QFD-Driven Rotational Moulding Optimization and Quality Control to Reduce Defects and Increase Efficiency in LLDPE Fuel Tank Production

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Abstract

The present study utilized a House of Quality (HoQ) methodology to develop a fuel tank manufactured using the rotational moulding process, employing LLDPE material. In order to methodically tackle this issue, three House of Quality (HoQ) charts were created, outlining consumer demands, functional necessities, and production control parameters. The results of the study emphasize the critical significance of identifying and adapting essential customer requirements, functional prerequisites, and production control parameters throughout the design and production phases of rotational moulded fuel tanks. The inquiry findings emphasized that the major customer requirements were on the provision of a fuel tank that possesses qualities of strength, longevity, reliability, and cost-effectiveness, while also ensuring a prolonged lifespan and an aesthetically pleasing external appearance. Furthermore, it was determined that the material qualities and tank design are the most crucial functional requirements. In addition, the precise regulation of oven temperature and the automation of the moulding process have been identified as crucial control criteria in guaranteeing the quality and functionality of the fuel tanks.

Keywords: House of Quality, Technical Specifications, Production Requirements, Correlation Matrix, Prioritization Matrix, Quality Control, Process Automation

1. Introduction:

Choosing the proper materials for a particular product is a crucial step in the engineering design procedure. In the modern manufacturing environment, where a vast array of technical materials and production methods are readily available, the decision-making process has become significantly more complex. Depending on the intended application of the product, product designers must take into account a wide range of factors, including mechanical, electrical, and physical characteristics, as well as corrosion resistance and financial considerations. Due to the intricate interplay of various selection criteria, the task of material selection becomes even more complicated and time-consuming [1]. The potential consequences of an improper material selection, which may lead to increased production costs or premature product failure in the field of application, thereby influencing the reputation of the manufacturing enterprise, are a significant factor in the complexity. Therefore, designers must have a thorough comprehension of material properties, cost dynamics, design concepts, and their interdependencies. Recognizing that improper

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material selection can result in these negative outcomes, it is incumbent upon product designers to carefully evaluate and select the material that best meets the product's specific performance requirements [2]. In doing so, they must establish a delicate balance between various factors to ensure that the chosen material is optimally suited for the given product.

"Quality function deployment" (abbreviated as "QFD") is "an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production" (i.e., advertising tactics, organizing, product engineering and design, testing evaluation, production process development, production, sales). Quality function deployment (QFD) is an acronym for "quality function deployment." (Sullivan, 1986b). after its inception in Japan in the late 1960s and early 1970s, Quality Function Deployment (QFD) has been the subject of an extensive body of written work, particularly after its fast growth to the United States in the 1980s and, later, to numerous industries across many countries.

Because of this, the comparison is no longer focused on the manufacturing technology in and of itself; rather, it is dependent on how well the company handles the technology in relation to its competitors. Managing the technology is only one component of an efficient production management strategy [3]. The process of selecting an appropriate material for a particular product involves taking into account a great number of influencing factors. These factors include things like the desired characteristics, operating surroundings, manufacturing procedure, expenses, accessibility to supplying sources, and so on. Because of this, the process of selecting a suitable material is referred to as a multi-criteria decision-making (MCDM) problem. Therefore, in order to make the process of selecting the appropriate materials easier, a technique that is both methodical and effective is essential.

This study will demonstrate to what extent Quality Function Deployment (QFD) can be applied in the selection of material and process parameters for rotational moulding process by defining customers requirements and converting them into detailed engineering specifications. Through the Voice of Customer (VOC) the customers requirements are translated into measurable design targets and drive them from assembly to production level.

2. Literature Review:

The fundamental distinction between QFD and other traditional quality management methods is that with QFD, quality is not extracted from a product through inspection, but rather, it is incorporated into the product from the beginning [4]. It is emphasized that the primary function of QFD is to gather the VoC in order to offer the beginning point for determining of technical specifications in a methodical manner during and during the development of an innovative service or product [5, 6]. This is the aspect that is emphasized the most. QFD is a strong tool because it provides a framework that can be used to deconstruct the goals and optimize the compromises throughout each stage of the development process, from the design phase through the production phase [7]. When it is properly implemented, quality function deployment (QFD) provides a great means of communication between departments, which in turn helps to establish a consistent quality emphasis throughout all functions and operations in a company [8].

