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# The Influence of Design for Manufacturing and Assembly on Production Efficiency and Product Quality; A Case Study of a 0.5 Inch Class 800LB Ball Valve

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**Abstract**

**Background:** The manufacturing industry faces increasing pressure to enhance production efficiency while maintaining high product quality standards. Design for Manufacturing and Assembly (DFMA) has emerged as a critical methodology for addressing these challenges by integrating manufacturing and assembly considerations into the early design phase
**Objective:** This study aims to analyze the effect of implementing the Design for Manufacturing and Assembly (DFMA) approach on production efficiency and product quality in the manufacturing of a 0.5-inch Class 800LB Ball Valve.
**Methods:** The research adopts a quantitative approach with a comparative analysis between the initial design and the optimized design developed based on DFMA principles. Data were collected through direct observation of manufacturing and assembly processes, in-depth interviews with production engineers, and examination of technical documentation regarding process time, cost structure, and component quantity.
**Results:** The results show that applying DFMA significantly reduces assembly time by approximately 20%, decreases the number of non-value-added components, and simplifies the assembly sequence, which collectively enhance overall production efficiency. Furthermore, the redesigned product demonstrates improved quality consistency, lower assembly defect rates, and better structural reliability during performance testing. Integrating DFMA with Value Analysis and Value Engineering (VAVE) also contributes to a more cost-effective and sustainable manufacturing system by aligning design simplicity with functional performance.
**Conclusion:** The findings emphasize that DFMA is not only a tool for operational improvement but also a strategic design framework that supports competitiveness, lean production, and continuous improvement in industrial environments. Hence, DFMA implementation is recommended as a standardized design practice to achieve efficiency, quality assurance, and innovation within the manufacturing sector.

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## INTRODUCTION

The Design for Manufacturing and Assembly (DFMA) concept is a systematic approach that integrates product design aspects with manufacturing and assembly process efficiency (Lu et al., 2021). By implementing DFMA in product manufacturing, companies can reduce production time, minimize the potential for assembly errors, reduce total production costs, and at the same time improve the quality and reliability of the resulting product (Zare et al., 2016).

In the context of the modern manufacturing industry, production efficiency is an important indicator in determining a company's competitiveness (Gerasimov et al., 2018). Global competition demands high-quality products, short production times, and low costs (Masroor & Asim, 2019). Therefore, integrating DFMA principles into the early product design stage is one of the main strategies in increasing productivity and profitability (Montazeri et al., 2024). This concept allows designers to focus not only on the function and aesthetics of the product, but also consider the ease of production and assembly processes from the early design stage.

One relevant application of DFMA is in the manufacturing industry that produces components in oil and gas pipelines that can withstand high-pressure fluids such as Ball Valves (Figure 1). This product functions to regulate, close, or control fluid flow in pressurized pipe systems, thus requiring high precision, material strength, and operational reliability (Rennels, 2022). The Ball Valve assembly process generally consists of many small components that interact with each other and must be installed in the correct sequence for optimal system performance (Yu et al., 2023). This complexity has the potential to increase assembly time, the risk of human error, and the possibility of product defects, especially if the design does not consider aspects of manufacturing and assembly efficiency from the start.

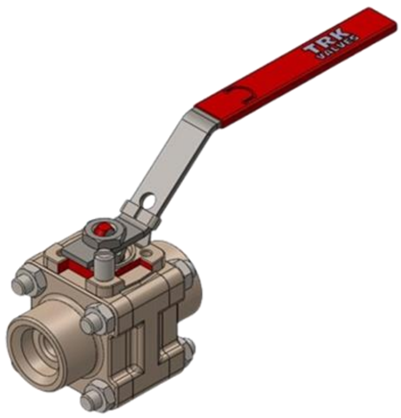


**Figure 1.** Floating Ball Valve Size 0.5inch class 800LB

The application of DFMA to ball valve products can provide a solution to these problems. Through the evaluation of the function of each component and analysis of the assembly sequence, product design can be simplified without sacrificing performance or operational safety. DFMA principles such as part count reduction, ease of handling, and assembly sequence optimization have been proven to increase assembly time efficiency and significantly lower production costs. Previous research by  stated that the integration of DFMA in product design can reduce the number of components by 30–50% and accelerate the assembly process by 20–60% depending on the complexity of the product design.

