table 1).

Table 1. Requirement conversion.

Customer Requirements	Design Requirements
Safety	Security items
Low cost	Low manufacturing cost
Good finish	Surface roughness
	Number of sharp edges
Avoid vibrations	Alignment of dynamic components
Bench leveling	Number of Leveling feet
Microcomputer connectivity	Number USB cable input
	Bluetooth connectivity
Load application	Number of actuators
Allow different usage settings	Number of Usage Settings
Have load/temperature cell	Number of sensors or temperature/load
Allow cyclic tests to be carried out	Number of load application ways

With the customer requirements and their technical specifications, it was possible to evaluate the relationship between the items to obtain the importance degree of the items through the QFD matrix, as illustrated in Figure 6.

Similarly, it is observed that the design requirement that presented the most importance were the safety items due to their need to protect the user of the equipment, as well as the low manufacturing cost was the item with the lowest importance degree. This hierarchy of design requirements indicates which item should take priority during the development stage of the tribometer.

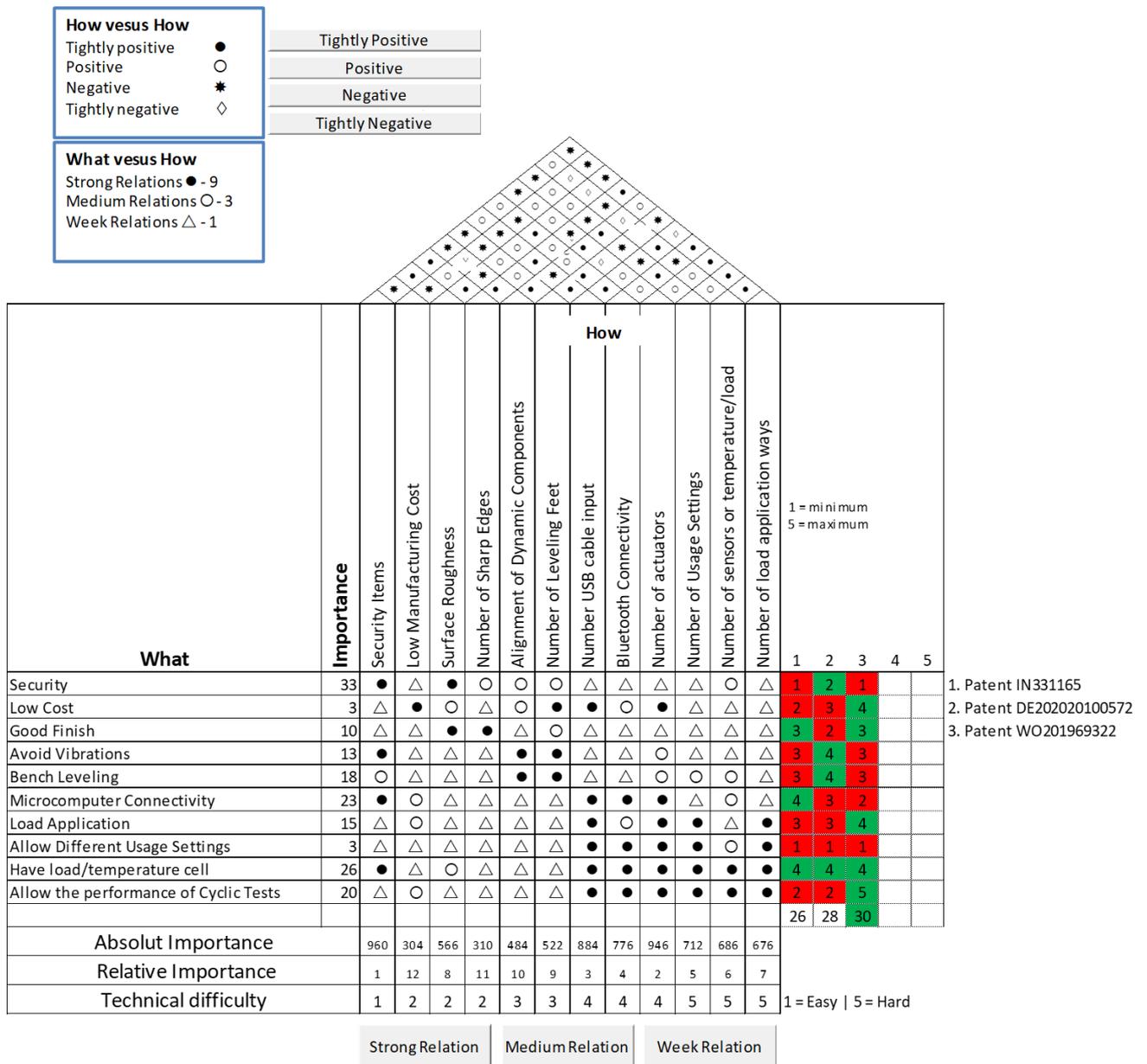


Figure 6. Quality House Application.

Table 2 sets out the requirements in a relevance degree and their complexity, which should be considered to satisfactorily meet the customers wishes in the preparation of the tribological testing equipment project.

Table 2. Priority order of technical specifications.

Order	Project Requirements	Technical Difficulty*
1	Security items	1
2	Number of actuators	4
3	Number USB cable input	4
4	Bluetooth connectivity	4
5	Number of Usage Settings	5
6	Number of sensors or temperature/load	5
7	Number of load application ways	5

8	Surface roughness	2
9	Number of Leveling feet	3
10	Alignment of dynamic components	3
11	Number of sharp edges	2
12	Low manufacturing cost	2

*1 it's easy and 5 is hard.

The technical difficulty is related to the adaptation of the item in the product design. It is identified that 25% of the requirements have a high complexity, while only the safety requirement items comprise a more lenient technical difficulty.

