Efficient Development Of Applied Technology Innovation Through Design For Manufacture And Assembly

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Abstract.
The conventional product design process and the design results from the designer need to be evaluated and optimized in terms of the manufacturing process and assembly process by the manufacturing department. In this process, it is sometimes necessary to make design changes that must be consulted with the designer to make it more efficient. This can be seen from three aspects of the product, namely quality, cost, and production time. A very applicable method to meet the needs of these 3 aspects of the product is the design method for manufacturing. One solution that can be applied is the design for manufacture and assembly (DFMA) method. DFMA is a method to evaluate the design of a product so that it can be easily assembled and manufactured. This paper will explain the application of the DFMA method to several applied technology product designs. As a case example for the application of the DFMA method, the development of a post-stroke bicycle frame from the initial design to the final design step, namely prototyping, is observed. A prototype was also evaluated with the help of the DFMA method and the evaluation results showed that the application of the DFM method provided significant improvements, where the total components of the bicycle frame at the beginning of the design were 53 pieces, in the final design could be reduced to 29 pieces (45%), with design efficiency increasing by 1.04%.

Keywords : *Efficient, Design, Innovation, Manufacture and DFMA.*

I. INTRODUCTION

In this modern and sophisticated era, the development of the manufacturing industry, both service industries and those that produce products, with a variety of shapes and models to attract customers. The development of technology is very rapid in the industrial world, causing rapid changes in the business world. To be able to keep up with the flow of competition, companies are required to continue to innovate and create quality products. This causes the manufacturing industry to be forced to produce products that can meet customer needs with very high expectations of product functionality, but at a lower cost. So, designers must be able to design products with maximum functionality, so that they can meet customer needs.The manufacturing industry is an industry that processes raw materials into semi-finished or finished products. To produce a product requires several processes including product design, selection of materials and manufacturing processes, sourcing of raw materials and components, and design and manufacture of auxiliary tools. n. In the last decade, a major feature of the innovation process has been the elimination or combination of unnecessary or non-value-added product components to simplify the process. This product innovation has a great impact in terms of productivity, cost, and quality [1].A tough challenge that Indonesia must face at this time is the AEC (ASEAN Economic Community), where products from outside will freely enter our country with competitive prices and quality. This causes various manufactured products from other countries to enter the Indonesian market swiftly. Low-priced electronic products are eating into the market share of Indonesian products. The same applies to other products, such as iron, steel, textiles, and other industrial goods.

Another problem that occurs in the manufacturing sector is the procurement of raw materials. So far, some manufacturing industries in Indonesia are still unable to procure their raw materials, so they import such as the procurement of plastic raw materials and upstream petrochemical products, raw materials for the steel industry, etc. In addition to these problems, problems often arise in the early design phase in the manufacturing industry, namely the strong separation between design, manufacturing, and quality control. This means that after the design (drawings are completed), the next responsibility lies with manufacturing,

product testing is carried out in the field of quality control, and there is no direct communication between these fields [2].According to UNINDO (World Industrial Development Organization) research, the growth of the manufacturing industry in recent years globally is only a few percent of the normal limit, for example in 20212 only 0.2 percent. This means that there is a problem with the manufacturing industry, but the opposite condition occurs in the manufacturing industry in Indonesia, which is growing rapidly. In 2012, the growth of the manufacturing industry sector, especially the non-oil and gas sector, cumulatively reached 6.5%. Even in the second quarter of 2012, growth reached 7.27%, but in reality, most manufacturing industries in Indonesia do not design independently, as they are highly dependent on job orders.

Not many get the job in the form of production drawings, only a component (product) that is damaged or does not fulfill its function, which is then made as a spare component/replacement component (spare parts). Another reality in the Indonesian manufacturing industry community, especially small - medium industries is that design is not included in the calculation of production costs [2].Based on this summary, it is understood that a product design must reach the end phase, which is to become a final product. In addition, to be able to compete in the market, creative and innovative steps need to be taken to catch up with technology from developed countries (industries). From this description, there needs to be a method that can be utilized to reduce external pressure. This certainly has a positive impact on the demands of the national manufacturing industry to be more creative in producing goods, so that demands for quality, relatively low process costs, and short manufacturing times can be met. One applicable method that is widely utilized in the design for manufacturing (DFM) method. The method can be used to evaluate which designs can be realized in manufacturing and what are the stages of manufacturing (manufacturing process), because manufacturing already involves the assembly process in it, then the cost estimation of manufacturing and assembly can be done.