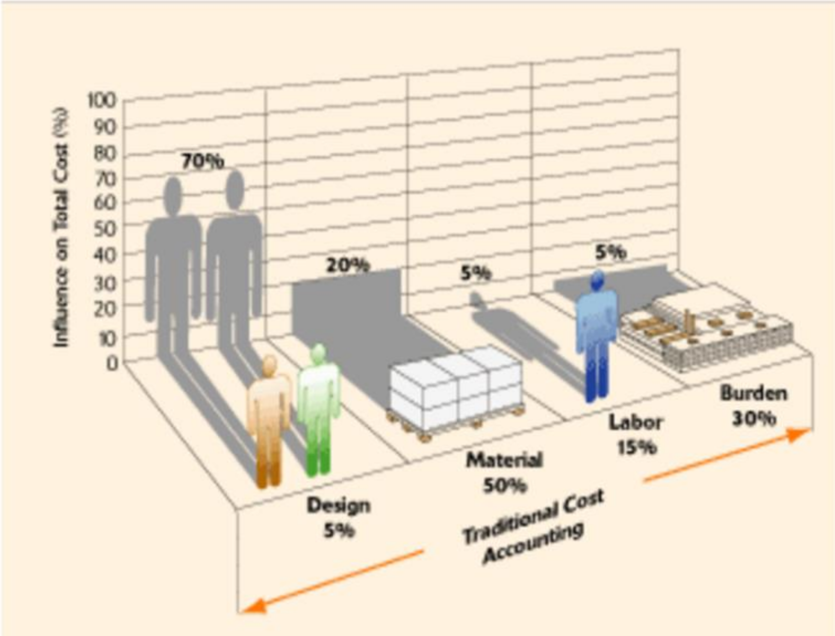



**Figure 2.** The effect of product development stages on production costs (Whitney. 1988)

This study aims to analyze the effect of DFMA implementation on production efficiency and product quality of 0.5 inch Class 800LB Ball Valve (Shukla, 2023). The analysis focuses on the comparison between the initial design and the optimized design using DFMA principles, by measuring changes in the number of components, assembly time, and the ratio of defective products (Gerasimov et al., 2018). It is hoped that the results of this study can be a practical reference for the manufacturing industry in applying the DFMA concept, as well as providing academic contributions to the development of manufacturing-based product design efficiency theory in Indonesia (Abrishami & Martín-Durán, 2021).

Recent comprehensive reviews have emphasized DFMA's transformative potential across industries, highlighting how systematic integration of design and manufacturing principles can fundamentally reshape operational efficiency and product quality (Montazeri et al., 2024). DFMA methods have evolved significantly over four decades, with mechanical product development showing particular benefits from systematic application of manufacturing and assembly optimization techniques during the design phase (Favi et al., 2022).

The integration of Industry 4.0 technologies with quality management has created new paradigms for manufacturing excellence, where data-driven decision-making and digital transformation enable unprecedented levels of process optimization and quality assurance (Alkhader et al., 2025). Digital lean production represents the convergence of traditional lean principles with emerging technologies, fundamentally reorganizing work processes to achieve higher productivity while maintaining focus on value creation and waste elimination (Dupuis & Massicotte, 2025).

Value engineering continues to evolve alongside technological advancement, with Industry 4.0 and emerging Industry 5.0 paradigms providing new frameworks for optimizing the function-to-cost ratio while addressing sustainability and digitalization challenges (Rijwani et al., 2025). These contemporary developments reinforce the strategic importance of integrating DFMA principles with value engineering methodologies to achieve comprehensive manufacturing optimization.

## METHOD

This study uses a descriptive quantitative approach with a comparative analysis method (Pahl et al., 2007) to examine the effect of the implementation of Design for Manufacturing and Assembly (DFMA) on production efficiency and product quality. This approach was chosen because it is able to provide a measurable understanding of changes in production process performance before and after the implementation of DFMA. The main focus of this study is to analyze changes in the number of components, assembly time, and product quality levels after the design process is optimized using DFMA principles.

