

PROJECT-BASED LEARNING FOR THE DESIGN OF PROGRESSIVE DIES SUPPORTING TOOLS

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In the oil and gas industry, manufacturing processes covered a variety of fields including pipe fittings production. Generally, this process involves a press machine utilized as a shape forming using punch-dies sets as mold profiles. The common problem found with the dies is the dimension of dies is not ergonomics to be handled manually by operators. Additionally, the support of dies tends to experience buckling upon receiving a pressure load of 15 MPa. Hence, alternative and practical designs are required, which have low deflection values and high fatigue resistance rates. Additionally, the designs are expected to be safe and economical. In this study, two alternative designs of punch-dies support are proposed. Subsequently, the FEA simulation was carried out for pipe fittings of 8 inches with ASME B16.9 standard size for WF Beam A36 Steel to compare the two proposed designs. The results show that alternative design 2 has a lower deflection value of 0.181 mm, a higher Factor of Safety of 3.21, and a higher cycle time of 358569 cycles than alternative design 1. Nevertheless, alternative design 2 has a higher production cost of 220 USD compared to alternative design 1. Therefore, this study shows that alternative design 2 has better performance while alternative design 1 is more economical.

Keywords: Progressive Dies, Supporting Tools, FEA, Solid-works

1. INTRODUCTION

PT Flo-Bend Indonesia is an oil & gas manufacturing company located in Batam, Indonesia, which manufactures steel pipe fittings. This company manufactures variety of products including elbows, reducers, tees, and cap. Most of the products forming process involved in this company is hot working with high pressure employing a mandrel machine to modify the shape of steel pipes [1]. According to Rasyid (2014), the process of hot working (metal forming) is the formation of metals (alloys) in plastic region above the recrystallization temperature. This process is generally conducted quickly to prevent the hardening of the metals so the shape of metals could be modified while maintaining materials continuity as expected [2]. After the forming process, the subsequent process is the sizing process. In this study, the product involved is elbows and the sizing process uses a 500-ton press machine (Figure 1). The press machine applies pressure to the dies and with the help of molds ensuring that the products adhere to the sizing standard by the company (ASME). Lu (2018) reported that the external force of the hydraulic actuator would forge the metal work piece into the desired shape [3].

In this study, the dies support used is a wide steel flange (WF) A36 Steel WF-400. The problem that this study addresses is the combined height of WF support made of two steel WF-beams (each 400-mm height) piled together, which is not ergonomic [4]. Furthermore, the support is still not capable to withstand the pressure exerted by a press machine (15 MPa), leading to buckling [5]. In his study, Sugiono (2018) states that ergonomics is a deep knowledge of human relations, machinery, work environment, organization, and work procedures, to be able to complete work efficiently, comfortably, and safely [6]. Meanwhile, according to Budiono (2003), the occurrence of fatigue cannot just occur suddenly, but there are several influencing factors, namely, lifting load, lifting frequency, and lifting distance [7]. Due to this reason, the company has set an ergonomic standard for WF support of 580 - 600 mm [8].

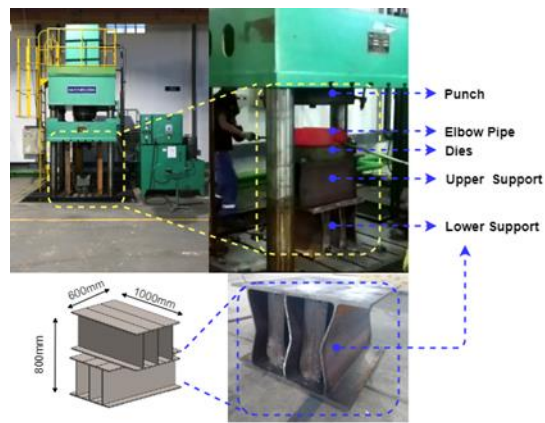


Figure 1. Production Layout on PT. Flo-Bend Indonesia.

