# *REDESIGN N* METAL CASTING TOOLS USING ANTHROPOMETRY AND QFD

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**Abstract**

The case in the metal casting process is when the metal is melted and then poured into a liquid metal reservoir and then poured into a pouring tool and then poured into a mold. In the process of pouring into the mold is still using manual equipment, namely by using wood which ends have a container such as a bucket ( *bucket)*) made of a mixture of white cement, brick fire sand and clay and the metal liquid pouring tool has a length of 1.5 cm, a weight of 5 kg with a diameter of 15 cm and a height of a container for liquid metal 20 cm does not include the load. If the pouring device filling with liquid metal, then the weight reaches ± 20 kg, with a weight of ± 20 kg the worker must pour the liquid continuously into the mold and at least each worker must go back and forth 6 times pouring metal liquid into a mold in a single combustion process.

Based on the *nordic body map* questionnaire data as many as 8 workers felt pain in the shoulder and arm because the burden was born, resulting in workers often feel pain in the muscles of the arms and back. Because the wooden handle used to pour metal liquid is too slippery (exposed to sweat), so there is a need for improvement in activities.

From the results of the above observations, it is necessary to design ideas for new work facilities. It expects to affect the improvements related to the position of the hand in the process of pouring liquid into the mold. Then the design idea needs to be done in the form of a casting tool that has been modified and can be used according to user needs and can be said to be ergonomic, safe, and comfortable. The method used in designing castings is *quality function deployment* and anthropometric techniques.

**Keyword:** Design, Anthropometry, Quality Function Deployment, Metal Casting

## INTRODUCTION

According to Situmorang (2003: 1), Occupational Safety and Health can describes philosophically and scientifically. Philosophically that is a thought and effort to guarantee the integrity and perfection of both the physical and spiritual workforce, the work, and culture towards a just and prosperous society. Whereas scientifically, occupational safety, and health is a science and its application to prevent the possibility of accidents and occupational diseases. According to Dainur (1993: 75), Occupational Safety and Health is safety related to the relationship of labor with work equipment, materials and processing processes, workplace foundations, and ways of doing the work. According to Suma'mur (2001: 104), work safety is a series of efforts to create a safe and peaceful work atmosphere for employees who work in the company concerned.

The concept of ergonomics has existed since primitive societies by making stone hand tools for cutting. They are then developed when the industrial revolution in the 19th century by FW Tailor, Frank, and Lilian Gilbreth, who began to introduce the word *ergonomits*. They recommend that when working, do not use the muscles in both hands together, symmetrical position, and move slowly and reduce excessive movement so that the use of energy is more optimal and efficient. Since 1949, ergonomics has become an interdisciplinary science to solve health problems in working people. In 1950, ergonomics was adopted into a discipline that was used in various aspects (Santoso, 2004).

*Manual Material Handling* (MMH) or *manual handling*, according to Suhardi (2008), is a moving activity carried out by one or more workers by carrying out lifting, lowering, pushing, pulling, transporting, and moving goods. During this time, understanding *the manual handling* was limited to the activities of lifting ( *lifting* ) and lowering ( *lowering* ) the notice aspect of the power vertical. In fact, *manual handling* activities are not limited to the activities mentioned above. There are still activities (pushing) *pushing* and (pulling) *pulling*.

Definitively anthropometry can be stated as a study relating to the measurement of the shape, size (height, width) weight, and others that are different from one another (Sutalaksana, 1996). According to Nurmianto (1991), anthropometry is a collection of numerical data related to the physical characteristics of the human body, size, shape, and strength and the application of these data for handling design problems. Anthropometry more widely used as an ergonomic consideration in the process of product planning and work systems that require human interaction.

Anthropometric data that successfully obtained will be applied more broadly include in terms of work area design ( *work station* ), work equipment design such as machinery, equipment, *tools,* design of consumptive products such as clothing, chairs, tables, and environmental design physical. Based on this, it can be concluded that the anthropometric data will determine the exact shape, size, and dimensions related to the product to be designed in accordance with the humans who will operate or use the product (Nurmianto, 2003).

The development of a product is not a temporary event and runs quickly, but requires steps that are systematic, measurable, and have clear boundaries. The product development process is defined as the sequence of steps or activities in which a company tries to arrange, design, and commercialize a product, providing added value to get closer to meeting the needs of consumers.