The conceptual design selection technique that was proposed by Fatchurrohman et al. [9] accommodated both concurrent engineering and MCDM tactics, and it combined concurrent system, quality function deployment (QFD), and AHP. The information gained through the questionnaire's customer needs' survey, technical explanations, and relative relevance was utilized to design HOQ for the instrument panel of the car that was developed by Hamidullah et al. [10]. Hamidullah et al. [10] also developed display products for automobiles. The outcomes of the HOQ serve as the foundation for the concept-creation process. Mayyas et al. [11] combined QFD and AHP in order to provide designers with assistance in the process of selecting materials for vehicular structures, most importantly vehicle body-in-white panels. The AHP technique would make distinctions between the competing possibilities where the associated objectives would need to be accomplished, however the QFD approach, which is customer centered, would start by gathering the customer demands and attempt to incorporate those needs into the product. This would be done in contrast to the way that the AHP method would work.

In order to improve the market demand for the tempered glass that the SAT Glass manufacturer was producing, Ahmed [12] utilized the QFD methodology as a means of incorporating the wants and needs of customers into the production process. Provided extra functional elements such as afterwards service and product modification methods in order to boost their market share. These features will draw new clients to the company and improve retention of customers. Khabbaz et al. [13] addressed the problem of picking the most suitable material for a sailor boat shaft in the shape of a hollow cylinder by using a modified fuzzy logic method. Rosnani, et al. [14] found a solution to the problem that the company was having with not being able to meet the needs of its customers because of the amount of time that was required to construct spring bed goods. As a result, an investigation is required to cut down on the amount of time needed for assembly and to lower the prices per unit.

Utilizing the concept of graphs and a matrix technique, Rao [15] was able to tackle the challenge of selecting the appropriate materials for a product that was intended to function in an atmosphere with a high temperature and a high concentration of oxygen. Edy Rustam Aji [16] QFD method by taking into consideration the most important goals of the technical features of educational table lamp items from the effective QFD analysis acquired 10 technical opinions, specifically, the results of the design and production of study table lamps with length 23 cm, width 20 cm, and height 12. 5 cm. The lamp can be lit without the use of any power, and it has the ability to turn itself off in stages depending on how it is being used. Findik and Turan [17] came up with a solution to the challenge of selecting the appropriate material for the load wagon walls by employing a strategy based on logic. On the basis of these five criteria—density, particular stiffness, corrosion resistance, wear resistance, and material cost—seven different alternatives to the material under consideration were assessed. Bukhari It is anticipated that Imron [18], by utilizing the QFD in order to fulfill the requirements that customers have for a product, will develop a charger that makes use of solar energy as a charger.

This study will demonstrate to what extent Quality Function Deployment (QFD) can be applied in the selection of material and process parameters for rotational moulding process by defining customers requirements and converting them into detailed engineering specifications. Through the Voice of Customer (VOC) the customers requirements are translated into measurable design targets and drive them from assembly to production level.

3. QFD approach

3.1 QFD at a glance

According to Akao, the definition of Quality Function Deployment (QFD) is as follows: "QFD is a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demands into design targets and major quality assurance points to be used throughout the production phase." [18]. The aim of quality function deployment, or QFD, is to transform even the most intuitive quality requirements into objective standards that are quantifiable and measurable, which can subsequently be applied to the process of designing and producing a product. It is an additional strategy that may be used to figure out how and where priorities should be assigned in the process of product development. The first of the three primary steps in the process of putting QFD into action is to prioritize both explicit and implicit client wants and needs. (b) To articulate these requirements in terms of their corresponding technical qualities and specifications. (c) To develop and provide a high-quality product or service by directing everyone's attention on ensuring the happiness of the client. In addition to the 'house of quality' matrix, QFD makes use of a variety of other management and planning tools for the majority of its applications.

