Investigation of Directly Print Pattern on Synthetic Leather Material

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Abstract: This study aims to conduct research and investigate the direct printing of patterns on synthetic leather. Polyurethane leather (PU), polyvinyl chloride leather (PVC), and leather microfibre are all examples of synthetic leather. The main objective of the study is to determine the feasibility of the ink and printer head used to directly print patterns on the synthetic leather materials and to determine the suitable variation and optimum printing parameter to print patterns on synthetic leather material. However, some disadvantages were discovered, including an unpleasant odour and several health concerns induced by excessive UV radiation exposure. Thus, research is essential to discover and resolve such issues. Therefore, the full factorial design of the experiment method (DoE) was to be conducted by using the Minitab software that is mainly subjected to optimise and identify the significant parameter and level of factor to be used as the printing parameter to obtain the response parameter of line width and pattern edge. Furthermore, for the recommendation of the research, the simulation results can be improved by the application response surface method technique to refine the study and determine the crucial factors for the response variable.

Keywords: Synthetic Leather, Polyvinylchloride Leather, Full Factorial Design, Minitab 19 Software, Line Width, Pattern Edge

1. Introduction

Synthetic leather material historically uses a synthetic organic teal introduced into the world as anionic acid teal in different categories that provide several colours and output characteristics. At London's first International Leather Congress, 1897, the inventor named W.H. Perkins was the first industrialise aniline dye. The Mauve and doubtlessly shared the knowledge of using the new synthetic dyes on the leather's surface [1]. It allows us to directly print on the surface leather using digital printing such as UV printing through new printing technology. The production techniques are applicable to a variety of applications, ranging from interactive posters and journals to luminous packages and printed biosensors [2]. Additive processes indirect printing can be classified as the inkjet process, flexography, screen printing, gravure, and offset technologies [2][3]. The optimum technique needs to be chosen in order to obtain the best result on synthetic leather.

The goal of the research is to determine the feasibility of the ink and printer head used to directly print patterns on the synthetic leather materials and to determine the suitable variation and optimum printing parameter to print patterns on synthetic leather material. The significance of the study to improve research and determine the solution that can be an idea to initiate a new technology for direct printing on synthetic leather printing. The printing parameters' significance in determining the optimum parameters to be used when printing images on synthetic leather. Which can result in quality images printed on synthetic leather. The study is significant to find the optimum input parameter for the design of the experiment using Minitab software. The study's significance is to produce a synthetic leather material printed using a suitable ink that does not have a harmful effect and is environmentally safe for daily life usage.

2. Materials and Methods

2.1 Materials

In this study, the ink's suitability is the most crucial factor printed directly on the surface of the PVC synthetic leather material. As the criteria of the printing ink are being chosen due to the solvent factors, which are economical and environmentally friendly. Besides, the eco-solvent has a most relevant factor that is odourless and can print with accurate colours by using plenty of ink. Besides, the eco-solvent ink is being chosen due to the printer model (Delone Eco-solvent M2-1800) used to print synthetic leather and apply the imported eco-solvent ink. The material of substrate that is used in this experiment is polyvinyl chloride (PVC) synthetic leather. The model of the PVC Synthetic leather is G90G. Choosing the PVC synthetic leather as the substrate is due to the properties that give the specification of the substrate that required. The PVC synthetic leather is also chosen to see the printability of the eco-solvent ink on the substrate using the Delone M2-1800 printer.

