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A PRELIMINARY DESIGN OF END EFFECTOR STAMP *CANTING* FOR *BATIK* STAMP AUTOMATED PRODUCTION USING DOBOT MAGICIAN ROBOTIC ARM

Perancangan Awal End Effector Canting Cap untuk Produksi Batik Cap Terotomasi dengan Menggunakan Robotic Arm "Dobot Magician"

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Kata kunci: otomasi, batik, canting cap, produksi, robotic arm

ABSTRACT

The lack of human resources (HR) hinders batik stamp production in Batik Kembang Mayang studio. At the same time, the high demand for batik must be fulfilled by the studio. This study aims to design an automated batik stamp production using the Robotic Arm "The Dobot Magician" as an alternative to achieve batik demand. The design was initiated by developing and testing a canting stamp tool on the Dobot Magician end effector. The development of canting stamp tool uses Quality Functions Deployment (QFD) method. The result showed 16 alternative designs of canting stamp tools based on the interpretation of Kembang Mayang Batik studio needs. Then, it is analyzed by Finite Element Analysis methods to get the proposed canting stamp tool design. The selected design of canting stamp tool has 13 attributes of tool specification. It uses polycarbonate material produced by additive manufacturing or 3D printing. Applying in Robotic Arm "Dobot Magician" showed it can produce a stamp batik.

ABSTRAK

Keterbatasan sumber daya manusia (SDM) menghambat produksi batik cap di sanggar Batik Kembang Mayang padahal permintaan batik yang tinggi harus dipenuhi oleh sanggar. Penelitian ini bertujuan untuk merancang produksi cap batik terotomasi menggunakan Robotic Arm "The Dobot Magician" sebagai alternatif untuk memenuhi permintaan tersebut. Perancangan dilakukan dengan menggunakan metode Quality Functions Deployment (QFD). Hasil penelitian memberikan 16 alternatif desain alat canting cap berdasarkan interpretasi kebutuhan sanggar Batik Kembang Mayang. Alternatif ini kemudian dianalisis dengan metode Finite Element Analysis untuk mendapatkan desain alat canting cap terpilih yang memiliki 13 atribut spesifikasi canting cap. Alat ini menggunakan material polikarbonat yang diproduksi dengan proses additive manufacturing atau 3D printing. Penerapan alat ini pada Robotic Arm "Dobot Magician" terbukti bisa menghasilkan batik cap.

INTRODUCTION

Batik is a process that performs repeated coloring to create a design piece of fabric with traditional tools (Syed Shaharuddin et al., 2021). Batik has three types: *batik tulis* (written batik), *batik cap* (stamp batik), and batik of combination, which is a combination of batik stamp and written batik. In the production process, written batik takes more time than stamped batik. For one lot (110 pieces), written batik takes 6,594 minutes, while stamped batik takes approximately 912 minutes from cutting the cloth to the "*penglorodan*" process (Pratiwa Siregar et al., 2020).

The problem that often occurs today in making batik is the need for more skilled workers. The decrease in expert labor for batik is due to the current generation's lack of interest in batik, so human resources (HR) are significantly reduced in the production of traditional batik. Besides the threads in batik production, there is a hazard risk for the workers. It can harm the surrounding environment, namely health problems caused by heat exposure to wax vapors used in the batik-making process, such as clinical lungs and bronchitis (Dwinugroho et al., 2019).

The design and use of Computer Numerical Control (CNC) is an automation innovation widely developed in batik production, especially stamped batik. Among the research and development carried out by Dwinugroho (2019), Muthi'ah (2018), and Akhmad (2020). Apart from automated production, there is also the development of batik stamp canting materials, such as using a copper electroforming process on acrylic material for batik stamp canting (Setiawan et al., 2020) and bamboo as an alternative to copper replacement material (Lias et al., 2020). Some technological developments still have gaps in automated batik production technology that can increase production capacity while maintaining the batik's originality by the batik's requirements. Based on these conditions, an automated batik production design was developed by applying the Dobot Magician robotic arm technology.