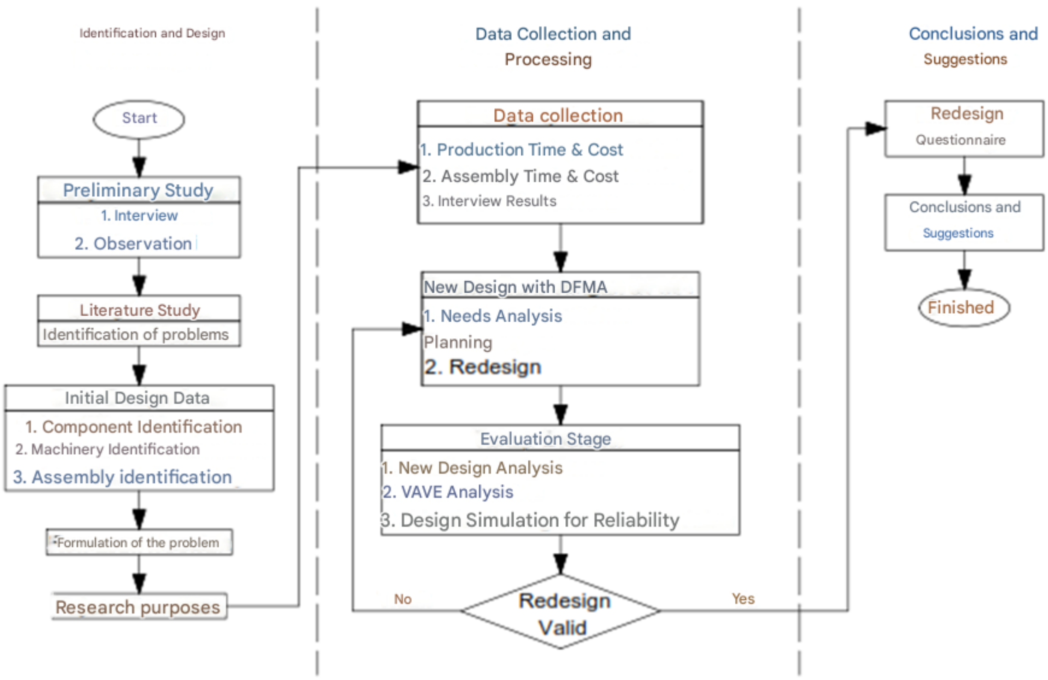



**Figure 3.** Flow Diagram

It is shown that the stages of this research include three main steps: (1) identification and design, (2) data collection and processing, (3) conclusions and suggestions. It began with a preliminary study that included interviews and direct observation on the 0.5 inch Class 800LB Ball Valve production line. The goal was to understand the ongoing manufacturing process and identify potential problems related to efficiency and quality. Next, a literature study was conducted to deepen the understanding of the DFMA concept and relevant analysis techniques. Based on the results of the preliminary study and literature, the main research problem was formulated, namely how the application of DFMA can improve production efficiency and product quality. Initial product design data was collected to identify the components, machining systems, and assembly processes used. This information became the basis for determining the focus of the redesign using the DFMA principle.

This stage involves collecting quantitative and qualitative data needed to conduct a comparative analysis. The collected data includes production time and costs, assembly time and costs, and the results of technical interviews. After the data is obtained, a redesign stage is carried out by applying the DFMA principle. The redesign includes analyzing design needs, eliminating non-essential components, and preparing a new design based on ease of manufacture and assembly. The results of the redesign are then evaluated through three main approaches: analysis of the new design by checking its functional suitability and then assembly. Value Analysis and Value Engineering (VAVE) analysis is used to assess functional value against costs and processes. Finally, design simulation for reliability using Solidworks software is used to verify the strength and performance of the DFMA design. If the evaluation results indicate that the design is not valid or inefficient, improvements are made until it reaches optimal conditions.

After the design was validated, a redesign questionnaire was developed for technicians and operators to obtain feedback on the implementation of DFMA for ease of assembly. The data obtained was then analyzed to draw conclusions regarding the effectiveness of DFMA on efficiency and quality. This stage also generated recommendations for further improvements and suggestions for implementing DFMA for other products with similar characteristics. Regarding the sampling scope, this study employed a purposive sampling approach focusing on the complete production cycle of the 0.5-inch Class 800LB Ball Valve manufactured at the case study facility.

The sample encompassed all major production batches conducted over a six-month observation period, including three production runs for the initial design and three production runs for the DFMA-optimized design, each consisting of 50 units. This sample size was determined based on statistical adequacy for comparative analysis while ensuring practical feasibility within the production schedule. To ensure data validity and reliability, a comprehensive data validation procedure was implemented through triangulation methods.

Production time data were cross-verified using time-and-motion studies recorded by independent observers and digital monitoring systems installed on the production line. Cost data were validated against official financial records and purchase orders verified by the accounting department. Quality metrics were measured through standardized inspection protocols following ISO 9001:2015 guidelines, with measurements conducted by certified quality control personnel using calibrated instruments. Furthermore, qualitative data from interviews and questionnaires were validated through inter-rater reliability checks and member checking with respondents to confirm accuracy of interpretation. All data collection instruments were pilot-tested prior to full-scale implementation to ensure consistency and precision.

Contemporary DFMA frameworks emphasize analytical rigor combined with empirical validation, ensuring that design decisions are both theoretically sound and practically implementable in real-world manufacturing environments (Laovisutthichai & Lu., 2025). This methodological approach aligns with the systematic evaluation procedures employed in this research, where theoretical DFMA principles are systematically applied and validated through actual production data.

Evaluation of production systems using integrated efficiency methodologies provides comprehensive insights into operational performance, enabling manufacturers to identify improvement opportunities through systematic data analysis and performance benchmarking (Almashaqbeh & Hernandez, 2024). The integration of such evaluation frameworks with DFMA analysis strengthens the methodological foundation of this research and enhances the reliability of comparative performance assessments.

## RESULTS AND DISCUSSION

The initial design for a 0.5-inch Class 800LB ball valve consisted of several main components, including the valve body, end closure, ball, seat ring, stem, gasket, and several fasteners such as bolts, washers, and nuts. This design had a complex structure with a relatively long assembly process.