Figure 1: Material used for printing process (a) Eco-solvent printing ink (Model: EU3518) (b) Polyvinyl chloride (PVC) synthetic leather

2.2 Pattern Design

The design has been chosen that gives the intricate pattern and simple pattern. The simple pattern gives a simple shape and size to be printed easily without a complicated pattern. Meanwhile, the intricate pattern gives a complex, and the compact pattern is repeated frequently and has multiple functions and illustrations in every pattern. The pattern for Sejadah design was created using SolidWorks software, which revealed the simple and intricate pattern of this project is shown in Figure 2. The detailed drawing for the pattern design is illustrated in Appendix A with the dimension that indicates whether it is intricate or a simple pattern. The intricate pattern is highlighted in the detailed drawing in the shape of circle while, the simple pattern is described in the shape of hexagon. According to the dimensions classified in the detailed sketch, the intricate pattern must be smaller than 5mm in size. Meanwhile, the simple pattern was specified to be more than 5mm in size.
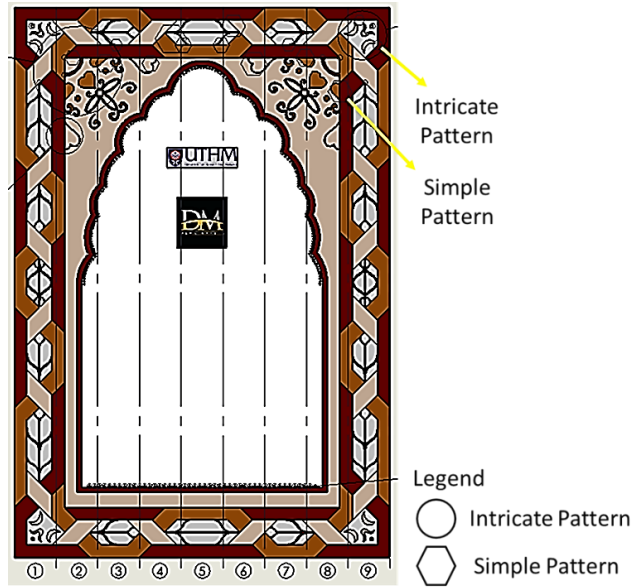
Figure 2: The intricate and simple pattern of Sejadah design

2.2 Methods

The method for this research is illustrated by the use of flow chart to obtain the goal of investigation. The chart begins with designing the flow of experiment with simulation to identify the significant parameter and ideal level of experiment by the full factorial method in Minitab software. The main parameter was chosen to be analyzed further by the initial 4 level of experiment were to set for identifying the significant of the level to obtain the required response parameter. Next, the printing process by the piezoelectric inkjet involves the employment of the printing ink for printing the PVC synthetic leather, which will be the eco-solvent ink and the employment of the optimum input parameter related to the number of pass and printing speed as it gives the significant level and parameter in Minitab software. Delone M2 printer – 1800 transfers the eco solvent ink to the PVC synthetic leather. For the verification of quality for the printed image, a reliability test will be carried out to check whether the image printed meets the criteria required. The smear testing will be done to check the reliability of the printed image. The morphological analysis that will be done to analyse the quality of the printed and cured image. The morphological analysis conducted is the CYMK analysis and the desired pattern edge analysed using the optical microscopic.
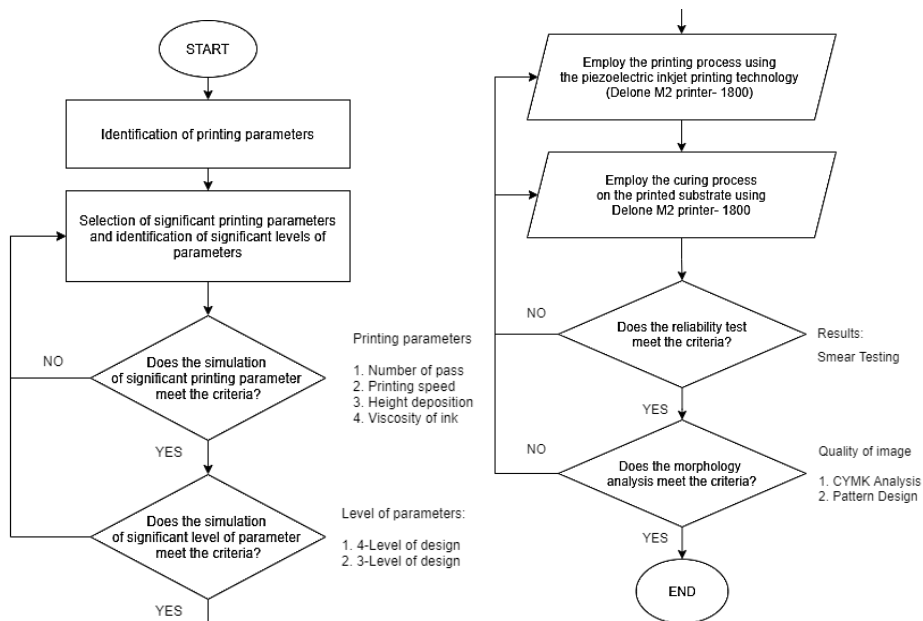