The reason a company must develop its products is:

1. Stay competitive in the market.
2. Increase satisfaction with the fulfillment of consumer needs for related products.
3. Increase profits and business growth.
4. It can prevent a significant drop in product competition on the market.
5. Improve product quality.
6. Improve production processes to reduce production costs and other resources to be more productive.

## METHOD

According to Permana, (2013). QFD is a method used to determine consumer desires by collecting *customer voices* and *customer needs,* which are then classified and sorted by priority. The main benefits of using the QFD method for companies, according to Ginting (2010) are as follows:

1. Reducing production costs
2. Increase revenue
3. Reduction of production time

The steps that must be taken in the application of the QFD method described by Ginting (2010) are:

1. Identification consumer wishes into product attributes
2. The use of questionnaire media to obtain the level of *importance* ( *importance rating* ) of customers for product attributes
3. *Competitive evaluation* ( *competitive evaluation* )
4. Create a resistance matrix between product attributes and characteristics
5. Identify the relationship between technical characteristics and product attributes
6. Identify relevant interactions between technical characteristics
7. Determine the description of the target to be achieved for technical characteristics.

*House of Quality* (HoQ) is a matrix or diagram that resembles a home that is used to determine the relationship between customers and the desires of a company or the capabilities of a product or company. HoQ is part of QFD, by utilizing matrix planning and linking what customers want, companies can plan how to produce products that meet customer desires. *House* in HoQ is a correlation matrix, which is the roof that is the product feature that the customer wants.

The main and core parts are used to evaluate competitors. This planning matrix is based on the belief that products must be designed to reflect the desires or tastes of consumers. This matrix is also used to increase cross-functional integration in organizations, especially between marketing, engineering, and manufacturing. This the explanation of the method below in image 1:

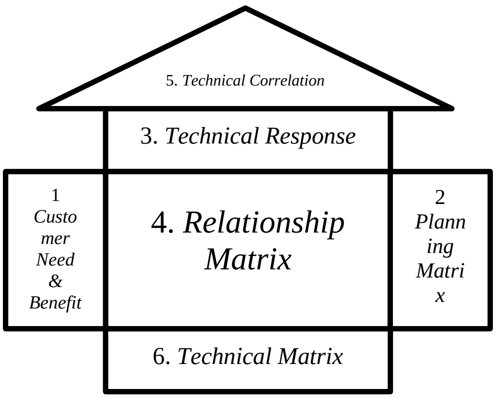


Image 1 House of Quality

1. Body Dimension Data on the Castings Process

Data processing was carried out, among others, namely the determination of percentile values on each dimension of the operator's radius, the length between the palms of the operator, and making QFD with the *House of Quality* (HoQ) tool. Data on the dimensions of the operator's body in the process of pouring metal liquid into the mold that is taken include data on the dimensions of the operator's radius and width between the palms and hand length that will be used to design the size of the handle segments based on the width of each finger by selecting *percentile* appropriate. This data processing process uses SPSS *software* with the aim of simplifying calculations.

Measurement of operator radius in the process of pouring metal liquid into the mold produced data like the table above. It is known that the width dimension between the smallest palms is 22 cm, and the biggest is 27 cm, then the width of the index finger with the smallest dimension is 1.5 cm, and the largest is 1.8 cm. The width of the smallest radius is 1.5 cm, and the largest is 1.7 cm, and the last little finger has the smallest dimension of 1.2 cm, and the largest is 1.5 cm, and the largest arm length is 72 cm, and the smallest is 63 cm. Based on the results of the data collection, it can be processed using *SPSS software* to get the *percentile* value of each dimension of the operator's body that has been measured.

2. *Percentile* Data Processing of Operator Body Dimensions

Data results of measurements before then processed using *SPSS software*, which is then used as the basis of determining the size of the tool after obtained measuring *percentile*, were appropriate. Below is Table 4.5 can be seen as the results of the processing of data *percentile* dimensions of the body of the operator in parts of pouring liquid metal into the mold.

