XVI International Conference
on
Systems, Automatic Control and Measurements

SAUM 2022

Proceedings

University of Niš
Faculty of Electronic Engineering
Faculty of Mechanical Engineering
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November 17-18, 2022

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- SAUM 2022 -

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SAUM is one of the leading associations in Serbia, in the field of Automatic Control. The Association SAUM (Systems, Automatic Control and Measurements) exists from 1985., under the name of Serbian Association for Systems, Automatic Control and Measurements- SAUM for short and it grew out from the Association USAUM, which was founded in 1980. and is working as a member of Association of Engineers and Technicians of Serbia. The Association gathers scientists and engineers from this field. In this period, SAUM achieved very significant goals, among which are three-year scientific conferences, held from 1982. and became a traditional. The first SAUM Conference was held in Belgrade and was dedicated to Professor Dr. Dušan Mitrović, a member of Serbian Academy of Science and Arts a research pioneer in the field of Automatic Control in Serbia. Following conferences were held in Belgrade, 1986., Vrnjačka Banja, 1989., Kragujevac, 1992., Novi Sad, 1995., Niš, 1998., Kraljevo, 2001., Belgrade, 2004., Niš, 2007., Niš, 2010., Niš, 2012., Niš, 2014., Niš, 2016, Niš, 2018, and Niš, 2021.

The first five Conferences were held in the Serbian language and were national with international participants. The other Conferences were international and English was official language. SAUM Conferences are considered highly esteemed meetings both in national and international scientific circles dealing with research and knowledge application in the fields of Systems, Automatic Control and Measurements. The facts that support previously mentioned are that approximately 1000 papers have been presented at SAUM Conferences, with many national and international participants.

Additionally, SAUM held two international seminars in Belgrade, first in 1985. and the second in 1987. Beside SAUM Conferences and seminars, there were many scientific lectures and meetings from the fields of SAUM. Also, SAUM was co-publisher of the Journal "CYBERNETICS" - Systems, Automatic Control and Measurements, from 1987. until 1990. (12 volumes per year).

This year SAUM Conference has 40 papers, with participants from 7 countries (Serbia, Slovenia, Bosnia and Herzegovina, Romania, Bulgaria, Russian Federation, and Montenegro). The papers are divided into one plenary session and six regular sessions (Information and Communication Technologies, Measurements & Instrumentation, Applied Mathematics, Manufacturing and Information Technologies, Mechatronics and Robotics, Artificial Intelligence and Machine Learning, and Renewable and Non-conventional Energy Sources). University of Niš is involved in the realization of many international and domestic projects, so there has been organized special Project session (ERASMUS + and H2020 projects presentation) where coordinators presented their results of four HORIZON projects (WATERLINE, IIMEO, SMART2, Tomorrow project), three Erasmus+ projects (FAAI, BRIGHT, Callme), two Jean Monnet projects (INNOWAT, SPaSE), two projects financed by Innovation fund of Republic of Serbia (AGAR, ATUVIS), and one project realized in the framework of EIT HEI Initiative (DIN-ECO).

We wish to mention our gratefulness to the conference sponsors for their support.

Furthermore, Faculty of Electronic Engineering in Niš and Faculty of Mechanical Engineering in Niš have contributed to the conference organization the most.

Niš, December 2022.

Prof. Dr. Vlastimir Nikolić

President of SAUM Association and
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XVI International Conference

SAUM 2022

Systems, Automatic Control and Measurements

17-18th November, Niš, Serbia

FINAL PROGRAM

SESSIONS OVERVIEW

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15:00 – 16:30	**Session C:** Manufacturing and Information Technologies	Room 1
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19:00	**Conference Dinner**	

Friday, November 18, 2022		
Time	*Activities*	*Place*
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11:30 – 13:00	**Session F:** Renewable and Non-conventional Energy Sources	Room 1
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15:00	**Conference Closing**	

*All sessions will be held at the **Faculty of Electronic Engineering in Niš**, street Aleksandra Medvedeva 14, 18000 Niš (https://goo.gl/maps/NhdxL8KzsaxeScQt7)*