The Dobot Magician (Shenzhen Yuejiang Technology Co. Ltd, 2022) is a desktop four-axis manipulator with an accuracy of 0.2 mm based on an industrial chip. It is installed with different end-effectors and can accomplish functions such as drawing, writing, 3D printing, and laser engraving. The Dobot Magician has been commonly applied in academic research. For instance, Zhang et al. (2019) developed an intelligent system that redecorates Chinese handwriting characters and physically writes in a specified calligraphy style using The Dobot Magician. It used a brush operated by a robotic arm in the end effector section of The Dobot Magician. This research develops the automated batik process by designing and developing Batik Stamp tools in the end effector section of Dobot Magician robotic arm.

Related Works

There is prior research in batik automation that closely relates to this study, as shown in Table 1.

Table 1. Previous Research in Batik Automation

Authors	Object	Output
(Muthi'ah, 2018)	Batik Written	Computerized-Batik using "Batik Kelowong" machine
(Dwinugroho et al., 2019)	Batik Stamped	Automatic Stamp Batik Machine Program with Automation Gripper
(Akhmad et al., 2020)	mBatik, CNC batik technology	Development of a wax applicator for mBatik, a written batik machine
(Setiawan et al., 2020)	Canting Stamped	Acrylic Canting Stamped with Copper Electroforming
(Lias et al., 2020)	Canting Stamped	Bamboo Batik Block

Table 2. Previous Research in Dobot Magician

Authors	Object	Output
(Ai et al., 2018)	Control System	Innovative control system architecture, adept at precisely monitoring the real-time trajectory of a robotic manipulator while maintaining a high level of stability.
(Zhang et al., 2019)	End Effector	Smart Chinese calligraphy of handwritten Dobot Magician robotic arm character
(Yamanaka et al., 2020)	End Effector	A novel robotic hand designed for food handling, capable of efficiently manipulating organic ingredients and swiftly transporting them.
(Tsai et al., 2021)	Drawing System	A pioneering development framework that seamlessly combines image processing and the creation of robot-arm drawings.

RESEARCH METHODS

The process of developing tools in this study is to compile, design, and commercialize tools based on Quality Function Deployment (QFD) methods. The stages of concept selection have two stages to overcome difficulties in evaluating the concept of the product. Concept screening and assessment are the two stages (Ulrich et al., 2020; Wahyuni et al., 2020). The following are the stages in product development carried out in this study.

a. Identifying Customer Needs.
   This study found out and identified the customer needs based on a case study in Kembang Mayang Batik studio. It uses a focus group discussion (FGD) with the batik operator. The discussion results were interpreting user needs into customer needs.

b. Product Specifications.
   Based on the previous result, specifications, and metrics will be determined to determine the needs of the tools to be designed. Then, it creates a need Metric-matrix, which is carried out to identify the relationship between pre-existing metric needs. The result obtained is a list of target specifications containing metrics, marginals, and values for these metrics.
c. Concept Generation.
   Based on the metric specification, this stage explores the concept space to meet customer needs. The design concept had several alternative parts according to the needs and it is mapped through a concept classification tree.
d. Concept Selection and Concept Testing.
   At this stage, various concepts are analyzed and disseminated to identify the most promising concepts, carried out several iterations with the creation of additional concepts and refinement. This study used the Finite Element Analysis (FEA) method to evaluate various concepts.
e. Prototyping.
   This stage is used to create a design or model to be tested with the same properties in form and function before the final product. This study used 3D CAD Modelling and a product prototype based on the final selected concept in the previous stage.

Objects

Batik Kembang Mayang studio is one of the batik producers that will be the object of this research. Several problems occur in Batik Kembang Mayang studio, namely the reduction of human resources (HR) who are experts or understand the process of making batik. In addition to problems regarding employment at the Kembang Mayang Batik Studio, most of the workers in this batik studio are elderly. Even though Batik Kembang Mayang studio lacks human resources (HR), the batik-making process still runs with sufficient capacity. Therefore, one of the alternative measures that will be carried out is to produce automated batik.

RESULTS AND DISCUSSIONS

Identifying Customer Needs

This initial stage uses a Focus Group Discussion (FGD) with the batik operator at Batik Kembang Mayang studio. FGD is divided into four questions: current conditions, things to like, things that are not liked, and proposed improvements in Batik Stamp's production. The discussion results were interpreting user needs into customer needs, and then changing customer needs into a hierarchy by dividing two groups, namely primary and secondary needs, as shown in Table 2. Primary Need is divided into three parts general needs; then secondary needs are obtained from customer needs that have been identified.