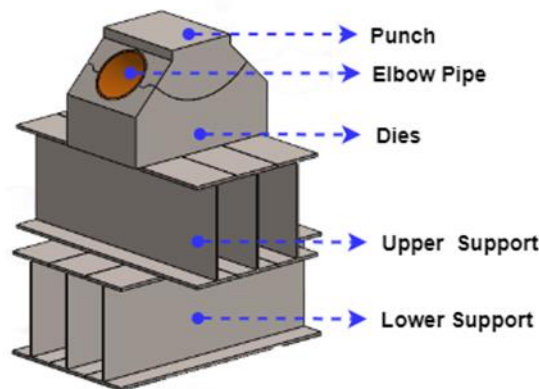


Figure 2. Former Design of Punch-Dies Sets

This study aims to create a WF support design for 8-inch dies on a press machine, which has an ergonomic height and capability to withstand press machine pressures to maintain the smooth operation of production process. Initially, analysis was conducted on the original design containing 2 levels of WF-400 steel (Upper & Lower Support) as shown in Figure 2. Subsequently, two alternative designs are proposed with Alternative 1 uses 2 levels of WF-294 steel while Alternative 2 uses 1 level of WF-600 steel. The infinite element analysis was carried out to find the value of deflection, the factor of safety, and the fatigue rate. Additionally, the estimated production cost for each design was compared for further consideration in the decision-making stage.

2. RESEARCH METHOD

The arrangement of WF steel construction is as shown in Figure 3, with Figure 3 (a) is the initial design of the company that has been realized and is currently used in the production process. The construction consists of four WF-400 steel H-beams that are joined by welding process into two rows and two levels. The welded joints have weld seam thickness of 5mm along 100mm without bevel, only on one side, and not full length with the welding wire of LB-40U type. Among the WF steel joints, 16pcs steel plates measuring 374x100x12mm were added to improve strength and to prevent buckling in the support. Nevertheless, buckling still happens in the operation.

In Figure 3 (b), it can be seen an alternative design (alternative 1) consisting of four WF-294 steel H-beams joined by welding into two rows and two levels. Among the WF steel joints, 6pcs of 270x168x8mm (Mid P1), 24pcs of 270x100x12mm (Mid P2), 12pcs of 270x84x8mm (Mid P3) steel plates were added. The welding process is assumed to be similar the original design as described in the previous paragraph.

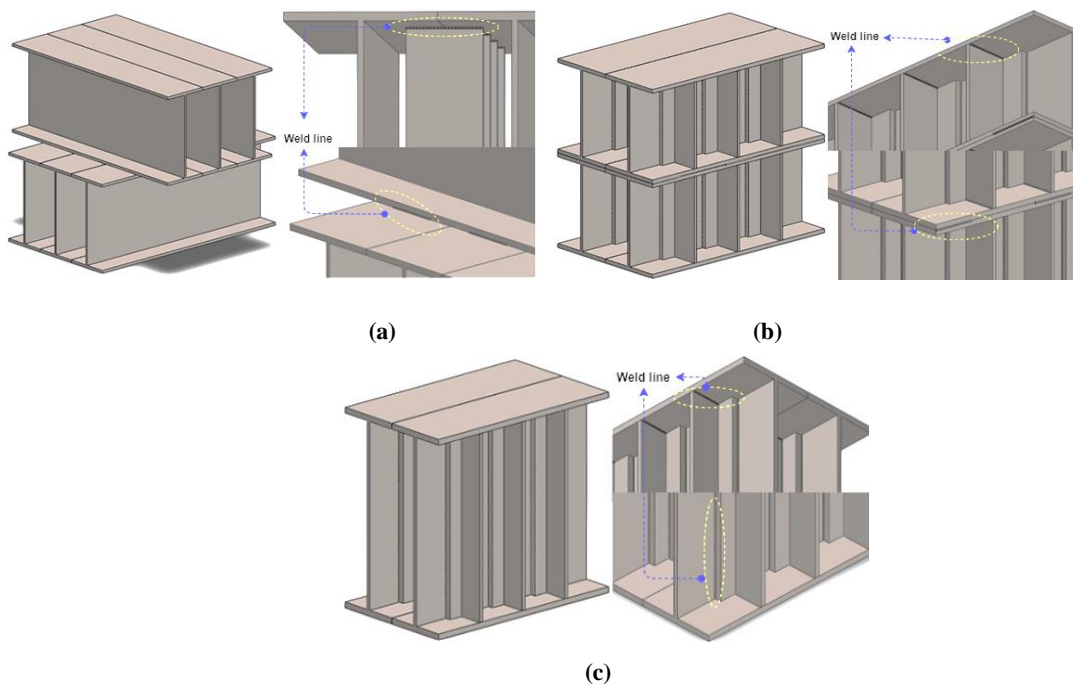


Figure 3: Design of WF Support (a) Original Design, (b) Alternative Design 1, (c) Alternative Design 2

Another alternative design (alternative 2) is presented in Figure 3 (c), which consists of four WF-600 steel H-beams joined by welding into two rows and one level. Among the WF steel joints, 12pcs of 566x100x17mm (Mid P1), 6pcs of 566x77.5x11mm (Mid P2), 3pcs of 566x155x11mm (Mid P3) steel plates were added. Likewise, the welding process is assumed to be the same with the original design.