Figure 3: Flow chart of the experiment

3.   Results and Discussion

By comparing the method for the design of experiment, Full Factorial Analysis was chosen as the main technique to conduct the experiment. The advantage of complete factorial method designs is the ability to estimate the main effects of factors and the number of interactions in two by two, three by three, and so on, up to the interaction involving k factors [4][5]. This helps to perform the simulation on Minitab by identifying the significant parameter and level of experiment. Minitab is a software that uses statistical analysis primarily to learn about statistics and to relate to statistical research [6]. Minitab can handle many tasks, from creating graphical and numerical summaries for a set of data to more complex statistical procedures [7]. Table 1 gives the input parameter and the range of the value for each of the parameter.

Table 1: Input parameter and their range of value

Input parameters	Value
Number of pass	Range from 1 – 10
Printing speed (VSD)	Range from VSD 1 – VSD 4
Height deposition of printer head, (mm)	Range from 2 mm – 5 mm
Viscosity of ink, (Pas)	Range from 0.1 Pas – 0.3 Pas
Diameter of printer head, (mm)	Range from 2mm – 5mm

3.1 Result of simulation: Selection of significance of printing parameter

A full factorial method was selected for the screening experiment to optimise printing parameters. For the printing process, the Minitab software was used to identify the right parameters for conducting an experiment. As the listed parameter is analysed using the software based on the quality tools. The response parameters, including line width and pattern edge, were randomly taken from Solidwork drawing as tabulated in Table 2. While Table 3 shows the selected levels of input parameter from the previous research.

Table 2: Response parameters and their settings value

Trial no	Line width (mm)	Pattern edge (mm)
1	41	30
2	5	25
3	50	2
4	5	35
5	1	6
6	27	10
7	35	7
8	1	41
9	25	1

Table 3: Table of level and printing parameter used

Level	Number of pass	Printing speed (VSD)	Height deposition of printer head (mm)	The viscosity of ink (Pas)
1	4	1	2	0.1
2	6	2	3	0.2
3	8	3	4	0.3
4	10	4	5	0.4

The Minitab result was divided into three different observations as it is analysed using Pareto Chart, Main effect plot, and Interaction plot. The analysis is identified either to be fixed as a constant parameter

or input parameter. According to research, says that the insignificance of factor AB can also be demonstrated by examining the normal plot, which emphasises the points that do not lie near the fitted line. The elements that have a minor effect on the output response are typically smaller and close to zero [8]. Figure 4 illustrates that the input parameter of number of pass and printing speed gives the result of statistically significant that the standardised effects of the pareto chart is being exceeded.
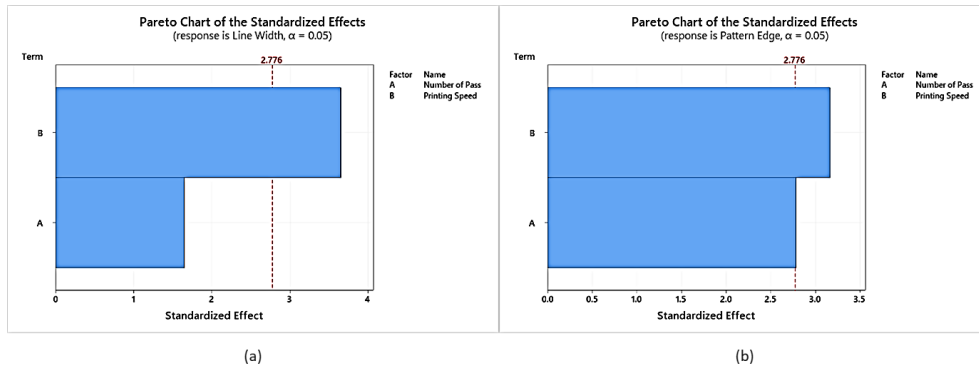