II. METHODS

In connection with this research, the author uses a type of qualitative research. I use a qualitative approach because it is appropriate in understanding the problems experienced by humans in the social order by creating a complex and comprehensive picture. In this study the authors also tried to explain the Efficiency of Design For Manufacture and Assembly towards the development of Applied Technology Innovation. Data collection is done using literature study. The sampling technique used is purposive sampling which is reviewed by collecting information to become the basis of the theory and design used by researchers. Qualitative data analysis uses interactive mode 1, explaining that the analysis technique consists of data collection, data condensation, data presentation and conclusion drawing [3].

III. RESULT AND DISCUSSIONS

Talking about efficiency is a word that shows the success of a person or organization for the efforts carried out which is measured in terms of the number of resources used to achieve the results of the activities carried out. In other words, efficiency is a comparison between sources and results. If it is related to system theory, then efficiency is a comparison between input and output. Inputs that are processed through a certain process will provide outputs according to certain measures and criteria. Production efficiency in an institution/company in incurring costs in the form of producing a product is one form of the company's production mechanism to produce the highest output from an investment.In connection with the efficiency of a product which then becomes an innovation, it is then expected to realize the goals or objectives of a company. The definition of the notion of product innovation Hurley and Hult define innovation as a company mechanism that tries to adapt to a dynamic environment so that companies are required to create new ideas, new ideas, and can provide innovative products so that customer needs can be met [4]. The definition of the notion of product innovation according to Myers and Marquis states that product innovation is a combination of various processes that influence each other [5].

Therefore, innovation is not a new concept, a new invention concept, or a new market development, but innovation is a description of all these processes. Kotabe argues that the higher the level of product innovation made by a company, the higher the company's performance through increased purchasing

decisions [6]. In global competition, companies must be able to modify their products to provide added value to the products they produce, and must be able to meet consumer needs and tastes.Production costs make a considerable contribution to the total costs that must be incurred to produce a product. When it comes to components and materials, high-end products contain relatively more components and sub-assemblies. Since the design will decide on the materials, machinery used, and labor required, the number of components to be assembled makes up 80% of the manufacturing cost depending on the initial design stage.Due to the high cost of component assembly, the trend of manufacturing companies' assembly percentage, and the importance of the early design stage of a product, the concept of Design for Manufacture and Assembly (DFMA) was born.

DFMA is a combination of two terms in manufacture, namely design for manufacture (DFM) with design for assembly (DFA) [7]. DFA is a part of DFM that aims to minimize the cost of assembling a product [8]. According to Ulrich, Design for assembly (DFA) is a design paradigm widely adopted by engineers in which several methods (such as analysis, estimation, planning, and simulation) are used to calculate all the possibilities that may occur during the assembly process, and then adjust the shape of the components to assemble them quickly and easily to minimize assembly on time which in turn can reduce product costs [9].Meanwhile, design for manufacture (DFM) can be said to be a limitation related to the initial phase of designing a product. At this stage, engineers can select materials, and technologies, and estimate possible costs incurred. Then, the existing product design plan is analyzed and reviewed so that errors can be corrected as soon as possible based on the feedback received. The basic concept of DFMA or design for manufacture and assembly is to analyze and solve problems arising in the manufacturing process and component assembly process in the early design phase so that the risk of product damage that may occur in the final product can be anticipated as soon as possible. Thus production time and costs can be minimized as much as possible [10].

According to some researchers and manufacturing experts, there are 10 guidelines of DFM, in which DFA has been integrated, and used to develop a more economical product with quality that still meets the requirements. These guidelines are [11] [12] [113]:

- Reduce the number of parts (components);
- Develop modular design;
- Use standardized components;
- Design parts to be multi-functional;
- Design components that are multi-purpose;
- Design components that are easy to manufacture;
- Avoid multiple connections/binders;
- Minimize different assembly directions;
- Maximize requirement fulfillment;
- Reduce handling.

