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Design and manufacture of automatic sheet metal bending machine tools in the press brake section

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ABSTRACT

Design and manufacture of automatic sheet metal bending machine tools in the press brake section with the aim of being able to streamline the operating time of bending machines in the Orange Teknik workshop. The main obstacle is that the bending machine is operated manually because it still uses an analog system. The main goal in creating this innovative tool is to assist the operation of a sheet metal bending machine so that it saves time and makes it easier to determine the results of the bending angle. In the process of designing and manufacturing automatic tools, it begins with an analysis of the problems in Orange Engineering, Literature Study, carrying out the design, manufacture and assembly of tools for bending machines, searching for bending data and analyzing data, creating equation formulas and ending with automatic data validation. The result shows that as the thickness of the plate used increases, the required punch force decreases, or the rotary encoder value becomes smaller to achieve the same angle as thinner plates. The effect of plate material variation in the bending process shows that the punch force applied in the press brake system is greater for black iron plates. Similarly, the rotary encoder value is higher to achieve the same bending angle compared to stainless steel plates.

1. Introduction.

As time progresses, numerous changes occur, particularly in the fields of science and technology. One of these changes is evident in the manufacturing industry, which must adapt and keep up with technological advancements. The manufacturing sector represents a significant industry in Indonesia, with many companies operating in this field, ranging from small-scale enterprises to large-scale industries [1].

According to the Ministry of Industry of the Republic of Indonesia (2022), the expansion of the manufacturing industry in Indonesia continues to grow. The contribution of the manufacturing sector to the Gross Domestic Product (GDP) has been increasing year by year. Since 2010, the industry has consistently made the largest contribution to national GDP, even during the peak of the COVID-19 pandemic in 2020–2021. In 2021, the GDP of the industrial sector was recorded at IDR 2,946.9 trillion, higher than the IDR 2,760.43 trillion achieved in 2020 [2].

This is evident from the significant expansion and growth in the manufacturing sector in Indonesia. Therefore, to support the industry, particularly in manufacturing, in improving its performance, one of the key aspects that needs to be addressed is the enhancement of technology in the manufacturing production processes.

Based on one of the Japanese management systems, the practical Kaizen method is an effective solution for improving both the quality and quantity of an industry. In the context of manufacturing industries, which are inherently tied to production activities, Kaize*n* involves continuous improvement across all aspects of a factory or company. The goal is to reduce production costs by minimizing waste in production activities [3].

Focusing on the manufacturing industry in Indonesia, particularly small and medium-sized enterprises (SMEs) or technical workshops in the manufacturing sector, many SMEs face challenges in keeping up with the technology used by large industries [4]. Currently, large industries have adopted automated machinery to enhance production efficiency and minimize human labor, making it difficult for smaller enterprises to compete technologically.

Orange Teknik is a small to medium-sized enterprise (SME) or technical workshop operating in the manufacturing sector. The company owns a manual sheet metal bending machine, which presents several operational challenges. These issues have been identified and developed into a project under PT Stechoq Robotika Indonesia.

The sheet metal bending machine currently operates manually, requiring a considerable amount of time during its operation. One of the key aspects is the press brake section of the machine, which is used to determine the desired bending angle. At present, the operator must manually adjust the punch pressure using an analog system on the machine.

Given the existing issues, a suitable technology to be implemented at Orange Teknik is the development of an automated tool for the sheet metal bending machine to determine the desired bending angle. In simple terms, this involves creating an automatic press brake system or punch descent mechanism on the bending machine that produces the pre-set bending angle. The goal of this design and development is to address the challenges faced by the small and medium-sized enterprise (SME) Orange Teknik.

2. Method

This research uses the R&D method, referring to the ADDIE model [5]. The model consists of five development stages: 1) Analysis, 2) Design, 3) Development or Production, 4) Implementation, and 5) Evaluation [6]. The details of the ADDIE model are divided into two steps, shown in Figure. 1 and Figure. 2.