Some examples of these tools include affinity diagrams, relations diagrams, hierarchy trees, matrices and tables, process decision program charts, analytical hierarchy process charts, and blueprinting.

3.2 House of Quality

The initial step in quality function deployment (QFD) is to gather and examine VOC data. After collecting this data, the next step is to determine the Critical Functional Requirements, also known as CFRs. These are the primary indicators of performance that a product has to be able to achieve in order meet the needs of the client. A few examples of critical failure requirements (CFRs) are tensile strength, yield strength, impact strength, creep characteristics, part quality, part cost, testing time, and testing cost. After the CFRs have been located, the HOQ can then be constructed with their assistance. The client's demands are located on the left-hand side of the document. At the point where every client need and each technical specification meet, a numeric value is entered. This value conveys the relative significance of the customer-to-requirement relationship. In most cases, the CFRs will be included in the HOQ's listing of technical requirements. After then, the significance of fulfilling each CFR is analyzed in comparison to the significance of meeting the other technical specifications, such as the cost and the manufacturability of the product. As a consequence of this process, a ranked list of technical specifications has been produced, which accurately reflects the significance of complying with each CFR. The important steps involved in Quality Function Deployment are as shown in Fig. 1.

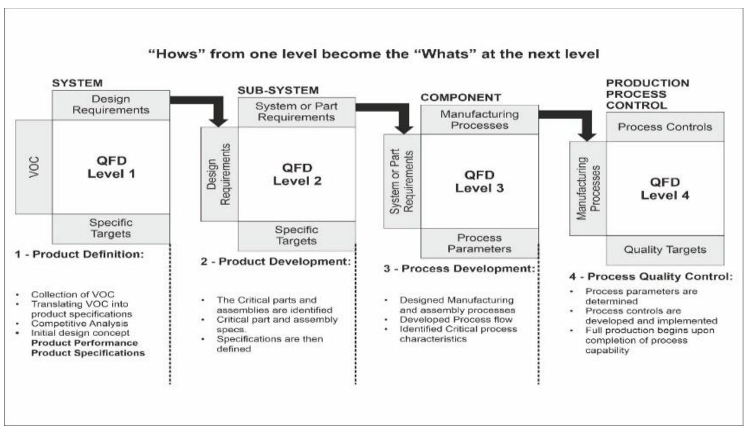

Fig. 1 Steps in Quality function deployment

3.2.1 House of Quality 1

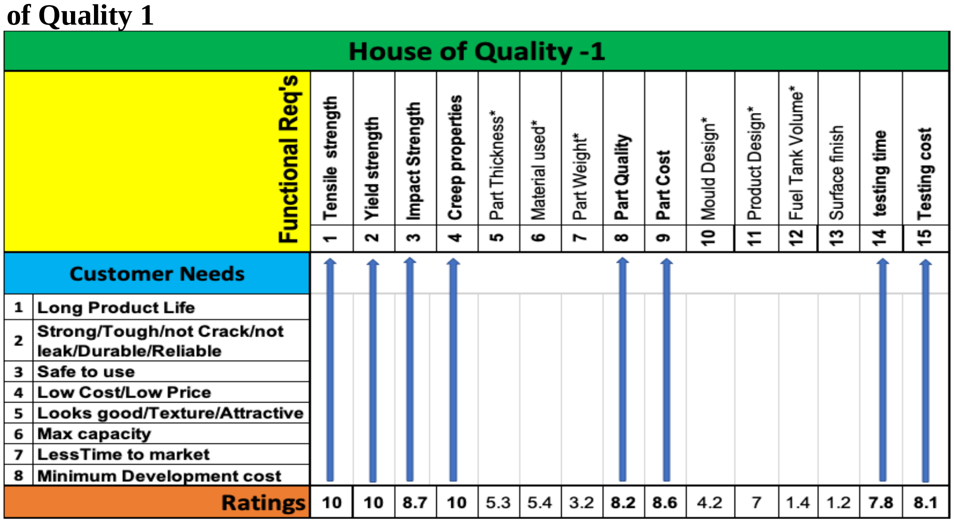

Fig.2 House of quality 1

During the process of developing a product, one of the tools that is utilized is called the House of Quality, and its purpose is to guarantee that the final product will fulfill the requirements of the client. It takes the demands of the customer and maps them to the technical characteristics of the product in the form of a matrix. The chart is divided into two primary sections: on the left side, a list of client wants is provided, and on the right side, a list of technical specifications is provided.