**Table 1.** Comparison of Old and New Designs

| No | Old Design Lama | | New Desain | |
|---|---|---|---|---|
| | Name Part | Qty | Name Part | Qty |
| 1 | Body | 1 | Body | 1 |
| 2 | Closure | 2 | Closure | 2 |
| 3 | Ball | 1 | Gland | 1 |
| 4 | Seat | 2 | Ball | 1 |
| 5 | Stem | 1 | Seat | 2 |
| 6 | Gland Ring | 1 | Stem | 1 |
| 7 | Stop Pin | 1 | Thrust Washer | 1 |
| 8 | Thrust Washer | 1 | Stud Bolt | 8 |
| 9 | Stud Bolt | 4 | Hex Nut | 8 |
| 10 | Hex Nut | 8 | O-RIng | 2 |
| 11 | O-Ring | 2 | Gasket | 2 |
| 12 | Gasket | 2 | Packing | 1 |
| 13 | Packing | 1 | Antistatic Ball | 1 |
| 14 | Oring | 1 | Antistatic Spring | 1 |

| No | Old Design Lama | | New Desain | |
|---|---|---|---|---|
| | Name Part | Qty | Name Part | Qty |
| 15 | Conical Spring Washer | 2 | O-Ring | 1 |
| 16 | Lever Operated | 1 | Lever Operated | 1 |
| 17 | Hex Jam Nut | 2 | Hex Jam Nut | 1 |
| 18 | Lever Cover | 1 | Lever Cover | 1 |
| 19 | Padlock Access | 1 | Hex. Screw | 4 |
| 20 | Antistatic Ball | 1 | Thrust Washer | 1 |
| 21 | Antistatic Spring | 1 | | |
| | Total | 37 | Total | 41 |

(Source: [From Company Data])

Table 1 shows a comparison of the initial design with the redesign results using DFMA. The previous design consisted of 21 parts, while the new design has 20 parts. Although only one part was reduced, some parts were replaced with parts that could maximize their functionality. The simpler design allows for a more efficient machining process. As shown in Table 2, which displays the machining time (in minutes) for each component in the ball valve product. Based on actual data, the average machining time per unit in the initial design was 123.3 minutes, while the new design required 103.3 minutes per unit, or an efficiency of ±16%. This efficiency is mainly due to the more symmetrical and simpler component shape, reduced material setting time on the machine, and the use of flat surfaces that are easier to machine with CNC machines.

**Table 2.** Comparison of Machining Time of Initial Design and New Design

| No | Name Part | Initial Design Time (Minutes) | New Design Time (Minutes) |
|---|---|---|---|
| 1. | Body | 79 | 27.22 |
| 2. | Closure NPT | 11.5 | 20.1 |
| 3. | Closure SW | 19.48 | 19.88 |
| 4. | Ball | 4.48 | 22.63 |
| 5. | Stem | 8.76 | 13.25 |
| | **Total** | 123.3 | 103.08 |

From the assembly side, the initial design requires approximately 153 minutes for one unit of product, while the new design reduces the time to 133 minutes per unit, or a reduction of ±13% as shown in table 3. Assembly operators confirm the efficiency of the design is easier to assemble, because all components can be assembled from one direction so that it is no longer necessary to turn the body back and forth during assembly. This makes the assembly operator faster and easier in the assembly stage. This efficiency is achieved through reducing the number of components, simplifying the assembly flow and eliminating processes that do not provide added value.

**Table 3.** Comparison of Assembly Time of Initial Design and New Design

| Design | Time (Minutes) |
|---|---|
| Initial Design | 153 |
| New Design | 133 |

These changes support the basic principles of DFMA, which emphasizes assembly processes and refinement of design structures to enable faster, simpler assembly, and lower failure rates. Therefore, redesigned products not only provide the benefit of time savings but also reduce the potential for errors in the assembly process. Recent systematic literature reviews of DFMA applications across mechanical and electromechanical products have demonstrated that this methodology consistently delivers measurable improvements in manufacturing efficiency, assembly time reduction, and overall product quality (Formentini et al., 2022).

**Table 4**. Comparison of Production Process Costs for Old and New Designs

| Production process | Old Design | New Design | Cost Savings |
|---|---|---|---|
| Machining Process Cost | Rp. 1,110,663.70 | Rp. 586,339.51 | 47% |
| Assembly Process Costs | Rp. 77,414.06 | Rp. 67,294.58 | 13% |
| Total cost | Rp. 1,188,077.76 | Rp. 653,634.09 | 45% |

Based on the comparison between the initial and new designs (Table 4), a total production cost savings of 45% was obtained, even though the number of components reduced by only one item. This condition indicates that the resulting cost efficiency is not only caused by the reduction in the number of components, but also by an increase in the overall efficiency of the production process as a result of the application of the Design for Manufacturing and Assembly (DFMA) principle. In the redesign stage, after discussions with CNC programmers, designers, particularly researchers, simplified the shape and configuration of components to make the machining process more efficient and more rapid.