Table 3. Primary and Secondary Needs Interpretation

Customer Needs Interpretation	
Primary Needs	**Secondary Needs**
Supporting Tools in Batik Stamped Production	Tools are designed to make it easier the stamped batik process.
	Tools are designed to replace human repetition work.
	Tools are designed to use additional existing batik cap equipment.
Automated System	Tools are designed to carry out the production process automatically with the supervision of 1 operator.
	Tools are designed to have effective and efficient movement.
Ergonomics System	Tools are designed to be safe and comfortable to use.
	Tools are designed to carry out the production process without lifting or moving the batik stamp.
	Tools are designed to carry out the production process without workers having to stand constantly.

Product Specification

The limitations of tool design are based on the dimensions and specifications of Dobot Magician's end effector, as shown below:

- The maximum weight of the tool is 500 grams.
- The tool is designed and integrated with a batik stamp.
- The tool created only has 1 type of motif that cannot be replaced other than changing the tool.
- Motifs of batik stamps are not complicated.
- The size of the batik stamp is limited to a maximum size of 10 cm X 10 cm.

During the initial product specification phase, the primary task involves defining specifications encompassing metrics and units relevant to the requirements of the tool under development(Ulrich et al., 2020). Then identify the need metric matrix to determine the relationship between the primary need, secondary need, and the level of importance and its metrics. The importance level is determined from the result of FGD in the Customer Need Identification stage. This metric then determined the target value for each specification to define and target the proposed tools that suit the needs as shown in Table 4.

Furthermore, mapping the House of Quality (HOQ) to determine the highest value of our importance rating. Figure 1 is the result of HOQ mapping, based on the highest HOQ rating of 136 obtained from the sum of the overall multiplication results of each metric relationship with customer need.

Table 4. Metric List and Specification Units

Need Metric	Importance Level	Unit
Length of Main Body	4	cm
Width of the Main Body	4	cm
Height of the Main Body	4	cm
Design of the Main Body	5	subj
Length of Connecting Part	4	cm
Width of Connecting Part	4	cm
Height of Connecting Part	4	cm
Design of Connecting Part	5	subj
Length of Batik Stamp	4	cm
Width of Batik Stamp	4	cm
Height of Batik Stamp	4	cm
Design of Batik Stamp	5	subj
Total of Weight	5	gram
Materials	5	list

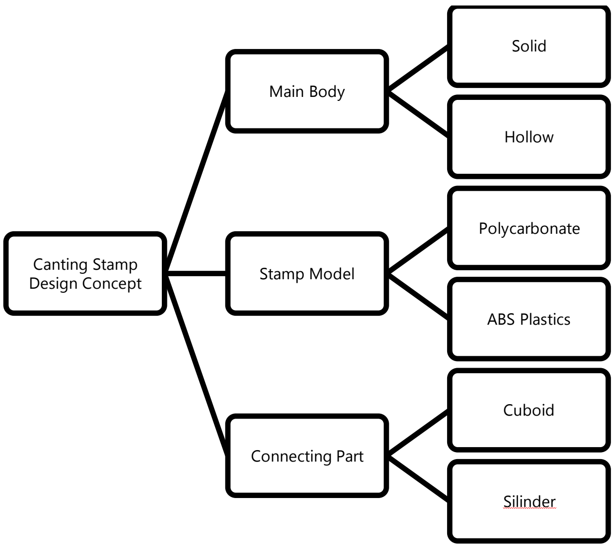


Figure 1. Concept Classification Tree

Concept Generation

The concept generation stage will be carried out to design the concept based on metric specifications, such as the tools, dimensions, and the materials used. Next, create a concept classification tree and map the concepts that will be used to select the best concept. The concept design consists of three parts: main body, connecting parts, and stamp tool. Each of the parts has two alternative designs that are shown in Figure 1 as the concept classification tree.

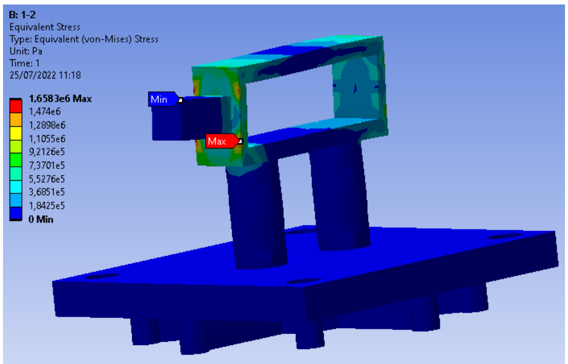
Based on each alternative, there are 16 combinations of concepts in Canting Tool Design as shown in Table 5.