From the results of the processing of data *percentile* in the above using the *software*, *SPSS* can be known to each value *percentile*. In the table explained, there are five dimensions of the radius of the womanly object of measurement that is finger forefinger, finger middle, finger sweet, finger little finger, and arm length. The result if the data show the results of that finger index *percentile* $5^{th}$ = 1.5 cm, $50^{th}$ = 1.6 cm, and $95^{th}$ = 1.8 cm, for mothers finger the middle of the $5^{th}$ = 1.4 cm, $50^{th}$ = 1.55 cm, and $95^{th}$ = 1.8 cm, further finger sweet from the $5^{th}$ = 1.5 cm, $50^{th}$ = 1.6 cm, and 95 $^{th}$= 1.7 cm, and the last finger pinkie $5^{th}$ = 1.2 cm, $50^{th}$ = 1.3 cm, and $95^{th}$ = 1.5 cm. From the results, if the data on the captured design grip tool castings liquid metal on each finger, that is the *percentile* $5^{0th}$. The reason for the determination these is that all operators have the size of a finger vary ranging from the smallest until the size of the site can operate the tool such.

3. Degree of Interests of Attributes According to Operators

The degree of importance of this attribute is used to identify the needs of the user of the tool or product in order to state the position of the importance level of the attribute. Giving weighting starts from number 5, which states attribute is very important to the figure 1which states attribute is not important. Weighting is calculated for each attribute of Interest Calculated from the average value of each attribute.

4. Average Value of Importance

The average value of this level of importance is a description of the questionnaire distributed that, according to respondents, the importance of each attribute compared to the others. To determine the average level of importance is to the formula below:

$$x = \frac{\sum_{i=1}^{n} DKi}{n} \quad ...(1)$$

Information:
DKi = number of importance to i,
n = number of respondents

Based on the formula above, the average value of the importance of each attribute and as an example calculation for the Ease when held (palm) attribute are as follows:

$$x = \frac{38}{8} = 4{,}75 \quad ...(2)$$

The sum of the importance level 38 is the sum of the total import value of the Ease attribute when held (palm).

5. Data Processing Questionnaire Target Value

The target value is a goal that will be achieved by the company after attention to the ability that made by the company. The target value is considered to be important because it will become a reference of how big a goal which is to be achieved. The weighting value of the target is determined by Work Metal.

6. Data Processing *Sales Point* Questionnaire

*Salespoint* informs about the ability to sell products or services t hat are based on how much the needs of customers can be met.

7. Benchmarking Process

Process *benchmarking* isthe stage doing an evaluation of a product or service that is there to compare it with a product or service that is owned by a competitor. In this study, it means comparing the metal liquid pouring equipment that is being used.

Performance *benchmarking* is required to know the position and the ability of the tool l metal compared with the ability of the tool else.

8. Scale *Up Factor* ( *Improvement Ratio* )

*Scale-up factor* or often called the *improvement ratio,* which is the ratio between the value of the target to be achieved ( *goal* ) of the company with the company's current formants. To scale-up the *factor,* the following formula is used:

$$\text{Scale Up Factor} = \frac{Goal}{Our\ Product\ Performance} \quad ...(3)$$

For example, calculations can be taken for the attributes of convenience when held ( palms ) are as follows:

5: 3 = 1.67

Value 5 is the value of the target value on the attribute of ease when held (no need for tools) on the results of the target value questionnaire. Value 3 is the value of the *evaluation score* for the convenience attribute when held ( palms ) of the *benchmarking* proposal.

*Raw Weight.* The overall value of the data included in the matrix of planning at every consumer need for further improvements in the development process of products, especially tools pours the liquid metal. The formula for calculating the *raw weight* value is as follows:

***Raw weight = importance to customer x scale-up factor x sales point*** *...(4)*

Examples of calculations for attributes made from Ease when held (palm) are as follows:

*Raw weight* = 4 x 1.67 x 1.2 = 8,016

Value 4 is a value level importance by consumers on attri butes is made of a material base natural, and the value of 1.67 is the value of *the scale-up factor* for the attribute is made of a material basis of a natural, whereas for the value of 1.2 is the value of *sales points* for attributes make of a material base natural.

9. Normalize Line Weight

Weight normalized value line is the value of *raw weight* made in scale between 0-1 or made with the form of a percentage. The formula for finding the normalized value for this line weight is as follows:

$$\text{Normalized raw weight} = \frac{raw\ weight}{\sum raw\ weight} \quad ...(5)$$

Examples of calculations for normalizing line weights on the convenience attribute when held (palm) are as follows:

$$Normalized\ raw\ weight = \frac{8.016}{135.786}$$
$$= 0{,}059$$

For the value of 8016 is the value of *raw weight* on attributes made from basic natural ingredients, while the value of 135,786 is the total value of *raw weight.*

10. Determine Technical Characteristics ( *Technical Characteristic* )

To determine the characteristics of this technique, necessary The characteristics of this technique are essential because they are used for making level 1 HoQ.