Lobby D – Lobby is located in front of the Dean's office
Room 1 – Congress hall is located on the left side before Dean's office
Faculty Restaurant – next to the Room 1
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Application of the Quality Function Deployment Method in the Mechanical Structure Design of the Two-roll Rubber Mill Frame

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Abstract ***– Mechanical design is the primary field of study to create mechanical products such as tools, components, parts, assemblies, machines, or functional physical objects of any kind. The well-conceptualized mechanical design will result in products with high-performance expectations. This paper shows the applicability of the quality function deployment (QFD) method on the mechanical design process of the two-roll rubber mill frame. Specifically, this paper focuses on the re-development of the existing component for which there is no technical documentation, and the original supplier does not exist. Emphasizing that the component is not accessible for scanning. Thus, the QFD method is recognized as a planning process in the product design, development, and implementation, based on the end users' requests, needs and desires. It defines customer requirements and translates them into engineering characteristics.***

Key words: ***mechanical design, quality function deployment (QFD) method, two-roll rubber mill frame, house of quality, the voice of the customer***

I. INTRODUCTION

Mechanical design or engineering design represents a process of designing parts, assemblies, or components for machinery. Mechanical engineers must be adequately educated in the field of mechanical components behavior to design and develop constructions – products which are safe, reliable and by the client's specifications.

The mechanical engineering design process consists of a couple of standard phases. Those phases represent steps such as: asking, researching, imagining, planning, creating, testing, improving, etc. Consequently, this process includes numerous criteria like functions, safety, reliability, manufacturability, weight, size, wear, maintenance, liability, etc [1]. All of this led to the development of the design theory which has defined various design methods, such as computer-aided design (CAD), the theory of inventive problem solving (TRIZ), the concurrent design (CD), the robust design (AD) method, and many others.

Traditional design methods as described show some limitations in obtaining functional information that could potentially reflect many problems, such as low design efficiency, waste of resources, and weak finished product reliability [2].

The modern era and the rapid information technology development have provided a new product development approach which enables final users to give their feedback and express their desires in real time [3]. Thus, the Voice of the Customer (VoC) model could be applied.

VoC represents the capture of what customers or final users are expecting of a business, product, or service [4].

By application of the VoC model to all stakeholders of the presented problem, a new and reliable design method which could provide a good ability for qualitative and quantitative analysis is the quality function deployment (QFD) method.

The quality function deployment (QFD) method is a design method used for the identification, expression, transformation and analysis of the functional requirements of products, structures, or services [2, 3, 4].

This design method provides mechanical designers with several additional benefits like customer focus, VoC competitor analysis, shorter development time and lower costs, structure, and documentation.

Given the fact that the method has been developed for more than 60 years, there is no abundant literature present. Nevertheless, researchers had been discussing the mechanical design process based on the QFD and used it as an integrated parametrized tool for designing a customized tracheal stent [5] or designing a special vehicle [6]. QFD was successfully applied in the mechanical structure design of a subsea power device [2], a sustainable futuristic airport design [7] or a generation and evaluation of product concepts by integrating extended axiomatic design with a design structure matrix [8]. There are also researches regarding an integrated quality function deployment approach on a voice of the customer real-time strategy [3] and large-scale group decision-making for prioritizing engineering characteristics in quality function deployment under a comparative linguistic environment [9], as well as a decision support model for estimating participation-oriented designs of crowdsourcing platforms based on quality function deployment [10].

The mechanical structure design is the most important process in the research and development of the two-roll rubber mill frame. Since there has been no technical documentation available the desires, needs, and requests of the end users are essential during the design and development process. Thus, the QFD methodology could be applied.

II. CASE STUDY

The two-roll rubber mill has a significant application in the production process of rubber products. There is the variety of different two-roll mill types, but basically, it represents a machine with two horizontally positioned stainless steel rollers (front and back roller). Those rollers rotate in opposite directions at different speeds and pose different friction to mix the rubber mixture.

The two-roll rubber mills [Fig. 1.] could be used in a preparational production phase or for the creation of different rubber compounds. Specifically, in the inner tube production factory, they are used in the preparation production phase.

Fig. 1. The two-roll rubber mill.