When the pin-on-disc tribometers existing in the patent records were evaluated, it was found that the PATENT WO201969322 (Figure 7) obtained the highest score, which was used as a mirror product for the development of the equipment to be elaborated with this study. According to Maldaner et al. (2021), the equipment has sliding contact with dynamic load, which is used to simulate accelerated wear. In addition, according to the analysis performed by the same authors, the working set of this equipment has a disc (named by figure 10) in rotation and the sample pin (called by number 120), which can still contain a sphere (121) fixed at the tip, in addition to a cyclic load generator (136) for loading application and a load cell for measuring tangential and normal forces (determination of the friction coefficient).

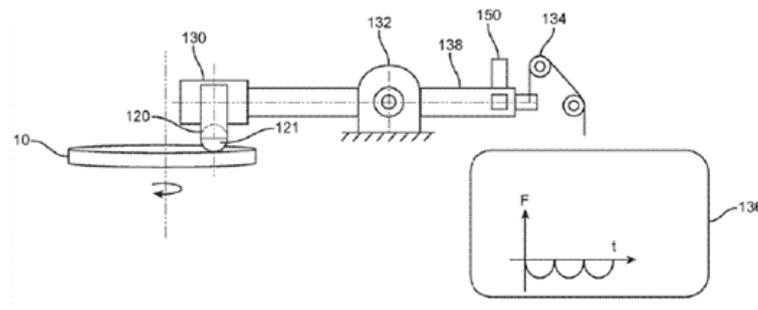


Figure 7. Mirror product obtained after application of the Quality House.

4. CONCLUSIONS

Considering the equipment for wear tests (tribometer), safety was obtained as a priority customer requirement, while the low cost and the fact of allowing several configurations of use presented the lowest importance degree after the application of the Mudge diagram.

After converting the customer requirements to technical specifications, the design requirement related to safety items was again identified as the most important through the use of the Quality House, with the low-cost manufacturing being the item with the lowest priority. This hierarchy allows designers to focus on the most relevant requirements to develop the product, in this case the tribometer, and that influence the purchase decision by the customer.

The comparison of existing tribometers allowed verifying what technical specifications evaluated are present and delimiting the characteristics necessary for the product development of this study.

Thus, it is observed that the use of the QFD matrix allowed the selection of requirements and their respective prioritization, being possible to identify and incorporate the demands of the consumer in the project stages.

5. ACKNOWLEDGEMENTS

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