11. Interaction Between User Needs and Technical Characteristics

This interaction is intended to find out how strong the relationship of each technical characteristic is in meeting the desires of the operator with the metal liquid pouring tool. This relationship can be in the form of strong, moderate, or weak relationships. The interaction of consumer needs with technical characteristics is expressed in terms of numbers and symbols. The interaction value is multiplied by the weight normalization value. The types of relationships are as follows:

□ = strong relationship level with a weight value of 9

○ = medium relationship with weight value 3

△ = level of a weak relationship with the weight value

12. Relationship Between Technical Characteristics

The relationship between the characteristics of the technique is used to determine the effect of the characteristics of the technique. The symbols used in the relationship between technical characteristics are as follows:

1. A strong positive relationship symbolized by (++) that is if the two attributes have a mutually supportive relationship in its implementation and the relationship is powerful.
2. Positive relationship (+), if the two attributes are mutually supportive in their implementation, and the relationship is moderate.
3. There is no relationship between the two technical characteristic attributes, or the two attributes do not have a characteristic technical relationship.

13. HoQ Matrix

In this HoQ matrix explains what the operator needs for metal pouring castings and how to meet those needs. This matrix is the data processing stage that was carried out previously until the interaction between the characteristics of the technique. In the HoQ matrix level 1, which has been compiled not yet fully applicable to the company, because in the HoQ matrix level 1, the component characteristics are not yet known for the development of metal break casting tools.

## RESULTS AND DISCUSSION

The size of the diameter of the metal liquid pouring tool is based on the results of length measurements between the palms carried out on the operator in the pouring metal liquid into the mold, from these results obtained *percentile* values of $5^{th}$ = 22 cm, $50^{th}$ = 23.50 cm, and $95^{th}$ = 27.00 cm, obtained from the results of data processing using *SPSS 16 software for windows*. Based on the analysis, the diameter size that will be used is the $50^{th}$ *percentile*, with a diameter of 23.50 cm.

The reason why the determination of the diameter using a *percentile* $50^{th}$ so operator using a cast metal liquid that if they have a width between palms small it will not be too difficult and too greatness if use tool castings fluids such metals, while operators have a size between palms are wide enough then they will be more comfortable because the size is not too small and also does not exceed (large) . Here it is a design drawing tool that measures the liquid metal castings where diameters have appropriate with the measurement results.

**1. Analysis of Results Computation At *House Of Quality***

The results of calculations in the previous chapter are then compiled into the *house of quality* matrix wherein the *house of quality is* known what the operator needs for metal liquid pouring equipment and how to meet those needs (determination of *technical requirements* ), interactions between user needs and technical characteristics, relationships between the technical characteristics used to determine the effect of the *technical requirements*, and the end of this calculation is to find out the order of priority *technical requirements* for metal liquid pouring equipment.

Based on the analysis conducted from the results of calculations between the *technical requirements* and *customer requirements, it is* known that the first priority sequence is the design of the form in accordance with the percentage 22.26 %, the second is the addition of places having 20.12%, the third is the anthropometric data with a percentage of 18.73%, then the fourth is the addition anti-sliding hand lock with a percentage of 15.95%, then the fifth type of iron castings with a percentage of 15.87%, and the last diameter of 15 cm with a capacity of 15 kg has the same percentage of 7.06%. This means that these results indicate what criteria for pouring liquid metal should be prioritized the most

2. **Old Metal Liquid Pour Tool Design**
Metal casting pouring
tool before benchmarking is a design that is currently still used to pour the metal liquid into the mold. Below is a picture of the casting tool used:

Image 2 Tools Before

The tool used in the form of bamboo with a length of 1.5 m with a diameter of 15 cm and a volume of 20 cm. And the hand position is too very advanced (approaching the *bucket* ).

3. **Metal Liquid Pour Tool Design Results Design**

Metal casting pouring tool after *benchmarking* is a proposal design after the calculation of the questionnaire so that the operator's desired attributes and the operator's body dimension measurements are known. The following is the proposed design of a metal casting tool.