Figure 4: Pareto Chart of input parameter for printing process (a) response of line width (b) response of pattern edge

Based on Figure 5, the factors in the parameter of height deposition and viscosity of ink do need exceed the reference line that eventually will be indicated as insignificant and kept constant for conducting the actual experiment.
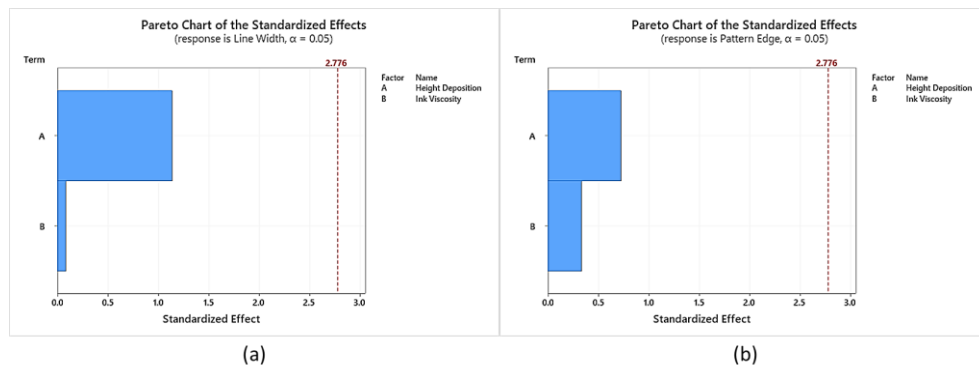

Figure 5: Pareto Chart of constant parameter for printing process (a) response of line width (b) response of pattern edge

Figure 6 shows the main effect plot for line width and pattern edge gives 2 points both for the number of pass and printing speed that exceed the reference line. Hence, the result from the main effect plot is statistically significant. Thus, it can be concluded that the printing parameter of number of pass and printing speed is the optimum parameter to obtain the response of line width and pattern edge.
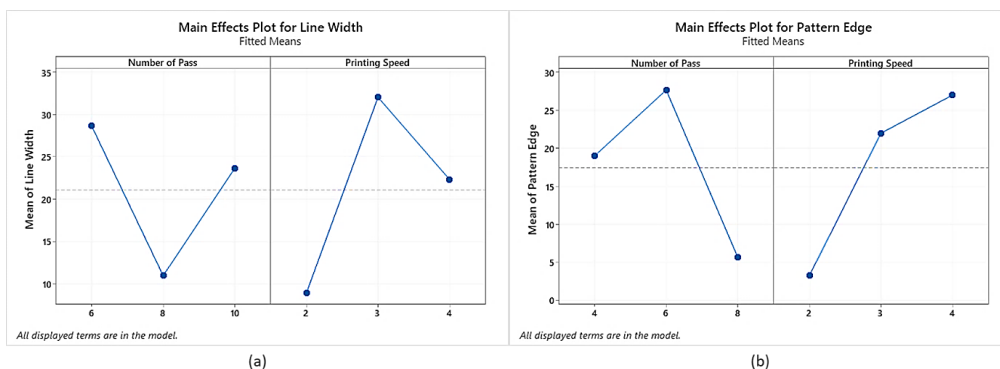