The new design was designed to be easier to machine using a CNC machine with fewer tools and without requiring frequent tool changes. This reduction in the number of tool changes significantly impacts cost savings, as machine setup time and tool consumption are the largest cost components in precision machining. Tool path optimization and machining strategy adjustments are performed to minimize cycle time without sacrificing product tolerances and the smoothness of the resulting components. Increased efficiency at this machining stage also reduces machine operating costs, energy consumption, and the need for regular tool replacement.

Although only one component is physically removed, the implementation of DFMA has a systemic impact on production efficiency. Costs can be significantly reduced through the integration of component functions, simplification of design forms, reduction in the number of operations, and more optimal equipment utilization. This is what scientifically explains why production cost savings reach 45% compared to the initial design, even though the component reduction appears relatively small quantitatively.

This cost efficiency also strengthens the finding that the implementation of DFMA is not only focused on reducing the number of components, but also on optimizing the production process as a whole, which has a direct impact on increasing productivity and reducing total manufacturing costs. Similar findings have been reported in other DFMA implementation case studies, where redesign efforts focused on manufacturing efficiency resulted in substantial cost reductions and improved design efficiency, further validating the systemic benefits of DFMA methodology (Butt & Jedi, 2020).

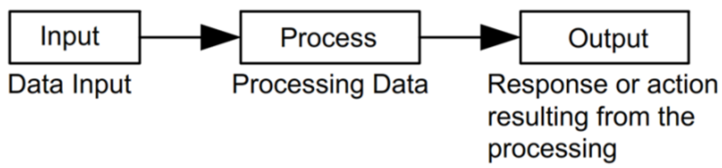


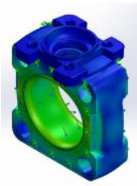
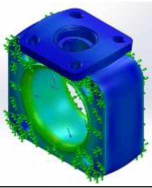
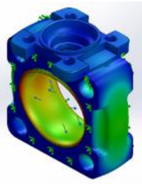
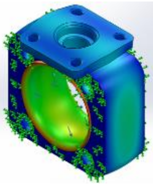
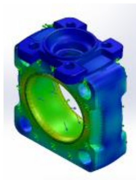
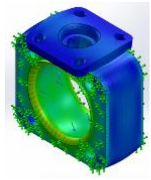
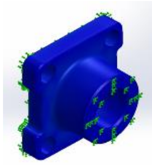
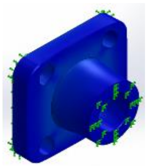
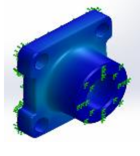
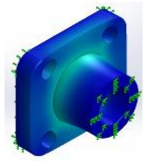
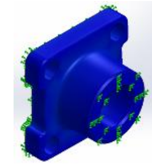
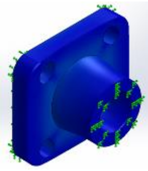
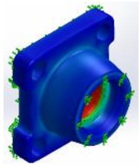
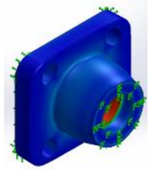
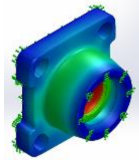
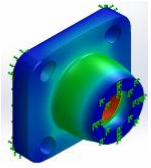
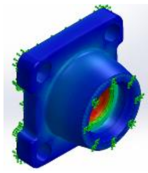
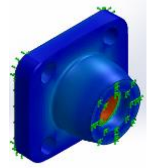
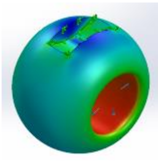
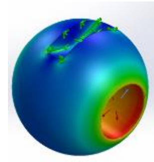
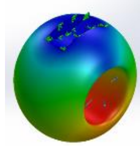
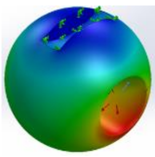
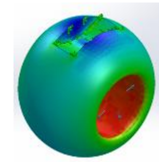
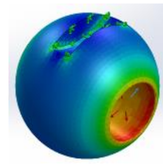
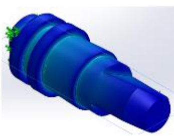
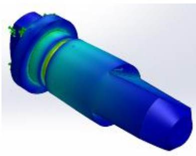
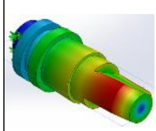
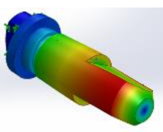
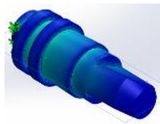
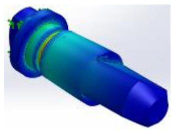

**Figure 4.** Stages of the Product Quality IPO Process

Based on Figure 4, which shows the quality analysis process carried out in stages using an Input to Output approach. In the input stage, data is obtained from the product's technical specifications and the results of production process inspections, as described in Table 5. Next, the process stage is carried out through DFMA analysis to assess the ease of production and assembly, and through numerical simulations to check the strength and deformation of the new design. The final stage (output) produces recommendations for design improvements and validation that the changes made do not reduce product quality.