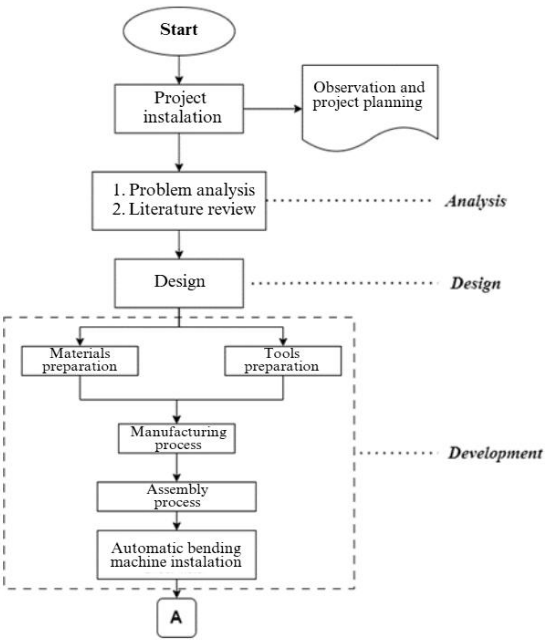

Figure 1. The first step research

In the Analysis stage, the need for product development is assessed. The development of a product often begins with identifying issues in existing or implemented products [4]. Development is carried out on the sheet metal bending machine at the Orange Teknik workshop. The operation of this bending machine is still manual, which requires a considerable amount of time during the process. One of the issues is the press brake section of the sheet metal bending machine, which is used to determine the desired bending angle. The operator must manually adjust the punch pressure using an analog system on the machine. After identifying the existing problems, an analysis is needed to design an automated tool for the bending machine.

In the Design stage, the first step is to develop the concept for the automated tool on the sheet metal bending machine, which includes components such as the PLC controller, user interface in the form of an HMI, and a rotary encoder sensor. Once the concept is finalized, the next step is to create design drawings in accordance with ISO standards. The design drawings include both the overall layout and detailed drawings of all the components.

The Development stage involves the creation of the automation tool for the sheet metal bending machine, based on the design plan created earlier. Once all the components are manufactured and purchased, the next step is the assembly process and installation of the tool onto the bending machine, followed by programming the manual control system. This control system is used for data collection during the bending process, which will later be used for the automated program.

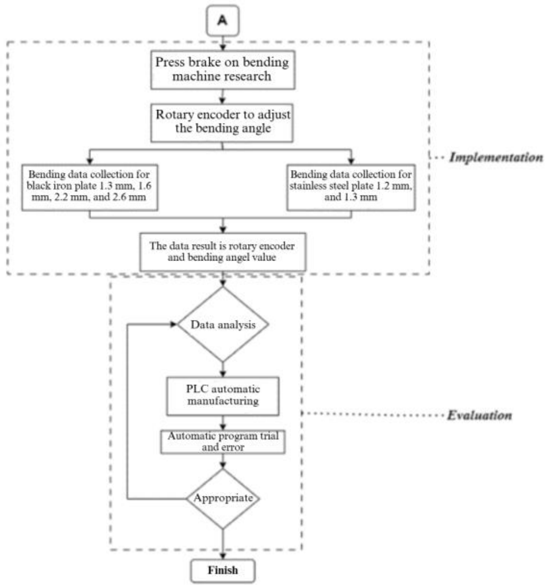

Figure 2. The second step research

In the implementation stage, the automated tool installed on the sheet metal bending machine is tested. This automated tool still uses a manual control system. During this stage, data is collected on the bending process, considering variations in plate thickness and types of plates. The data collection is carried out to determine the impact of the encoder values on the resulting bending angle. For each plate type and thickness, data is gathered using a mapping method. Once the data is collected, it is used to create a graph. From this graph, an equation formula is derived, which will be used as the basis for the automated program on the PLC controller.

The final stage is the evaluation phase, which aims to correct any discrepancies [7]. In this phase, data validation is performed for the automated program on the bending machine automation tool.

Automated data validation is used to check whether the derived equation formula is correct. If the formula is not accurate, adjustments need to be made to ensure that the automatic control system operates effectively.

3. Result and discussion

Results of the design of the automation machine are shown in Figure 3.