Consumer Needs: The first thing to do is figure out what the requirements of the customer are. In this particular scenario, the requirements of the customer include a long product life, strength/toughness/no crack/not leaking/durability/reliability, safe to use, low cost/low price, looks good/texture/attractive, maximum capacity, less time to market, and least development cost.

Standards of a Technical Nature: On the right-hand side of the chart is a list that contains the technical requirements. These are the particular requirements that need to be fulfilled in order to fulfill the demands of the consumer. Fig. 2 presents the product's technical parameters together with the ratings that correlate to each one.

Matrix of Correlation: The correlation matrix is employed in order to determine the nature of the connection that exists between the customer needs and the functional requirements. Every client requirement is compared with every functional requirement, and then a correlation value is assigned to reflect the degree to which the two are related to one another.

> For instance, if the lifespan of a product is extremely dependant on the material that is utilized, then a high correlation value will be provided to the link that is present between "long product life" and "material use." In most cases, the correlation values are ranked on a scale ranging from one to ten, with ten signifying a very strong connection and one signifying a very weak correlation. These are depicted in the Fig. 2 located above.

Prioritizing Matrix: The purpose of the prioritizing matrix is to rank the relevance of the various functional needs in terms of how important they are to satisfying the customer requirements. Multiplying the correlation values with the ratings that have been provided to each functional need results in the creation of the prioritizing matrix.

> For instance, if the value of the correlation between "long product life" and "material use" is 10, and the rating that has been allocated to "material use" is 5.4, then the prioritizing value for "material use" will be 10 times 5.4, which would equal 54.

Final HoQ Chart: The prioritizing values for each functional need are organized into the "roof" of the house in order to construct the final HoQ chart as shown in Fig. 3, which is then used to create the final HoQ report. Both the client requirements and the functional specifications are outlined in this chart. The customer requirements can be found on the left side, while the functional requirements can be found across the top. The graphic illustrates how each functional need contributes to achieving the requirements outlined by the customer. To emphasize the most essential functional needs that need to be resolved in order to meet the client requirements, the prioritizing values are employed.