Regardless of the two-roll mill type or size, the concept of the machine as well as its foundation and frame are identical. Frame or chaise must ensure adequate functionality and alignment of the machine and its additional equipment (engine, disk brake, reduction gearbox, and transmission). Thus, the frame must be manufactured and installed correctly.

Earlier designs of the two-roll mill frames were robust and manufactured from the one-piece cast-iron plate with a specific installation procedure. After the concrete foundation had been done, the frame was mounted and then concretized to ensure the connection with the foundation. Only the connection plates are left above the concrete surface to allow alignment adjustments and machine connection.

The production process modification requests the change of the machine's layout position which conveys that the two-roll mill frame must be developed, manufactured, and installed.

Given the fact that there is no technical documentation present, that the supplier does not exist and that the frame is under the thick level of concrete the Quality Function Deployment concept must be applied to maximize the end user's needs and requests and to perform the design process and installation of the new frame.

Quality Function Deployment (QFD) represents processes and tools used for the definition of customers' requirements and their conversion into detailed engineering specifications and procedures required for the production of desired products with fully defined characteristics. QFD renders customer requirements (VoCs) into usable design parameters and induces them from the assembly level through the sub-assembly, component, and production process levels. This methodology provides a defined set of matrices used to facilitate this progression.

The QFD methodology consists of 4 that lead defined activities through the product development cycle. A set of matrices are formed at each phase to transfer the VoCs to design requirements for each system, sub-system, and component.

The four phases of QFD are:

1. Product Definition Phase,
2. Product Development Phase,
3. Process Development Phase,
4. Quality Control Phase.

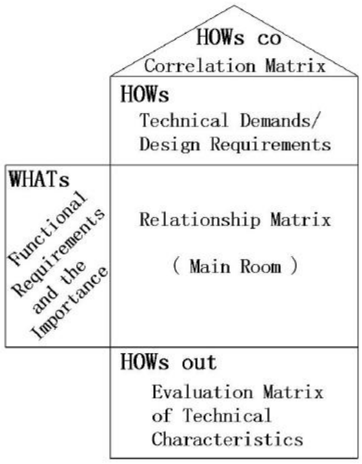

Fig. 2. The structure of the HoQ model.

Regardless of the QFD phase each of them is defined by the properly constructed matrix which is called the House of Quality (HoQ). This matrix is used to define the "whats" and "hows" of the whole design process, to determine the structural, functional, and design requirements, technical attributes, and other relevant elements, and to analyze the relationships among them [2, 11].

The structure of the HoQ resembles the house in which different rooms represent different contents, parameters and design elements [Fig. 2.].

A. Level 1 QFD

The house of quality gathers the customer wants and needs into product or service design characteristics utilizing the relationship matrix [4]. Thus, the “what’s” room is listed and the ceiling which represents the “how’s” contains the design features and technical requirements of the product which will need to align with the VoC. This way in the first QFD level functions and technical characteristics are defined.

The decision-making team is responsible for the evaluation of each function based on its level of importance to the customer.

The main room is used for ranking the “hows” according to the correlation with “whats”. The ranking is obtained by the symbols which correspond to numerical values.

There is also the correlation matrix on the roof which is used to indicate how the design requirements interact with each other, and the evaluation matrix of technical characteristics in the basement or foundation where specific target values for technical specifications relate to the” how’s”.

The relative importance feature contains the results of the calculation of the total sums of each column when multiplied by the importance factor. Those values are often represented in percentages and could help resource planning.

The first QFD level for the development of the frame for the two-roll rubber mill is represented in the Fig. 3.