Table 5. Combinations of Concepts

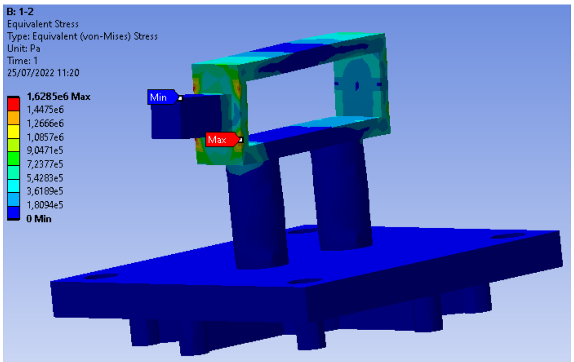
Concept	Main Body	Connecting Part	Stamp Model	Materials
I	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
II	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
III	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
IV	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
V	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
VI	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
VII	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
VIII	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
IX	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
X	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
XI	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
XII	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
XIII	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
XIV	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
XV	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics
XVI	Solid	Cuboid	Single Parts	PC
	Hollow	Cylinder	Two Parts	ABS Plastics

Concept Selection and Testing the Concept

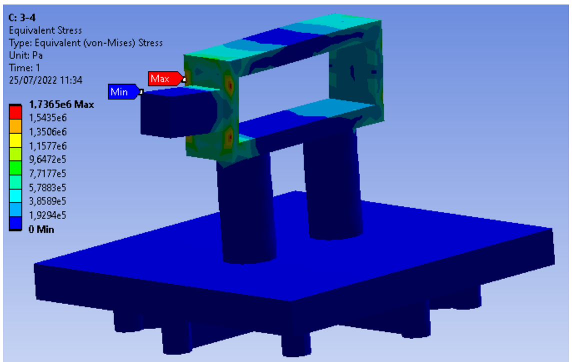
The concept selection and concept testing stages are assessed using the Finite Element Analysis (FEA) method which is simulated in ANSYS software(Ali et al., 2021). Additionally, the aim is to analyze the mechanical strength of concept design to choose the best alternative concept. The result of the FEA simulation is shown in Figure 2.