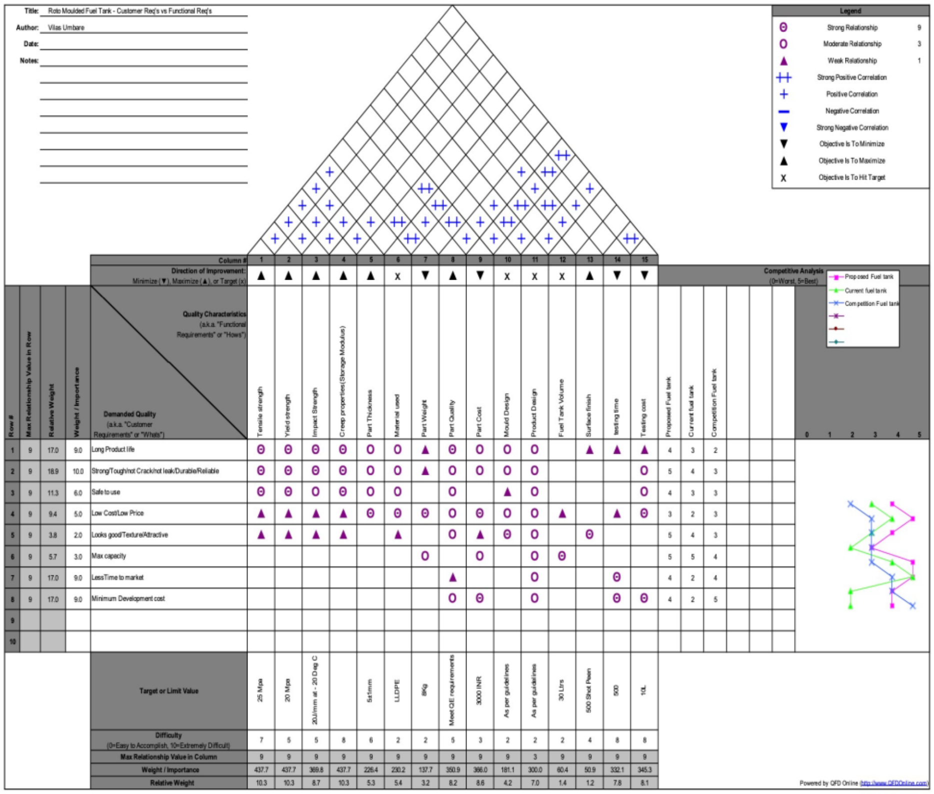

Fig.3 Detailed House of Quality chart 1

3.2.2 House of Quality 2

The first house of quality chart and the second house of quality chart both have distinctive formats, although both are based on the same functional needs. The important production needs are listed horizontally across the top of the chart, while the functional demands are presented vertical on the left side of the chart. Oven Residence Time, Peak Internal Air Temperature (PIAT), Under Heating, Over Heating, Creep Testing, Fatigue Test, Impact Test, and Bulge Test/Burst Test are the essential production criteria.

This chart's objective is to demonstrate how each of the important manufacturing demands contributes to the successful completion of the functional demands. In order to determine the nature of the connection that exists between the functional needs and the important production requirements, a correlation matrix is employed. A coefficient of correlation is assigned to each set of functional requirements and critical production requirements after they have been compared with one another, and this value indicates the degree to which the two sets of requirements are related to one another. The house of quality chart 2 for the given set of parameters are as shown in Fig. 4.

For instance, if the "impact strength" functional need is extremely dependent on the "impact test" key production requirement, then a high correlation value will be ascribed to the relationship between "impact strength" and "impact test." In most cases, the correlation values are ranked on a scale ranging from one to ten, with ten signifying a very strong connection and one signifying a very weak correlation.

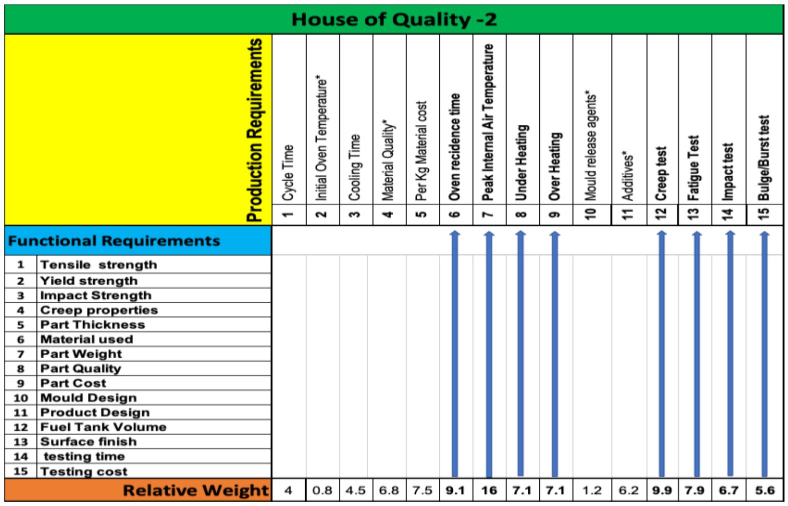

Fig.4 House of Quality 2

The prioritizing matrix is used to rank the crucial production requirements in order of importance, taking into account how important they are in terms of achieving the functional requirements. Multiplying the coefficients of correlation with the ratings that have been provided to each important production need results in the creation of the prioritizing matrix.

For instance, if the value of the correlation between "impact strength" and "impact test" is 8.7 and the rating that was given to "impact test" was 6.7, then the prioritizing value for "impact test" would be 8.7 multiplied by the rating, which would equal 58.29.