Based on the guidelines of the DFM method, it is necessary to take systematic steps to implement these guidelines, starting from the initial stage to the final stage. In some cases, not all steps of the guidelines may be performed, depending on the type of product and its assembly. The following is a complete description of the sequence of steps of the design evaluation guidelines such as:

a. Part count reduction is an alternative and the best opportunity to reduce costs. A reduction in the number of parts has the effect of reducing purchasing, storage, handling, processing time, equipment, assembly difficulty, and inspection;

b. The use of modular design will simplify and reduce manufacturing activities, such as inspection, testing, assembly, purchasing, maintenance, re-design, and service;

c. Standardized components can reduce prices (costs). Because its availability can be guaranteed, production lead times can be reduced. In addition, standard components will make purchasing easier, both in terms of quality and cost, and time;

d. The component can be made by selecting the largest tolerance and/or surface roughness value, but the function of the component is still fulfilled;

e. By utilizing uniform joints, the assembly process is also similar, thus reducing assembly time and costs;

f. By avoiding different joining or assembly directions, assembly time will be reduced. In addition, reduce the variation of connection dimensions, so that the tools used do not vary much;

g. In the assembly of some components it is necessary to design special signs so that the assembly is not wrong. For example, giving a champer at the end of the shaft will guide the shaft into its partner component, and;

h. To maintain accurate positioning, orientation, and installation, reduce assembly by hand. Use appropriate equipment.

i. Multiple functions can reduce the total number of components in the design, as is the case with no. an above;

j. Multi-use component design can illustrate that a component can be used (different functions) in different products;

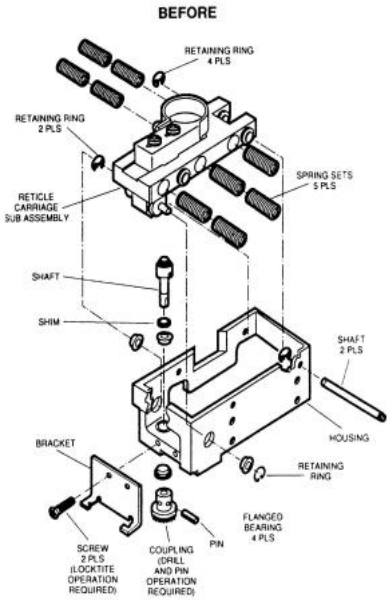
k. In addition to simple geometry, make an economical selection of materials and manufacturing processes. Applied technology is defined as a technology whose function is to bridge the research technologies that have been made by researchers so that they can be applied to everyday life. This means that applied technology is the estuary of research results into a useful product, which is an embodiment of research results in product manufacturing and development. Therefore, the goal of DFM is aligned with applied technology, both for low- and medium-technology products and high-technology products. This means that design for manufacturing and assembly is very influential on any type of product [14].

One of the DFMA methods that have been developed is the DFMA method by Boothroyd and Dewhurst. According to this method, the DFA analysis is performed by knowing the product re-assembly process. The time required for each assembly process can be known from Boothroyd's manual assembly table [8]. Besides estimating the duration required to assemble the product, this method assesses the product assembly process using an index, namely:

$$\text{Indeks DFA} = \frac{N_{min} \times t_a}{t_{ma}}$$

N_{min} = Minimum number of essential components
t_a = Ideal component assembly duration
t_{ma} = Product assembly duration

Several principles must be met in designing to improve an assembly process, including simplifying and reducing the number of components, standardizing and using components with uniform materials, designing for ease of assembly by utilizing simple patterns of movement and minimizing the number of assembly axes, designing for combined and efficient fasteners and designing modular products for assembly [14]. Based on these principles, a design improvement can be made using the Design for Manufacturing and Assembly (DFMA) method through the development, combination, or elimination of unnecessary components or components that do not contain added value [13].The following is an example of the application of DFM to the development of a product in the defense industry, namely night surveillance equipment as shown in Figure 1. Figure 1 shows the initial design of manual surveillance equipment, in which the number of different components is 24, the number of assembly operations is 58, and the DFM method has not been applied.