Analytical method was used to determine the value of the static simulation results using Solidworks [9]. The steps conducted were as follows [10]: Making 3D models, Simulation - Static Study, Material Definition, pedestal placement and load, Defining component contacts, Making meshing in models and defining solvers, Interpretation, and Analysis of FEM results.

For the selection of materials, the data were generated from the datasheet provided by the supplier of the company [11], both for A36 steel (Table 1) and Kobelco Lb-52U welding electrodes with a diameter of 4 mm welding wire (Table 2). These data were entered into the material library.

Furthermore, the definition of the fixture and the load, the design results, the condition of the load, and the fixture based on the press machine condition were defined. Fixed - fixture setting parameter at the bottom of the WF steel, with 15-MPa of external loads, were applied on the bottom side of the dies-set. The contact set used global contact (bonded) type with a friction constant of 0.05. For the selection of mesh types, curvature-based mesh type with mesh density (Fine Type) [14] was used. This setting was designed to process data on the welded joint.

Table 1. Material Data Sheet of A36 Steel [12]

| | |
|--|--|
| <i>Material</i> | <i>A36 Steel (1023 Carbon Steel Sheet)</i> |
| Ultimate Tensile Strength (MPa) | 400-550 |
| Yield Strength (MPa) | 250 |
| Tensile Strength (MPa) | 425 |
| Elongation (%) | 20 |
| Elastic Modulus (GPa) | 200 |
| Mass Density (Kg/m³) | 7,850 |

Table 2. Material Data Sheet of Kobelco Lb-52U Welding Electrode [13]

| | |
|--|---------------|
| <i>Material</i> | <i>Lb-52U</i> |
| Yield Strength (MPa) | 480 |
| Tensile Strength (MPa) | 560 |
| Elongation (%) | 31 |
| Yield Strength (MPa) | 283 |
| Mass Density (Kg/m³) | 7,858 |
| Tensile Strength (MPa) | 425 |

The final step was defining a solver. The finite element method (FEM) using algebraic equations are selected. This solver could solve simultaneously until converging, using a direct method or also called the iterative method [9]. Of the choices provided in Solidworks to analyze mesh in numerical form (FEE Plus, Direct Sparce Solver, Large Problem Direct Sparse (LPDPS Solver), Intel Direct Sparce, Intel Network Sparce and Auto), the auto option was applied to perform numerical calculations up to the mesh size of the welded joint [10].

3. RESULT AND DISCUSSION

3.1 Stress Analysis

The theoretical yield strength for WF A36 is 250 MPa that is lower than the value provided by the supplier of, which is 283MPa. Based on the results of the simulation (Figure 4), the maximum stress value for the original design is 472MPa, which is greater than the theoretical yield strength and this value is within the limits of the ultimate tensile strength of 400-550MPa [12]. Furthermore, the maximum stresses for alternative design 1 and 2 are 247MPa and 200MPa, respectively. These values are smaller than the theoretical yield strength.

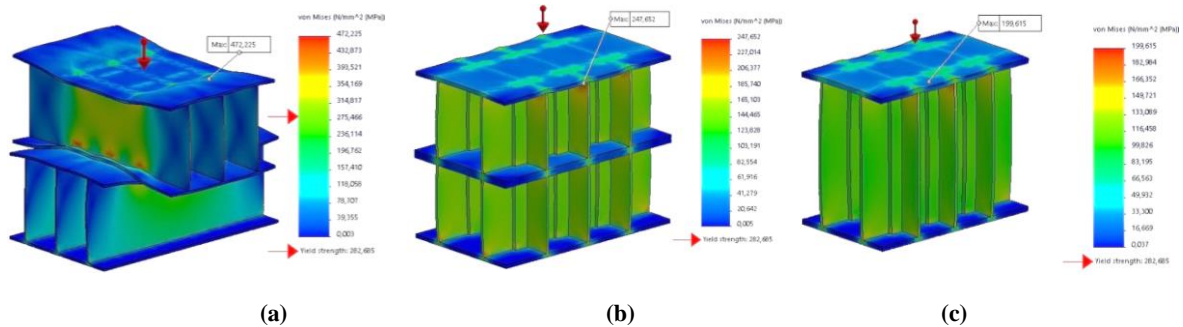


Figure 4: Stress Analysis for (a) Original WF Support Design, (b) Alternative Design 1, (c) Alternative Design 2

3.2 Displacement Analysis

From the Von Mises simulation approach, the maximum displacement results for each design are presented in Figure 5. The simulation show that deformation has already occurred in the original design in accordance to the field observation. The materials in the original design has already undergone transformation into the plastic region as what has happened in the company. From Figure 5, it can be seen that the original design has the highest maximum displacement value of 0.24mm, while the proposed designs have lower maximum displacement values of 0.215mm (alternative design 1) and 0.181 (alternative design 2).