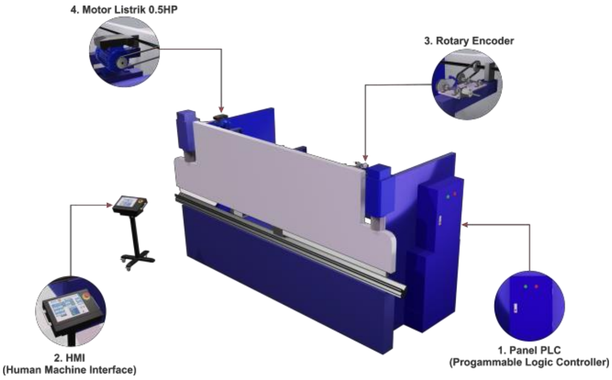

Figure 3. Design the automation machine

Here are the components and their functions in the design and development of the automation tool for the sheet metal bending machine, specifically in the press brake section:

1. PLC Panel
   The PLC panel box is a container or enclosure, typically in a rectangular shape, housing the PLC controller and other electronic components. This panel measures 60cm x 40cm x 20cm and is made from sheet metal.
2. HMI (Human Machine Interface) Station
   The HMI station functions as a stand or support for the HMI or user interface. The station is made from sheet metal and features wheels on the bottom for mobility.
3. Rotary Encoder
   The rotary encoder is an electronic component that serves as a rotation sensor, used to measure rotations. A bracket or mounting is needed to attach the rotary encoder to the machine.
4. Electric Motor
   The electric motor acts as an actuator to drive the shaft, which is connected to two stoppers in the press brake system.

The automated tool on this bending machine operates with two control systems. The first is a manual control system, where the operator inputs the encoder value and lever value, and can press the “up” or “down” buttons. The second is an automatic control system, where the operator inputs the bending angle and bending parameters, and the press brake system operates automatically based on the entered values.

This data collection uses the concept of data mapping[5], where data is gathered by inputting the rotary encoder rotation values, which result in bending angles (degrees). In this data collection process, each plate’s thickness and type is measured individually. The variations in plate thickness and types used for this data mapping are as shown in Table 1.

Table 1. Variations in plate thickness and types

Plate Thickness (mm)	**Plate Types**	**V Dies Types**
1.2	stainless steel	2
1.3	stainless steel	2
1.3	black iron	2
1.6	black iron	3
2.2	black iron	4
2.6	black iron	4

After the data collection, the bending results of the stainless steel with thickness of 1,2 mm are presented in Table 2.

Table 2. Bending results

No	**Rotary Encoder Value**	**Bending Result (rad)**
1	11980	90
2	11930	87
3	11880	83
4	11830	79
5	11780	76
6	11730	71
7	11680	67
8	11630	64
9	11580	60
10	11530	56
11	11430	47
12	11330	39
13	11230	30
14	11130	22
15	11030	13
16	10980	9

This study determined the rotary encoder values which will later result in the bending angle (degrees) of the workpiece used. From this research, a graph was created, which will eventually generate a formula derived from the data collected. The graph is shown in Figure 4.

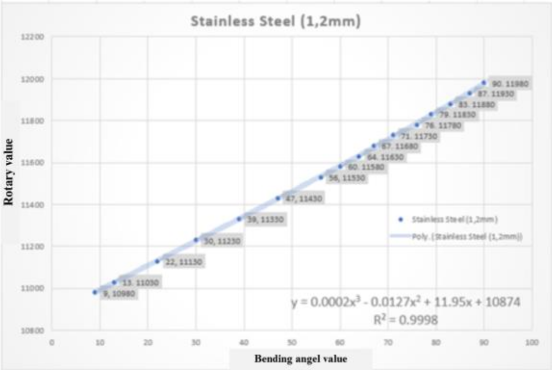

Figure 4. Bending data collection

After generating the graph, a polynomial equation of order 3 will be derived. This equation can be obtained using the Microsoft Excel application. Based on the results of the bending data collection, The formula equations can be written as the following:

Stainless steel, 1,2 mm

$$y = 0.0002x^3 - 0.0127x^2 + 11.95x + 10874 \quad (1)$$
$$R^2 = 0.9998$$

Stainless steel, 1.3 mm

$$y = 0.0005x^3 - 0.046x^2 + 13.416x + 10827 \quad (2)$$
$$R^2 = 0.9998$$

Black steel, 1.3 mm

$$y = 0.0003x^3 - 0.0176x^2 + 12.84x + 10927 \quad (3)$$
$$R^2 = 0.9997$$

Black steel, 1.6 mm

$$y = 0.0011x^3 - 0.1199x^2 + 18.636x + 10810 \quad (4)$$
$$R^2 = 0.9993$$

Black steel, 2.2 mm

$$y = 0.00113x^3 - 0.0751x^2 + 26.569x + 10651 \quad (5)$$
$$R^2 = 0.9997$$

Black steel, 1.6 mm

$$y = 0.0012x^3 - 0.1206x^2 + 26{,}52x + 10509 \quad (6)$$
$$R^2 = 0.9997$$

The equation is used as the basis for creating the automated program on the PLC controller. In the automated PLC program, this equation will be used to determine the encoder value for a specific bending angle.