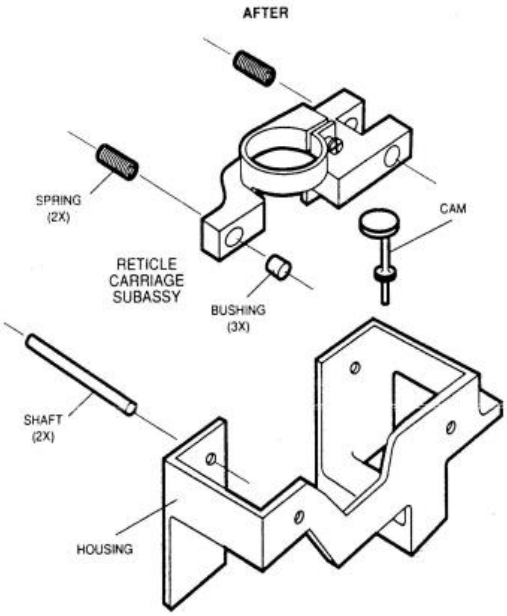


Fig 1. Original Design [13] **Fig 2.** Re-Design [13]

From the two figures, it can be seen that the manufacturing design has included the assembly design in the application. This means that DFA is indirectly included in DFM. Therefore, the design application has followed DFM. The results of the comparison of the two designs are shown in Table 1.

Table 1. Comparison of original and new equipment designs surveillance equipment [13]

Initial Parameters	Original Design	Re-Design	Improvements (%)
Assembly Time (Hour)	2,15	0,33	84,7
Number of different parts	24	8	66,7
Total Part	12	12	74,5
Operation amount	13	13	77,6
Production Time (Hour)	12,36	23,62	71,1
Weight (lb)	0,48	0,26	45,8

An example of DFM-DFA application to the development of a post-stroke bicycle is given below, as shown in Figure 3. The post-stroke bicycle has two front wheels and one rear wheel. The bicycle can be moved either by foot or hand. It is intended, if the patient has a hand stroke, then the person concerned can move the bicycle with the foot. Meanwhile, if the patient has a leg stroke, the bicycle is driven by hand.

Fig 3. Post-stroke bicycle design [2] **Fig 4.** Post-stroke bicycle Re-design [2]

In the final design, several standard components are used such as folds, chains, sprockets, gears, brakes, saddles, backrests, springs, fastening bolts nuts, and washers, all of which are available on the market. From the evaluation of the frame, it can be seen that the number of frame sub-parts in the initial design is 11, with 53 components. While in the final design it became 10 sub-parts, with 29 components. The comparison results of the two bicycle frame designs are shown in Table 2.

Table 2. Comparison results of the initial and final designs of the post-stroke bicycle [2]:

Parameter desain	Original Design	Re-Design	Improvments (%)
Number of different parts	11	10	9
Total part	53	29	45,2
Assembly Time (Hour)	11,01	7,56	31,36
Produstion Time (Hour)	4,25	3,03	28,57
Weight (kg)	30	14,3	52,33
Efficient Design (%)	24,10	25,14	1,04

From these two examples, it is clear that design orientation should be directed toward the final design of a product to prototyping, so that the performance of a product can be known before it is produced. If there are errors or shortcomings, improvements can be made immediately [16] [17]. This is very much in line with the analysis of applied technology, which before being realized into a final product, it is necessary to make a prototype and test its function and performance. This means that the design process of a product requires a long process, starting from inventorying ideas, to realizing and using the product and evaluating it. If something does not fit or is wrong (does not fulfill), then improvements or design changes are made. As a result, design costs increase. Therefore, many manufacturing industries carry out product development using the reverse method (reverse engineering), namely by evaluating errors (deficiencies) of a component (system) of a product, then repairing it, so that it becomes a higher quality and economical product, but in its development, it is still targeted to utilize the DFM method.To find out how far the influence of DFM on product development is necessary to evaluate product design from the aspect of assembly - DFA. Because with DFA, it can be seen how much the design efficiency increases for assembly if the design of a product is changed. Thus the overall production cost and time can be estimated at the beginning of the design phase.