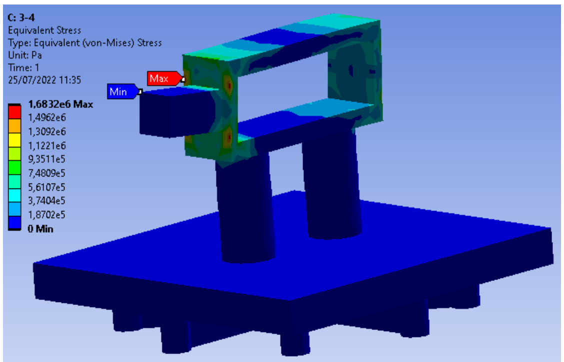
Concept I



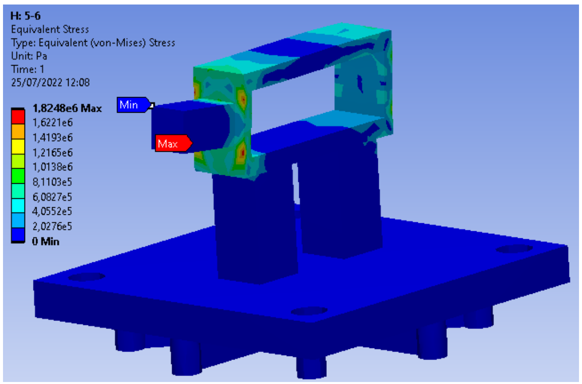
Concept II



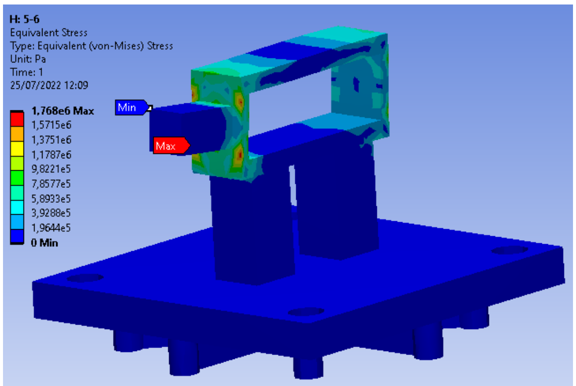
Concept III



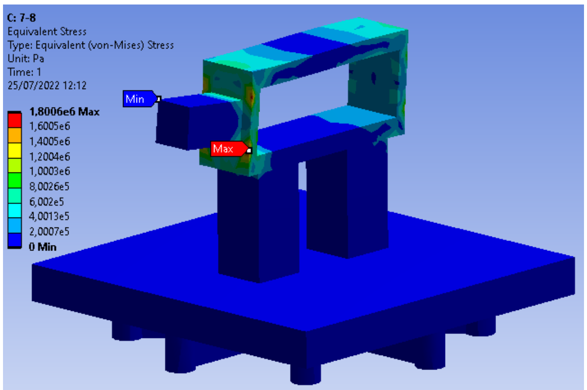
Concept IV

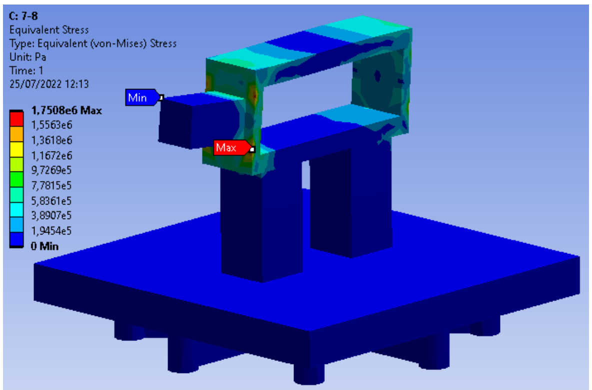


Concept V



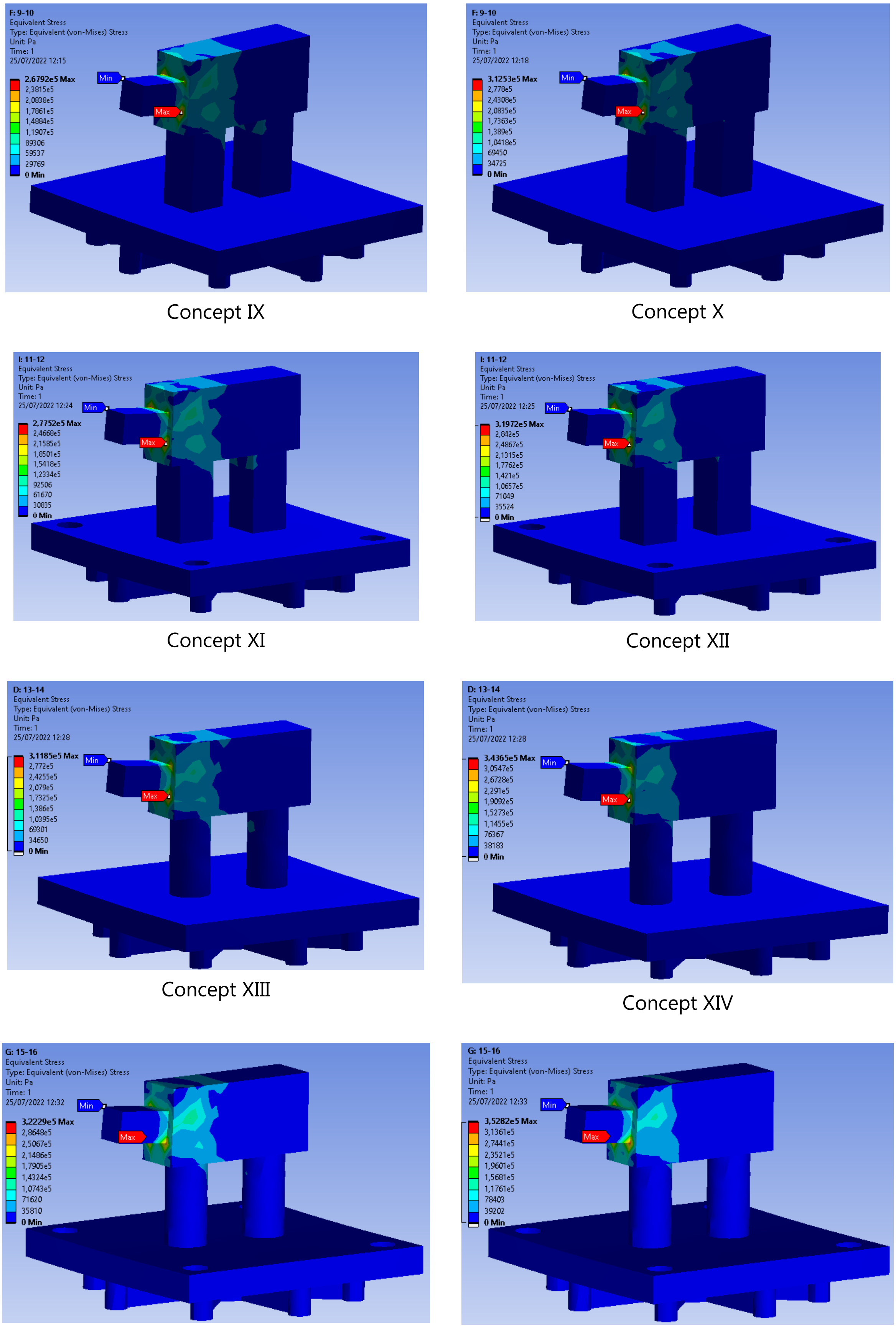
Concept VI





Concept VII

Concept VIII



Concept IX
Concept X
Concept XI
Concept XII
Concept XIII
Concept XIV
Concept XV
Concept XVI

Figure 2. FEA Simulation Results in ANSYS Software

Based on the simulation result shown in Figure 2, it can be noticed that the whole stress is concentrated on the end effector connector to Dobot Magician robotic arm. The region with the highest concentration of the von-Mises stress (joints) reflects the risk of fracture. This result becomes a consideration in concept selection and testing through the matrix screening and scoring concepts to rate the chosen alternative design. The weighting of the criterion comes from the sum of the importance levels of each criterion in the previous stage. Then the average value is converted into a weighted percent obtained from the average divided by the total number