As shown in Fig. 5, the prioritizing values for each essential production requirement are organized into the "roof" of the home in order to construct the final HoQ chart. The important production needs are presented horizontally across the top of the chart, while the functional specifications are presented vertically down the left side of the chart. The graphic illustrates how each important production need helps achieve the functional requirements of the project. To emphasize the most significant and critical production needs that need to be resolved in order to achieve the functional requirements, the prioritizing values are employed.

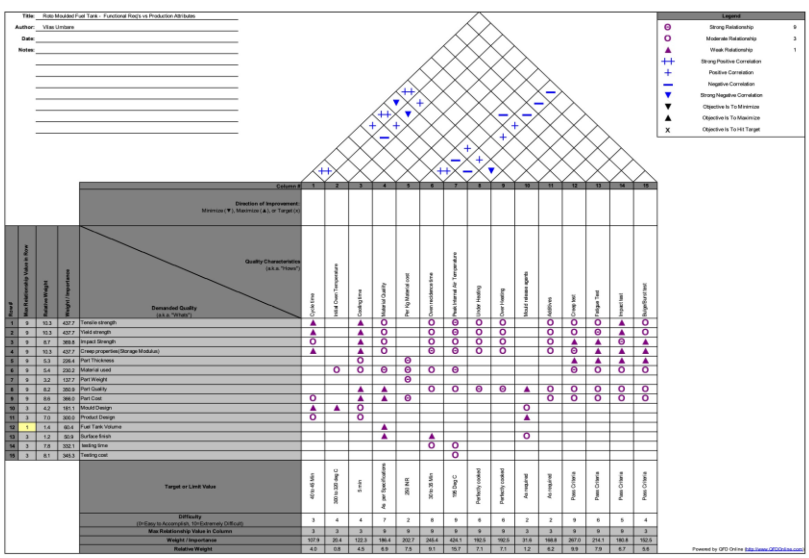

Fig. 5 Detailed house of quality chart 2

3.3.3 House of Quality 3

The specifications for manufacturing and the quality control of manufacturing are the basis for the final house of the quality chart. The criteria for production are given in a vertical format on the left side of the chart, whereas the needs for production control are listed in a horizontal format across the top. Oven Temperature Control, Moulding Process Automation, Roto Logger for process Temperature and Pressure monitoring, Polyethylene powder Grade, Mould Material, Mould Thickness, and other production control parameters are illustrated in Fig. 6.

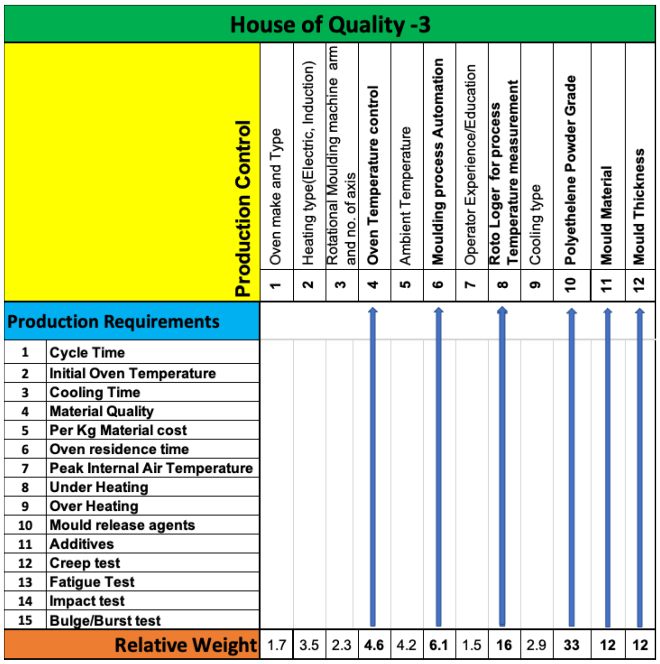

Fig. 6 House of Quality 3

Matrix of Correlation: The correlation matrix is employed in order to determine the nature of the connection that exists between the production control parameters and the production requirements. A correlation value is given to each production control parameter and production requirement after they have been compared with one another, and this value is meant to reflect how strongly the two factors are related to one another. In most cases, the correlation values are ranked on a scale ranging from one to ten, with ten signifying a very strong connection and one signifying a very weak correlation.