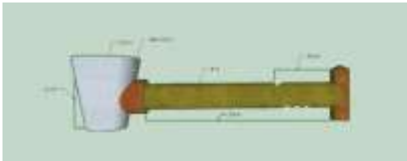

Image 3 Metal Side Casting Castings

## CONCLUSION

1. Based on the results of the questionnaire, there are 8 attributes that the operator desires in the process of pouring liquid metal into the mold, including ease of handling ( palm of the hand ), stability in production (the tool is not slippery, so it is easy to move ), the robustness of the construction of the tool, the material used safe, lighter tools than before, the suitability of the tool with the average worker, there is a hole for the place of the hand in the pouring tool, there are additional materials in the handgrip, so it is not slippery (rubber). This metal liquid pouring tool is the result of design using the *quality function deployment* method by adjusting the operator's desires to the pouring metal liquid into the mold and anthropometric techniques designed based on the dimensions of the operator's body. Then there are developments in several design shapes such as the handle is made

of the material. The insulating material is coated with wood and designed. According to the shape of the radius of the operator in the pouring metal liquid into the mold. Furthermore, at the back end of the handrail there is a T-shaped handle that serves as a barrier for the process of pouring metal liquid into the mold and as a lock so that the casting tool is easily moved.

2. Based on the calculation of *technical requirements* in the *house of quality* the first priority order is the design of the shape in accordance with the percentage of 22.26%, the second is the addition of a handheld with a percentage of 20.12%, the third is anthropometric data with a percentage of 18.73%, the fourth is the addition of locking or anti-sliding with the percentage is 18.21%, then the fifth is the addition of a lock or anti-shear with a percentage of 7.16%, and the last is a diameter of 24 cm with a capacity of 4 kg has 15.95%, the fifth is the type of iron casting material with percentage e as much as 15.87%, then the last namely a diameter of 15 cm with a capacity of 20 kg with a percentage of 7.06%. This means that these results indicate what criteria for pouring metal liquids should be prioritized the most.
3. Based on the results of anthropometric data processing carried out to the operator in the pouring of metal liquid into the mold, then the handrails on the handle of the castings use *percentile* with the size of each on the index finger that is *percentile* $50^{th}$ = 1.6 cm, middle finger $50^{th}$ *percentile* = 1.55 cm, $50^{th}$ *percentile* ring finger = 1.6 cm, and $50^{th}$ *percentile* ring finger = 1.3 cm, while the diameter of the *bucket* is still with the size of the old pouring tool, which is 15 cm in diameter with a volume of 20 cm.

**REFERENCES**

[1]Dainur. 1993 . Ilmu Kesehatan Masyarakat. Widya Medika . Jakarta.

[2]Ginting,R . 2010. *P*erancangan Produk. Graha Science. Yogyakarta.

[3]Nurmianto, E. 1991. *Pendalaman Ergonomi* . Grafindo. Surabaya.

[4]Nurmianto, E 2003. *Ergonomi* Konsep Dasar Dan Aplikasinya. Guna Widya. Surabaya.

[5]Permana, IP. 2013. Analisis Kualitas Pelayanan Dengan Menggunakan Metode Quality Function Deployment (Qfd) Pada Restoran Warung Misbar Di Bandung. Fakultas Ekonomi Universitas Islam Bandung. Bandung.

[6]Santoso, G. 2004. *Ergonomics, Human, Equipment, and Environment.* Literature Achievement. Jakarta.

[7]Situmorang, C . 2003. Mengikuti Prosedur Menjaja Keselamatan Dan Kesehatan Kerja. Depdiknas. Direkorat Pendidikan Menengah Kejuruan. Jakarta.

[8]Suhardi Bambang. 2008. *Perancangan Sistem Kerja Dan Ergonomi* Industri. Direktorat Pembinaan Sekolah Menengah Kejuruan. Jakarta.

[9]Suma'mur. 1989. *Corporate Higene and Occupational Health*. Pt. Agung Mountain Shop. Jakarta.

[10]Suma'mur. 2001. *Work Safety and Accident Prevention*. Cv Haji Masagung. Jakarta.

[11]Sutalaksana. 1996. *Material Ergonomics* , Anthropometry.