IV. CONCLUSION

From the results captured by the researcher, it can be concluded that the comfort when using the tool is very influential, from the results of several current innovations, interestingly, there are additional components and other additions so that it is comfortable to use. From the results of the DFMA analysis, the product changes very far because there are additional additions to other components so that more items can be placed without reducing comfort when used. Here the author also learns that the DFMA stages can provide practical and economical guidance in product development, especially in the context of applied technology development and innovation, thus helping designers in product development. In the case of post-stroke bicycle development, the application of the DFM method provides significant design improvements, where the total components at the beginning of the design are 53 pieces, can be reduced to 29 pieces (45%), and design efficiency increases by 1.04%. For a more thorough product evaluation, it is recommended to utilize the DFA method in the design and development of a product.

REFERENCES

[1] L, Luchetta, G, Zavatta, R. (2013). Assessing the cost and benefits of regulation.

[2] Batan, I Made Londen, (2015): The Role of Design For Manufacture in Applied Technology Development and Innovation. SNTT-JTM Polinema.

[3] Creswell, John W. (2014). Research Design, Qualitatives, Quantitative, and Mixed Methods Approcahes (Fourth Edition). United State of America: Sage Publications.

[4] Heryanti, Y. (2020). Product Innovation of Prodior Women's Sandals in Ciponyo Village, Mangkubumi Village, Mangkubumi District, Tasikmalaya City. ***Jak Publik (Journal of Public Administration & Policy),*** 1 (1).

[5] Suyaman, D. J., Andriani, E. F., Alifiana, S., Juniar, D., & Azzahra, F. (2021). The Effect of Product Innovation and Sales Promotion on Buying Interest in Suzuki Satria F150 Motorbikes (Survey on the Suzuki Satria F150 Indonesia Community). ***Jesya (Journal of Sharia Economics and Economics),*** 4 (1), 472-587

[6] Shaleh, R. (2017). The Effect of Product Innovation, Lifestyle, Price, on Purchasing Decisions for Stalker Pomade Hair Oil (Case Study on Stalker Pomade Hair Oil Buyers at UN PGRI Kediri). ***Simki Economic Journal, 1 (01).***

[7] Yuan, Z., Sun, C., & Wang, Y. (2018). Design for Manufacture and Assembly-oriented parametric design of prefabricated buildings. Automation in Construction, 88, 13-22

[8] Geoffrey Boothroyd, Winston Knight, Peter Dewhurst, Product design for manufacture and assembly, Marcel Dekker, New York, 2001
[9] Ulrich, K. T. & Steven, D. (2002): Product Design and Development, McGraw- Hill, Inc.
[10] Butt, J., & Jedi, S. (2020). Redesign of an In-Market Conveyor System for Manufacturing Cost Reduction and Design Efficiency Using DFMA Methodology. Designs, 4 (1), 6
[11] El-Tamimi, Abdulaziz, M.: Design for Manufacturing, Industrial Engineering Departement, College of Engineering, King Saud University
[12] Chang, Tien-Chien, Wysk, Richard A., & Wang, HsuPin (1998). Computer Aided Manufacturing, Second Edition, PP 596-598, Prentice Hall.
[13] Boothroyd, G. Dewhurst, P. (2002): Product Design for Manufacture and Assembly. Second Edition Revised and Expanded, Marcel Dekker, Inc.
[14] Stoll, H. W. (1996): Design for Manufacture – an overview in Handbook of Design for Manufacture. John Cobatt, Addison Wesley
[15] Magrab, Edward B. (2010). Integrated Product and Process Design and Development: The Product Realization Process. London : Taylor and Francis Group.
[16] Otto K. & Wood, K. (2001): Product Design Techniques in Reverse Engineering and Product Development, Prentice-Hall, Inc.
[17] Bralla, James G. (2003): Design for Manufacturability Handbook, Second Edition, McGraw-Hill book.