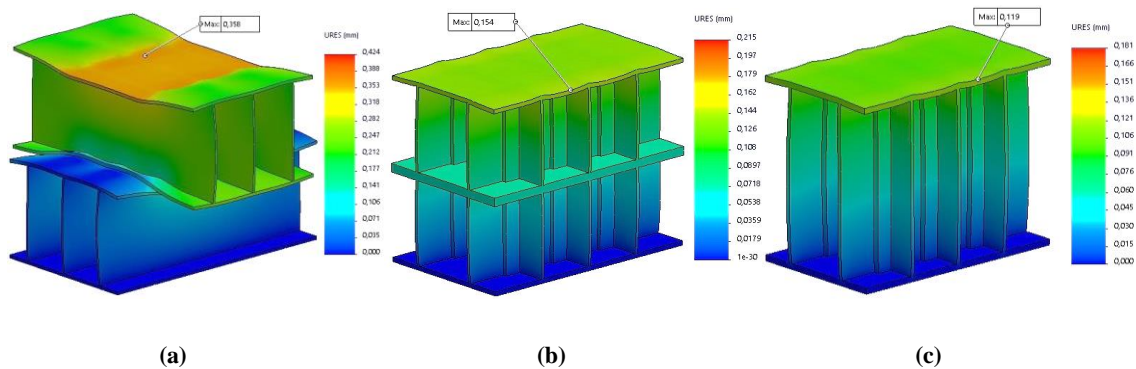


Figure 5: Displacement Analysis for (a) Original WF Support Design, (b) Alternative Design 1, (c) Alternative Design 2

3.3 Factor of Safety (FoS) Analysis

Safety Factor or commonly called Factor of Safety (FoS/FS) could be defined as a factor used to evaluate the safety level of a product [15]. The value of FoS could be calculated from Equation (1).

$$\text{FoS} = \text{Ultimate TS/Actual TS} \tag{1}$$

Based on the calculation, the original design has an FoS value of 0.84, whilst the proposed designs have higher FoS values of 1.6 (alternative design 1) and 2 (alternative design 2). The FoS values obtained from the simulation are depicted in Figure 6. The figure shows that the original design (a), has the minimum FoS value of 1.78, whereas the alternative design 1 (b) and alternative design 2 (c) have minimum FoS values of 2.76 and 3.21, respectively.

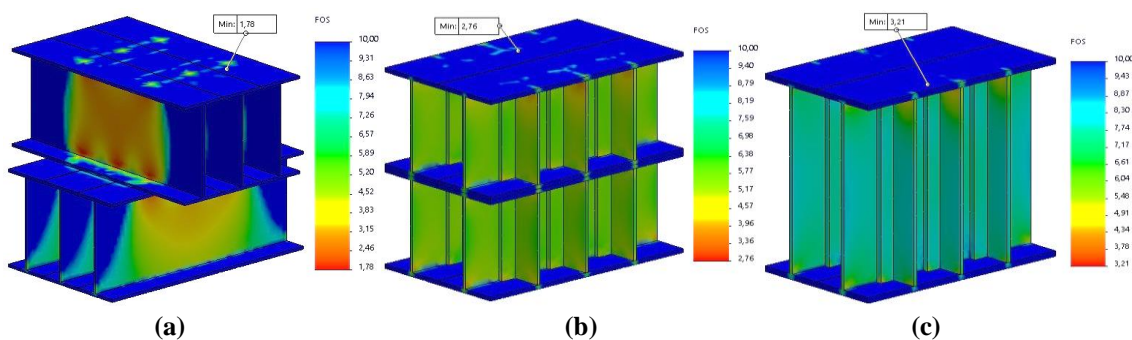


Figure 6: Factor of Safety Analysis for (a) Original WF Support Design, (b) Alternative Design 1, (c) Alternative Design

3.4 Fatigue Analysis

Fatigue life analysis is a method that is usually carried out to predict the failure of a structure. The unit of measurement is in cycles or can be concluded in days, months, or even years to predict the age of an instrument [16]. This analysis is useful to reduce or to eliminate the risk of fatal damage [17]. As can be seen in Figure 7, the original design (a) has the lowest minimum life cycle value of 4,466 cycles. The far greater life cycles are observed for the proposed designs with the alternative design 2 (c) has the highest value of mini-

imum life cycle (311,609) cycles and the alternative design 1 (b) has the minimum life cycle value of 99,653 cycles.