Prioritizing Matrix: The purpose of the prioritizing matrix is to rank the production control parameters according to how important they are in terms of fulfilling the production criteria. Multiplying the correlation values with the ratings that have been provided to each production need results in the creation of the prioritizing matrix. For instance, if the value of the correlation between "oven temperature control" and "oven residence time" is 8, and the rating that has been assigned to "oven residence time" is 10, then the prioritizing value for "oven temperature control" would be 8 multiplied by 10, which would be 80.

Final House of Quality Chart: The prioritizing values for each production control parameter are organized onto the "roof" of the house in order to construct the final House of Quality chart, which is depicted in Fig. 7. The chart is organized with the production requirements listed on the left side, and the production control parameters listed across the top. The graphic illustrates how each control parameter for production contributes to satisfying the production requirements. The prioritizing values are utilized to bring attention to the production control parameters that are of the utmost significance and must be addressed in order to satisfy the production requirements.

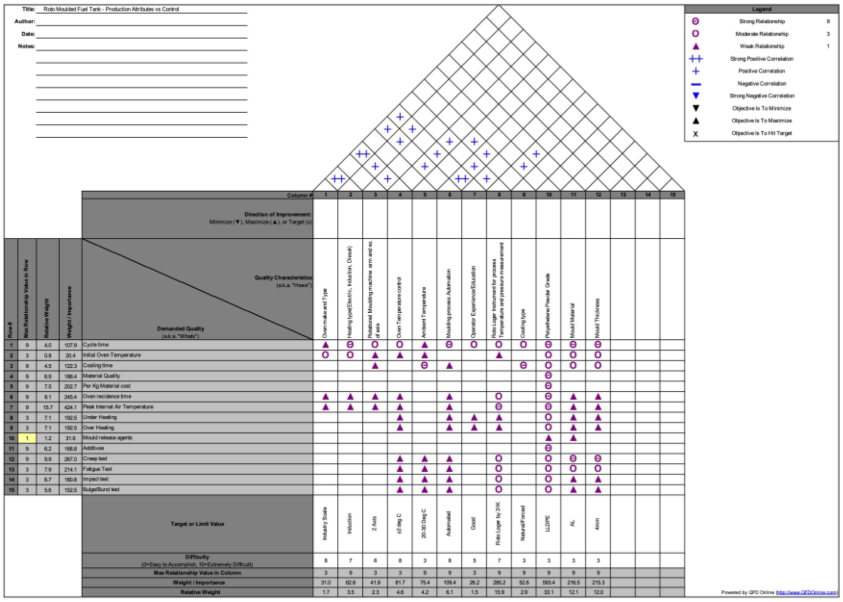

Fig. 7 Detailed house of Quailty chart 3

4. Conclusion

The study's analysis of the three House of Quality charts reveals crucial insights for the successful rotational moulding production of petrol containers. Several essential factors must be thoroughly considered. Priorities addressing the functional requirements, particularly tensile strength, yield strength, and impact strength, as a matter of first importance. These parameters are closely aligned with consumer expectations regarding product durability, longevity, and dependability. Consequently, the manufacturing process should prioritize the fulfilment of these functional requirements. To satisfy consumer demands for cost-effectiveness, it is essential to prioritize production requirements such as automation of the moulding process and mould thickness. These production parameters have a direct impact on cost considerations and should be optimized in accordance with customer budgetary expectations.

Thirdly, it is essential to pay close attention to production control parameters, such as oven temperature control, mould material, and polyethylene powder grade, in order to produce gasoline tanks of consistent, high quality. These factors have a substantial impact on diverse production requirements and contribute to meeting functional requirements. Effective rotational moulding of petrol tanks necessitates a holistic approach that recognizes the interdependence of production requirements, functional prerequisites, and consumer desires. This strategy applies not only locally but globally as well. To simultaneously improve the quality, durability, and dependability of petrol containers while reducing production costs, manufacturers must prioritize criteria with the highest correlation coefficients. By doing so, they can streamline their efforts and make significant advances towards meeting customer and market demands.

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Competing Interests -

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