of averages multiplied by 100%. Table 6 is a matrix scoring concept table that shows the best ranking table selected is Concept XI with a total score rank of 5.00. It means that Concept XI which has specifications with **a solid main body, cylinder connecting parts, two parts separated stamp model, and polycarbonate material** will be produced using 3D printing method.

Table 6. Matrix Scoring Concept

Matrix Scoring Concept									
Criteria Selection	**Weight**	**Concept II**		**Concept IV**		**Concept XI**		**Concept XII**	
		Rtg	**Ws**	**Rtg**	**Ws**	**Rtg**	**Ws**	**Rtg**	**Ws**
Dobot & Tools facility	28.58	4	1.14	3	0.86	5	1.43	3	0.86
Automated System	35.05	3	1.05	4	1.40	5	1.75	3	1.05
Ergonomics System	36.37	5	1.82	5	1.82	5	1.82	5	1.82
TOTAL	100%	4.01		4.08		5.00		3.73	
Rank		3		2		1		4	
Continue		Yes		No		Yes		No	

Notes:
Rtg : Rating
Ws : Weighted Score

Prototyping

The last stage in this study is prototyping. This study will be used to design services and software that must be designed and manufactured in 3D CAD Modelling. Based on the selected concept of end effector stamp canting, Table 7 shows the detailed specification of Concept XI.