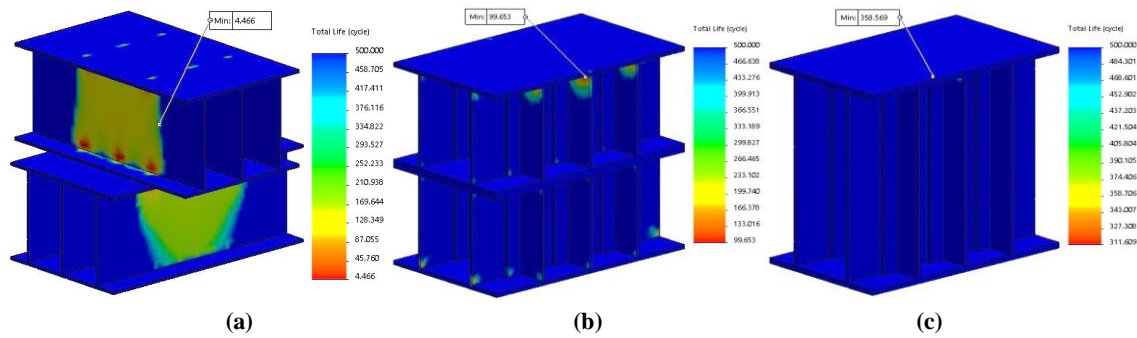


Figure 7: Fatigue Analysis for (a) Original WF Support Design, (b) Alternative Design 1, (c) Alternative Design 2

If the company produced 50pcs of products in a day (50 cycles/day) with 20 production days per month, then the WF support lives of the original design, alternative design 1, and alternative design 2 are 4.7 months, 8.3 years, and 25.97 years, respectively.

3.5 Production Cost Analysis

In this study, the production cost included material costs, machinery costs, and the cost of consumable parts used for the fabrication of WF support based on the original and proposed designs. The method of calculation was the variable costing method. The product price was obtained from the production cost including tray material, labor, and company overhead as well as the commercial cost consisting of marketing and administrative costs. The results of this calculation are presented in Table 3.

Table 3. Manufacturing Cost for Progressive Dies Supporting Tools

| Design | Overall Dim. (mm) | | | Manuf. Cost (USD) |
|-----------------------|----------------------|-----|-----|----------------------|
| | L | W | T | |
| Original Design | 1000 | 600 | 800 | 480 |
| Alternative Design 1 | 655 | 400 | 588 | 420 |
| Alternative Design. 2 | 655 | 400 | 600 | 640 |

*Currency rate: 1 USD = Rp. 14,958.92

Based on the results, there are differences in production cost between the original design and the proposed designs. For the alternative design 1, the manufacturing cost is lower than the cost for original design with the cost reduction of 12.84%. Whereas in alternative design 2, there is around 33.33% increase in manufacturing cost compared to the original design.

The summary for each of the analysis conducted in the previous paragraphs could be seen in Table 4. This tabulation of data is expected to assist the company during the decision making process.

Table 4. Tabulation Data of General Results

| Analysis | Design | | |
|------------------------|----------|---------------|----------------|
| | Original | Alternative 1 | Alternative 2 |
| Max. Stress (MPa) | 472,225 | 247,652 | 199,615 |
| Max. Displacement (mm) | 0,424 | 0,215 | 0,181 |
| Min. FoS | 1,78 | 2,76 | 3,21 |
| Min. Fatigue (Cycle) | 4.466 | 99.653 | 358.569 |
| Manuf. Cost (USD) | 480 | 420 | 640 |

4. CONCLUSION

In this paper, the simulation results show that there has been deformation in the WF support of the original design. Hence, two alternative designs proposed are expected to have higher resistance to deformation. Based on the values of tensile strength, displacement, and FoS, the new designs have better performances than the original design. The alternative design 2 is superior compared to alternative design 1. The alternative 2 has the lowest tensile strength of 199.615 MPa, the smallest displacement value of 0.181 mm, and the highest FoS value of 3.21. In addition, alternative design 2 also has the longest product life of 311, 609 cycles compared to the original design (4,466 cycles) and alternative design 1 (99,653 cycles). Nevertheless, the manufacturing cost for alternative design 2 is estimated to be 33.33% and 52.38% higher than the original design and alternative design 1, respectively. From this conclusion, the company can choose alternative design 2 if it wants the best quality regardless the cost. On the other hand, considering the fabrication cost, the alternative design 1 is the right choice afterward.

5. ACKNOWLEDGMENT

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