**Table 5.** Stages of Product Quality Analysis

| Stages | Aspects Evaluated | Indicators/Criteria to be Evaluated |
|---|---|---|
| Input | - Initial design data and redesign results from DFMA Data hasil simulasi teknis<br>- Technical simulation data<br>- Production and assembly time data | - Number of product components<br>- Design complexity<br>- Production method<br>- Production and assembly time |
| Process | - DFMA analysis<br>- Functional analysis and component values using the VAVE method<br>- Deformation, stress, and strain simulation using software | - Ease of machining and assembly processes<br>- Reduced number of production steps<br>- Identification of low-value components<br>- Efficient production processes |
| Output | - Efficiency of new product design<br>- Quality of new product results<br>- Value to cost ratio | - Reduction in total machining and assembly time<br>- Reduction in the number of components and operational process stages<br>- Improvement in the value ratio from the VAVE analysis results<br>- Validation of technical perceptions from the questionnaire (ease of production, design reliability, and cost efficiency) |

**Table 6.** Comparison of Software Simulation Results

| | Stress | | Displacement | | Strain | |
|---|---|---|---|---|---|---|
| | Old Design | New Design | Old Design | New Design | Old Design | New Design |
| BODY |  |  |  |  |  |  |
| MIn | 9.603e+03 N/m$^2$ | 6.416e+04 N/m$^2$ | 0.000e+00 mm | 0.000e+00 mm | 4.64E-08 | 5.82E-07 |
| Max | 6.348e+07 N/m$^2$ | 1.070e+08 N/m$^2$ | 2.102e-03 mm | 3.490e-03 mm | 2.24E-04 | 3.16E-04 |
| CLOSURE NPT |  |  |  |  |  |  |
| MIn | 1.912e+04 N/m$^2$ | 1.539e+04 N/m$^2$ | 0.000e+00 mm | 0.000e+00 mm | 4.56E-08 | 1.12E-07 |
| Max | 2.646e+07 N/m$^2$ | 3.332e+07 N/m$^2$ | 4.730e-04 mm | 6.739e-04 mm | 9.98E-05 | 1.26E-04 |
| CLOSURE SW |  |  |  |  |  |  |
| MIn | 4.138e+04 N/m$^2$ | 3.473e+04 N/m$^2$ | 0.000e+00 mm | 0.000e+00 mm | 1.32E-07 | 1.92E-07 |
| Max | 3.488e+07 N/m$^2$ | 3.721e+07 N/m$^2$ | 7.360e-04 mm | 7.938e-04 mm | 1.39E-04 | 1.47E-04 |
| BALL |  |  |  |  |  |  |
| MIn | 3.382e+0.5 N/m$^2$ | 5.080e+05 N/m$^2$ | 0.000e+00 mm | 0.000e+00 mm | 2.14E-06 | 2.47E-06 |
| Max | 3.15e+07 N/m$^2$ | 4.934e+07 N/m$^2$ | 1.020e-03 mm | 1.526e-03 mm | 1.24E-04 | 1.97E-04 |
| Stem |  |  |  |  |  |  |
| MIn | 3.529e+04 N/m$^2$ | 1.772e+04 N/m$^2$ | 0.000e+00 mm | 0.000e+00 mm | 5.43E-07 | 1.11E-07 |
| Max | 1.562e+07 N/m$^2$ | 3.575e+07 N/m^2 | 3.576e-03 mm | 2.004e-03 mm | 4.51E-04 | 1.38E-04 |

(Source: [From Company Data])

The simulated product consists of several components, including the body, closure, ball, and stem. Each component is simulated and compared between the initial design and the redesigned product. The CAD software uses simulated data to analyze stress, displacement, and strain for each manufactured component. These components are simulated because they are subjected to fluid or pressure. The simulated product consists of several components, including the body, closure, ball, and stem. Each component is simulated and compared between the initial design and the redesigned product. The CAD software uses simulated data to analyze stress, displacement, and strain for each manufactured component. These components are simulated because they are subjected to fluid or pressure.

As shown in Table 6 from the simulation results of the body, SW closure, NPT closure, ball, and stem components. The body, SW closure, NPT closure, and ball were simulated with pressure inside the component, unlike the stem component. The stem component was simulated by stem component with torsion, so there are differences in results with other components. The table above shows the results of the comparison of stress, displacement, and strain analysis on these components. Each component is made using a safety factor of at least 1.5 times the established standard. This is done to improve the quality of the manufactured product. The results of the stress analysis simulation show an increase in maximum values for all components in the redesign compared to the initial design. This increase is due to the simplification of the design shape, which results in a more even distribution of stress concentrations. This results in a more efficient component design in dissipating stress.

The results of the displacement analysis simulation, or deformation under pressure, show an increase in each component, but a decrease in the stem. This is due to the difference in the simulation method, which uses torsional torque. However, the change is not too large and is still below the values in the material data sheet, so it can be concluded that the design changes are still acceptable. Design changes in displacement affect the deformation when the component is subjected to internal pressure (components outside the stem). The strain analysis simulation results show that all components, except the stem, experienced an increase in maximum strain after the redesign.