Table 7. Detail Specification of The Selected Concept

Parts	Dimension	
Main Body	Shape	Cuboid
	Length	5.7 cm
	Width	1.8 cm
	Height	2.7 cm
Connecting Parts	Diameter	1.8 cm
	Height	3 cm
	Shape	Cylinder
Batik Stamp	Length	10 cm
	Width	10 cm
	Height	2 cm
	Model	2 Separated Parts
Total Weight		≤ 500 kg
Materials		*Polycarbonate*

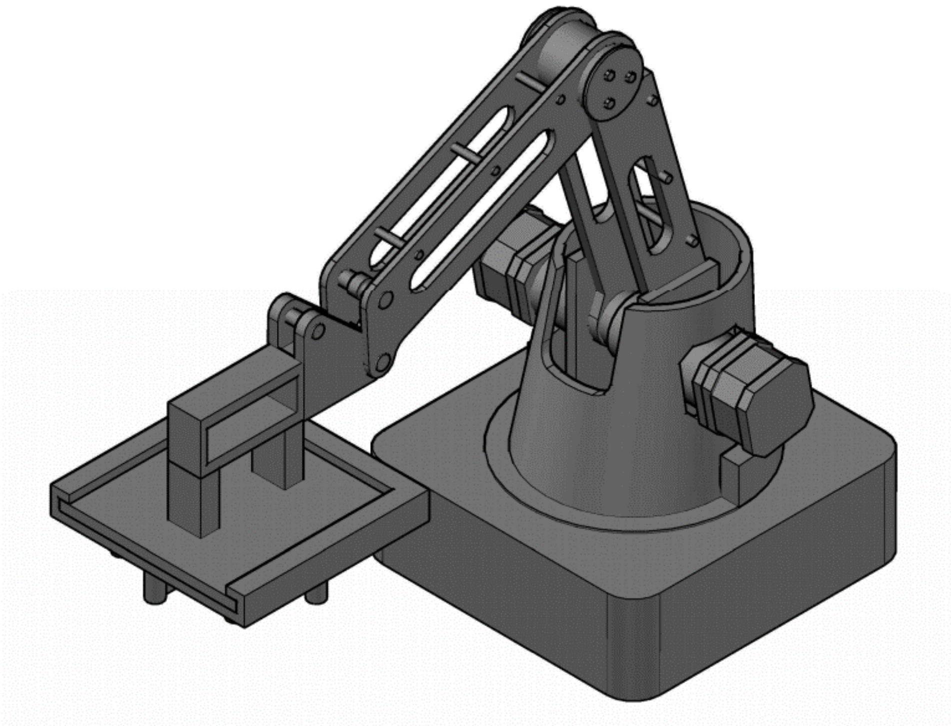


Figure 3. 3D CAD Model of End Effector Stamp *Canting* in Dobot Magician

Figure 3 shows 3D CAD Modelling of end effector stamp canting in Dobot Magician Robotic Arm. Figure 4 shows a viewport and Figure 5 is a 3D plotter of product details of the end effector tool stamp canting selected concept. Figure 6 shows the result of 3D Printing end effector tool stamp canting prototyping where it is used in the Batik Stamp Process as shown in Figure 7.