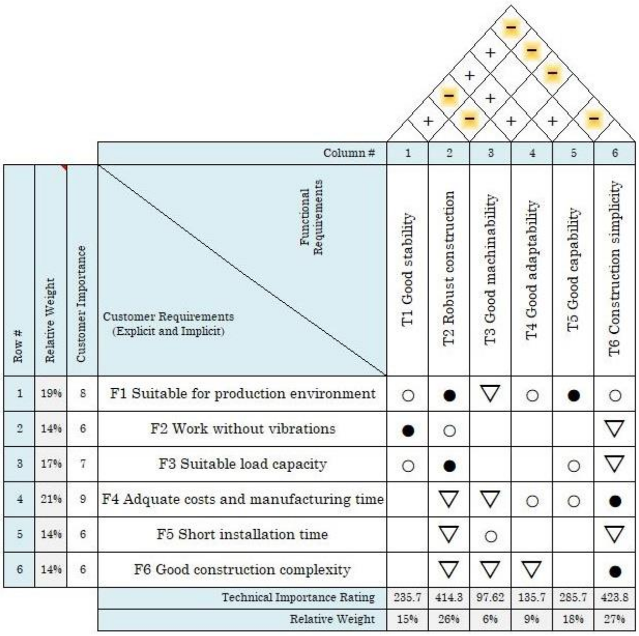

Fig. 3. Level 1 QFD.

B. Level 2 QFD

By advancing from the lower to a higher level the “hows” from the previous level becomes the “whats” of the current level.

This phase is used to evaluate technical characteristics and systems which are newly defined. There, the importance and the impact of meeting the product design requirements and key design parameters are defined regarding the assemblies, systems, sub-systems, and components.

The second QFD level for the development of the frame for the two-roll rubber mill is represented in the Fig. 4.

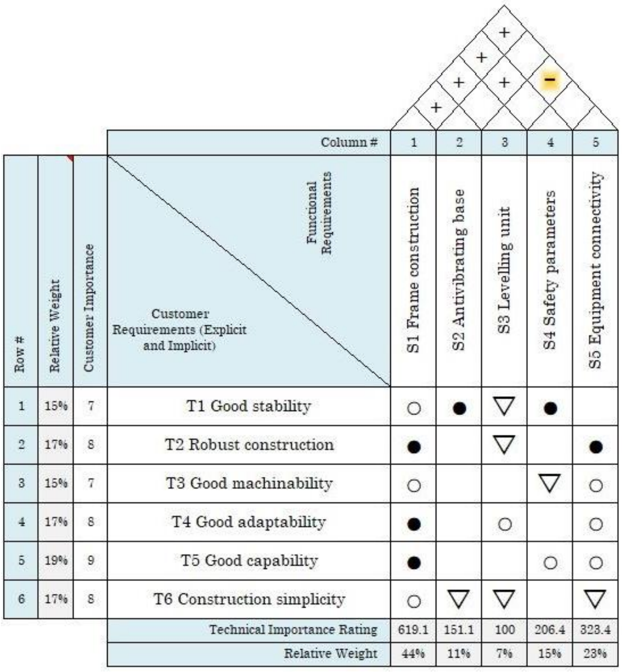

Fig. 4. Level 2 QFD.

C. Level 3 QFD

The level 3 QFD examines which of the processes or process steps have any correlation to meeting the component or part specifications. There, the “whats” are technical specifications and the “hows” are the manufacturing processes. The matrix highlights which of the processes have the biggest impact on meeting the product’s specifications.

The third QFD level for the development of the frame for the two-roll rubber mill is represented the Fig. 5.

D. Level 4 QFD

This level is not always considered. It lists all critical processes in the “what’s” section and determines the “hows” for assuring the quality of the manufactured product. For this paper’s purposes, the 4th level of QFD will not be considered.

After the QFD methodology deployment, the virtual development of the frame could be applied. The proposed model of this analysis is welded steel construction [Fig. 6.]. This construction is mounted on the levelling mechanisms beneath which there are vibration absorbers.

Row #	Relative Weight	Customer Importance	Customer Requirements (Explicit and Implicit) / Functional Requirements	P1 Welded steel construction frame	P2 Vibration apsorbers	P3 Levelling mechanism	P4 Service platforms and fences	P5 Singular construction
			Column #	1	2	3	4	5
1	17%	8	S1 Frame construction	●		▽	○	●
2	19%	9	S2 Antivibrating base	○	●	▽	▽	○
3	15%	7	S3 Levelling unit		○	●	▽	
4	19%	9	S4 Safety parameters		●		●	
5	17%	8	S5 Equipment connectivity	○			▽	●
			Technical Importance Rating	261.7	389.4	170.2	274.5	363.8
			Relative Weight	18%	27%	12%	19%	25%

Fig. 5. Level 2 QFD.