This increase was caused by load redistribution and geometric changes that affected deformation in these components. However, in the stem component, there was a decrease in strain values, which can be explained by the difference in simulation methods that used torsional loads, rather than internal pressure as in the other components. The decrease in strain in the stem indicates an increase in torsional stiffness due to the geometric changes that made the stem more resistant to deformation due to torsional moments. Although there was a decrease in strain, this change was not significant compared to the material data sheet, so it can be concluded that the redesign is still within acceptable limits. Overall, the analysis results using SolidWorks software on product components show a significant impact from the implementation of redesign based on Design for Manufacturing and Assembly (DFMA) principles. Although there are some reductions in maximum values in the stem components, these changes are still within the elastic limits of the materials used, thus not indicating the potential for permanent failure.

Increased displacement in some components indicates a more efficient load redistribution. On the other hand, the reduction in strain in the stem indicates that the redesign has succeeded in increasing stiffness against torsional loads, which improves structural stability. These simulation results strengthen the belief that the redesign not only improves production efficiency but also maintains the mechanical integrity of the product. Thus, component quality analysis using this software provides a clear and reliable picture of the structural performance of the product after the redesign.

The application of this value evaluation matrix proves that the integration of Design for Manufacturing and Assembly (DFMA) with the Value Analysis and Value Engineering (VAVE) approach is very effective in helping design teams identify optimization opportunities more objectively. By balancing technical aspects (function and reliability) with economic aspects (production costs), the design process can be directed to produce efficient, high-quality products that are suitable for mass production (Miles, 2015). As a strengthening of the analysis, this study also considers several design alternatives using the VAVE Matrix approach, which evaluates each option based on four main aspects, namely: function, cost, risk, and ease of implementation in the manufacturing process.

**Table 7.** Values for Each Ball Valve Component

| No | Name Part | Function (scale 1-10) | Old Production Costs (Rp.) | New Production Costs (Rp.) | Old Value | New Value |
|---|---|---|---|---|---|---|
| 1 | Body | 9 | 648.67 | 291.94 | 0.01 | 0.03 |
| 2 | Closure | 9 | 195.85 | 118.27 | 0.05 | 0.08 |
| 3 | Gland | 7 | - | 80.5 | - | 0.09 |
| 4 | Ball | 10 | 46.67 | 37.02 | 0.21 | 0.27 |
| 5 | Seat | 10 | 54.00 | 78.00 | 0.19 | 0.13 |
| 6 | Stem | 10 | 23.61 | 20.84 | 0.42 | 0.48 |
| 7 | Gland Ring | 4 | 25.5 | - | 0.16 | - |
| 8 | Stop Pin | 4 | 10.5 | - | 0.38 | - |

| No | Name Part | Function (scale 1-10) | Old Production Costs (Rp.) | New Production Costs (Rp.) | Old Value | New Value |
|---|---|---|---|---|---|---|
| 9 | Thrust Washer | 7 | 47.3 | 47.3 | 0.15 | 0.15 |
| 10 | Studbolt | 8 | 24.15 | 18 | 0.33 | 0.44 |
| 11 | Hex Nut | 8 | 5.65 | 5.65 | 1.42 | 1.42 |
| 12 | O-ring | 8 | 1.15 | 1.15 | 6.96 | 6.96 |
| 13 | Gasket | 7 | 17.5 | 17.5 | 0.40 | 0.40 |
| 14 | Packing | 7 | 14.5 | 14.5 | 0.48 | 0.48 |
| 15 | Conical Spring Washer | 2 | 2.1 | - | 0.95 | - |
| 16 | Antistatic Ball | 6 | 0.1 | 0.1 | 60.00 | 60.00 |
| 17 | Antistatic spring | 6 | 0.1 | 0.1 | 60.00 | 60.00 |
| 18 | O-ring | 8 | 1.15 | 1.15 | 6.96 | 6.96 |
| 19 | Lever Operated | 8 | 64.00 | 50.00 | 0.13 | 0.16 |
| 20 | Hex Jam Nut | 8 | 4.2 | 4.2 | 1.90 | 1.90 |
| 21 | Lever Cover | 5 | 12 | 12 | 0.42 | 0.42 |
| 22 | Hex Screw | 6 | - | 0.4 | - | 15 |
| 23 | Padlock Access | 4 | 8 | - | 0.50 | - |
| 24 | Thrust Washer | 7 | 47.3 | 47.3 | 0.15 | 0.15 |

(Source: [From Company Data])

The radar chart above illustrates the results of a questionnaire administered to the technical team regarding the application of the DFMA principle to the 0.5-inch, 800LB class ball valve. The assessment was conducted using a Likert scale, ranging from 1 to 5, with 1 representing "strongly disagree" to 5 representing "strongly agree." The visualization above yields several data points, including:

1. Product quality received the highest score, with a score of 4.6. This indicates that respondents significantly experienced an improvement in quality after implementing the DFMA method. The new design was deemed capable of reducing errors, increasing product consistency, and improving performance.
2. Cost and Implementation Efficiency, with a score of 4.3, is the second-highest aspect. This indicates that the DFMA approach is considered effective in reducing production costs, reducing production time, reducing assembly time, and simplifying the implementation process in the field.
3. Assembly and Value Engineering Value Analysis both scored 4.1. This indicates that DFMA successfully simplified the number of components and assembly sequences and opened up opportunities for functional improvements without significantly increasing costs.
4. Machining and production with a score of 3.8, even though the figure is high, is still a signal that there is still potential for development in the machining process or the use of more efficient production technology.
5. Product Structure and Design scored 3.7, making it the lowest-scoring aspect. This indicates that even though DFMA has been implemented, the new design structure is still considered suboptimal in terms of manufacturability.

**Table 8.** Perception Analysis of Product Redesign

| Assessment Aspects | Average Rating (Scale 1-5) | Interpretation |
|---|---|---|
| Product Structure and Design | 3.7 | Respondents strongly felt the design quality had improved. |
| Machining and production | 3.8 | There is still potential for development in the production process. |
| Assembly | 4.1 | DFMA has successfully simplified the assembly process. |
| Product Quality | 4.6 | Respondents strongly felt the quality had improved. |
| Cost Efficiency and Implementation | 4.3 | DFMA has successfully reduced production costs. |
| Value Analysis and Value Engineering | 4.1 | DFMA has successfully made improvements by maximizing the function of each component. |

Respondents assessed the implementation of DFMA as having a very positive impact, particularly in improving product quality and cost efficiency. Scores above 4 on most aspects indicate strong acceptance of this approach. Slightly lower scores on product structure and design indicate room for improvement early in the design phase to achieve even greater manufacturing efficiency. Multi-objective optimization techniques have demonstrated significant efficacy in valve design, particularly when combining response surface methodology with advanced genetic algorithms to simultaneously optimize structural performance and manufacturing feasibility (Wen et al., 2025). The application of such sophisticated optimization approaches in ball valve design validates the methodological rigor employed in this research, where structural analysis and manufacturing considerations are systematically integrated to achieve optimal design configurations.

Computational fluid dynamics has become indispensable for valve performance analysis, providing detailed insights into flow patterns, pressure distributions, and energy losses that inform optimal design configurations (Dhumal et al., 2025). The utilization of SolidWorks simulation in this study aligns with contemporary best practices in valve engineering, where advanced computational tools enable comprehensive performance prediction and design validation before physical prototyping and production.

Integration of intelligent manufacturing technologies with production process optimization enables real-time quality control and adaptive process adjustments, resulting in superior product consistency and reduced defect rates. These findings from contemporary manufacturing research reinforce the strategic value of combining DFMA principles with advanced quality control methodologies, as demonstrated in this study through systematic process optimization and comprehensive quality assessment protocols.

## CONCLUSION

This study demonstrates that the implementation of Design for Manufacturing and Assembly (DFMA) significantly improved production efficiency and product quality in the manufacture of 0.5-inch, 800LB class ball valves. The DFMA implementation results in a 16% reduction in machining time, from 123.3 minutes to 103.3 minutes per unit, while assembly time was reduced by 13%, from 153 minutes to 133 minutes per unit. Despite reducing the number of components by only one item, from 21 to 20 parts, the total production cost efficiency reached 45% through component shape simplification, tool path optimization, reduced tool change frequency, and improved assembly flow that allows all components to be assembled from a single direction.

The strategic impact of this research is that it confirms that DFMA is not simply an operational improvement tool, but rather a strategic design framework that supports competitiveness, lean production, and continuous improvement in the manufacturing industry. Therefore, the implementation of DFMA is highly recommended as a standard design practice to achieve efficiency, quality assurance, and continuous innovation in the Indonesian manufacturing sector, particularly in the precision components industry, which demands high levels of accuracy and reliability.

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**AUTHOR CONTRIBUTION STATEMENT**

Muhammad Nur Apriady developed the research framework, conducted the comparative analysis between initial and optimized ball valve designs, performed DFMA implementation and evaluation, collected manufacturing and assembly data through direct observation and interviews with production engineers, analyzed process time and cost structures, executed technical documentation review, created design simulations using SolidWorks software, developed VAVE analysis matrices, conducted component quality assessments, and prepared the initial manuscript including all tables, figures, and technical content. Bambang Syairudin provided research guidance and technical expertise in manufacturing design, validated the DFMA methodology application, supervised the entire research process, facilitated access to production facilities and technical resources, reviewed and refined the manuscript for academic rigor and clarity, and ensured alignment with research objectives and industry standards.

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