3.1. Automatic Data Validation

Data validation is the process of verifying to ensure that the data created meets the established criteria. The purpose of data validation is to confirm whether the equation for the automated system is accurate, ensuring that the set angle matches the actual bending angle results.

3.2. The influence of plate thickness

The bending data results for black steel with varying plate thicknesses, including 1.3 mm, 1.6 mm, 2.2 mm, and 2.6 mm, are shown below. After the data collection process, the bending results are presented in Figure 5.

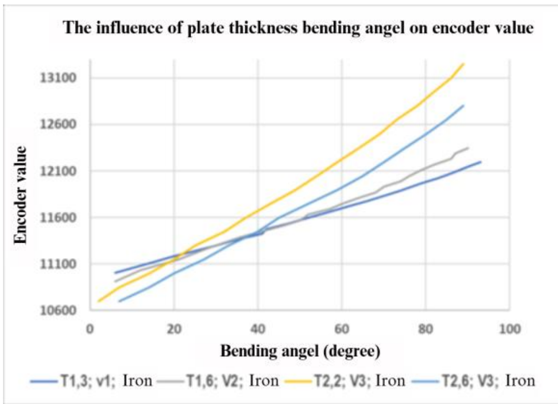

Figure 5. The influence of plate thickness on encoder value

The effect of plate type variation on the bending process, as observed in this study, shows that the punch pressure in the press brake system is higher for black steel plates. This means that the rotary encoder value needs to be greater to achieve the same bending angle compared to stainless steel plates. This can be seen in the graph showing the variation in plate types.

4. Conclusion

The design and development of the automation tool for the sheet metal bending machine, specifically the press brake section, consists of design planning, tool fabrication, component assembly, installation of the automation tool on the sheet metal bending machine, and data collection for use in the automated program. The automated tool on the bending machine operates with two control systems. The first is the manual control system, where the operator inputs the encoder value and lever value and can press the "up" or "down" buttons. The second is the automatic control system, where the operator inputs the bending angle and bending parameters, and the press brake system operates automatically. If the material used in the bending process becomes thicker, the punch pressure required will decrease, or the rotary encoder value will be lower to achieve the same bending angle as with thinner plate thicknesses. This study shows that the punch pressure required in the press brake system is higher for black steel plates. This means that the rotary encoder value must be higher to achieve the same bending angle compared to stainless steel plates.

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Conflicts of Interest:

None.

REFERENCES

[1] Direktorat Statistik Industri, "PERKEMBANGAN INDEKS PRODUKSI INDUSTRI MANUFAKTUR," Jakarta, 2023.

[2] KEMENPERIN, "Industri Manufaktur Semakin Ekspansif," Kemenperin. [Online]. Available: https://kemenperin.go.id/artikel/23125/Industri-Manufaktur-Indonesia-Semakin-Ekspansif

[3] "PERKEMBANGAN INDEKS PRODUKSI INDUSTRI MANUFAKTUR".

[4] *Cost Management in Plastics Processing*. Elsevier, 2018. doi: 10.1016/C2016-0-04874-X.

[5] W. Dick and L. Carey, *The Systematic Design of Instruction*. Virginia: HarperCollins College Publishers, 2009.

[6] W. G. Macpherson, J. C. Lockhart, H. Kavan, and A. L. Iaquinto, "Kaizen: a Japanese philosophy and system for business excellence," *Journal of Business Strategy*, vol. 36, no. 5, pp. 3–9, Sep. 2015, doi: 10.1108/JBS-07-2014-0083.

[7] M. S. Reed *et al.*, "Evaluating impact from research: A methodological framework," *Res Policy*, vol. 50, no. 4, p. 104147, May 2021, doi: 10.1016/j.respol.2020.104147.