The re-examination of the QFD method shows that all the initial requirements provided by the end users are satisfied.

The welded steel frame construction does not represent complex construction, and because of that, it does not have a long installation time.

The construction is mounted on the levelling mechanisms and vibration absorbers and not concretized beneath the floor level.

Given the fact, there are vibration absorbers the second request is also respected.

Robust steel construction can carry the full weight of the machine and its equipment.

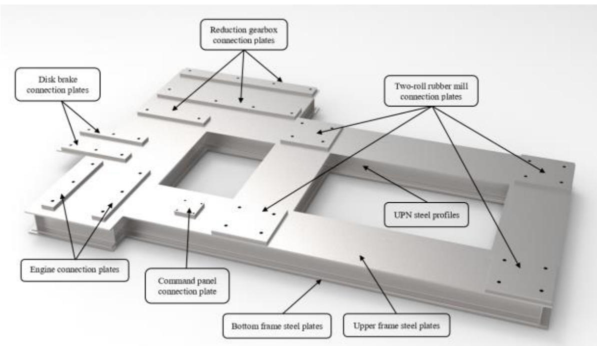

Fig. 6. The final design of the two-roll rubber mill frame.

III. CONCLUSIONS

QFD methodology effectively communicates customer or end-user needs and requirements to enhance the operations such as design, quality, manufacturing, production, marketing, and sales.

The process which leads to the final design of the two-roll mill frame started by the end user focus to define the requirements that the frame must comply with. Then the QFD levels define the systems and sub-systems which were evaluated, and on which results the final design is presented.

The decision-making process at every level could be subjected to change and improved by MCDM (Multi-Criteria Decision-Making) methodology which has a more objective approach and a couple of frame design solutions could be FEA (Finite Element Analysis) analyzed to confirm the desired results.

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REFERENCES

[1] Z. Bi, “Chapter 8 – Applications – Solid Mechanics Problems”, *Finite Element Analysis Application – A Systematic and Practical Approach*, pp. 281-339, 2018.
[2] J. Yan, W. Luo, J. Wang, W. Yang, Y. Ma, D. Jiang and J. Jia, “Application of the quality function deployment method in the mechanical structure design of subsea power devices”, *Ocean Engineering*, vol. 247, 2022.
[3] Y. Shen, J. Zhou, A. A. Pantelous, Y. Liu and Z. Zhang, “A voice of the customer real-time strategy: An integrated quality function deployment approach”, *Computer&Industrial Engineering*, vol. 169, 2022.
[4] Quality-One International, Discover the Valued, https://quality-one.com, last accessed on 10.10.2022.
[5] E. L. Melgoza, L. Sereno, A. Rosell, and J. Ciurana, “An integrated parameterized tool for designing a customized tracheal stent”, *Computer Aided Design*, vol. 44, pp. 1173-1181, 2012.
[6] J. J. Yan, “Design of a special vehicle based on QFD”, *School of Mechanical&Automotive Engineering*, South China University of Technology, 2016.
[7] S. K. Kaya, and N. Erginel, “Futuristic airport: A sustainable airport design by integrating hesitant fuzzy SWARA and hesitant fuzzy sustainable quality function deployment”, *Journal of Cleaner Production*, vol. 275, 2020.
[8] H. R. Fazali, and Q. Peng, “Generation and evaluation of product concepts by integrating extended axiomatic design, quality function deployment and design structure matrix”, *Advanced Engineering Informatics*, vol. 54, 2022.
[9] Q. Yang, Z. S. Chen, C. Y. P. Chan, W. Pedrycz, L. Martinez, and M. J. Skibniewski, “Large-scale group decision-making for prioritizing engineering characteristics in quality function deployment under comparative linguistic environment”, *Applied Soft Computin*, vol. 127, 2022.
[10] X. Zhang, J. Su, and E. Herrera-Viedma, ”A decision support model for estimating participation-oriented designs of crowdsourcing platforms based on quality function deployment”, *Expert System with Applications*, vol. 202, 2022.
[11] L. D. Miles, “Techniques of value analysis and engineering”, McGraw Hill, New York, 1962.