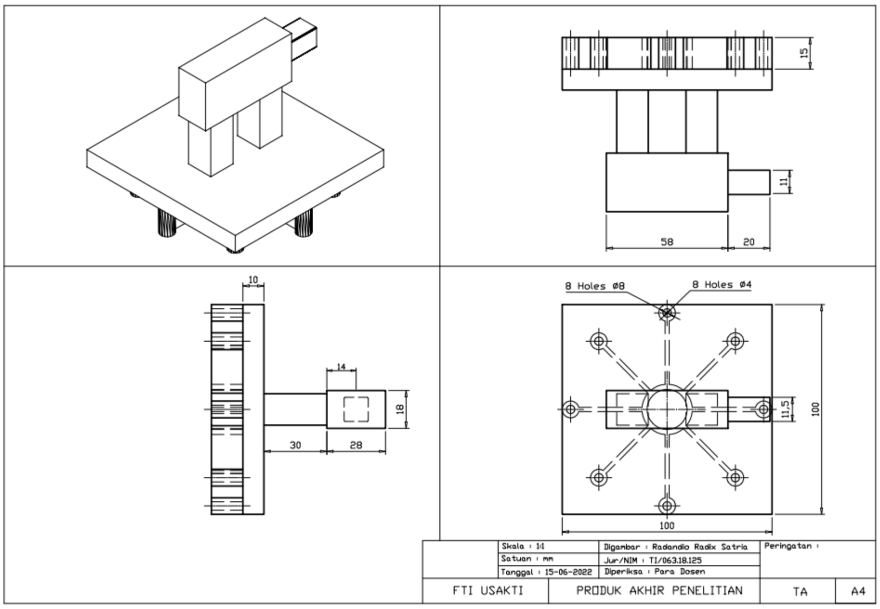


Figure 4. Viewport Product Detail Tool Canting Cap Concept XI

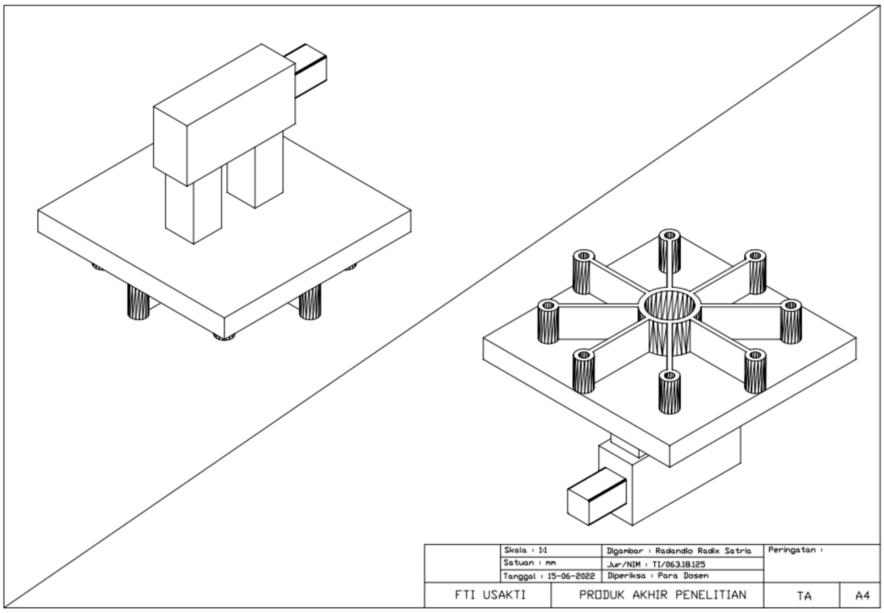


Figure 5. Plotter Product Detail Tool Canting Cap Concept XI

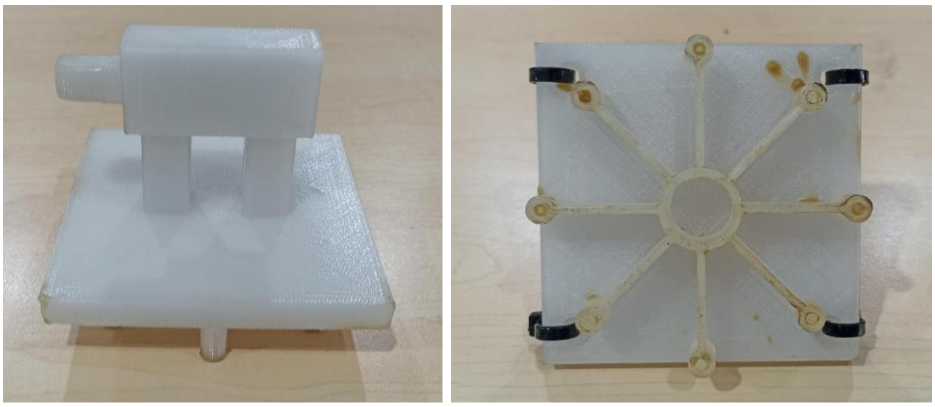


Figure 6. Prototyping of Selected Concept XI

Figure 7. Prototyping of Selected Concept XI in Batik Stamp Process

CONCLUSION

This study develops a preliminary design concept of an end effector batik stamp *canting* tool with **a solid main body, cylinder connecting parts, two parts separated stamp model, and polycarbonate material** that will be produced using 3D Printing. The Quality Function Deployment methods have only been tested in the prototype stage, but the results are promising and can be used to further research in batik automated production.

AUTHOR'S CONTRIBUTION

Conceptualization, I.M., R.S.S., and Y.K.M; methodology, I.M., R.S.S., and A.W.; validation, I.M., and M.I.M.; formal analysis, I.M., A.W., and A.D.A.; investigation, I.M., R.S.S., and Y.K.M.; writing—original draft preparation, I.M., R.S.S., and Y.K.M.; writing—review and editing, I.M., Y.K.M. and A.W.; supervision, I.M., and A.W. All authors have read and agreed to the published version of the manuscript.

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