Figure 6: Main effect plot of input parameter for printing process (a) response of line width (b) response of pattern edge

Meanwhile, the parameter of height deposition and viscosity of ink resulted in just 1 point above the reference line for both the response of line width and pattern edge as shown in the Figure 7.
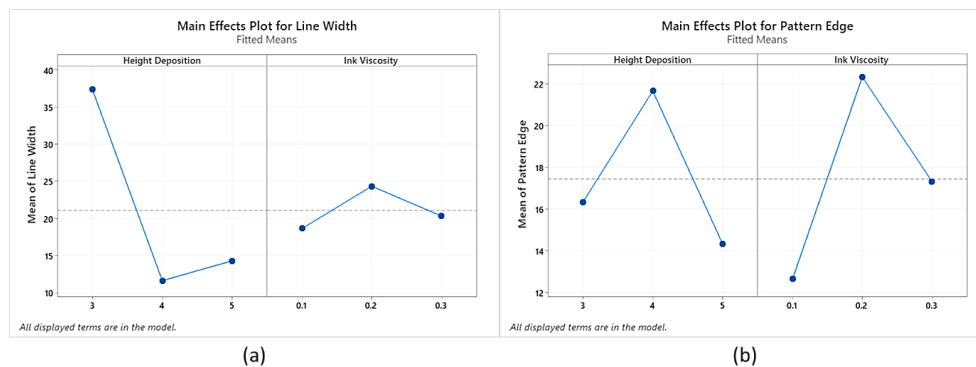

Figure 7: Main effect plot of constant parameter for printing process (a) response of line width (b) response of pattern edge

For the Interaction plot as shown in the Figure 8, the connection between the parameter by forming the interaction shows the important of the parameter for obtaining the response variable. As can be observed from Figure 8 (a), the interaction plot gives much better relation compare to the interaction plot on the Figure 8 (b). Even though the plot gives great interaction of parameter, the significant effect must be tested using an appropriate ANOVA test to check the statistical significance of the parameters [9][10]. According to the result from ANOVA table for the following simulation (refer to Appendix B) that proves the both linear for the response of line width and pattern edge are significant as their p-values are below 0.1.
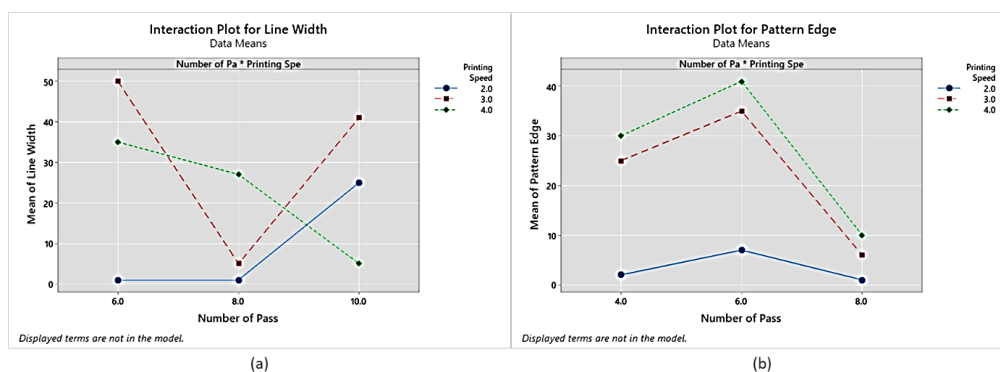

Figure 8: Interaction plot of input parameter for printing process (a) response of line width (b) response of pattern edge

Meanwhile, for the factor of height deposition and viscosity of ink both the Figure 9 (a) and 9 (b) shows a numerous relation between the input parameters. According to the result from ANOVA table for the following simulation (refer to Appendix B) that proves the both linear for the response of line width and pattern edge are insignificant as their p-values are above 0.1.
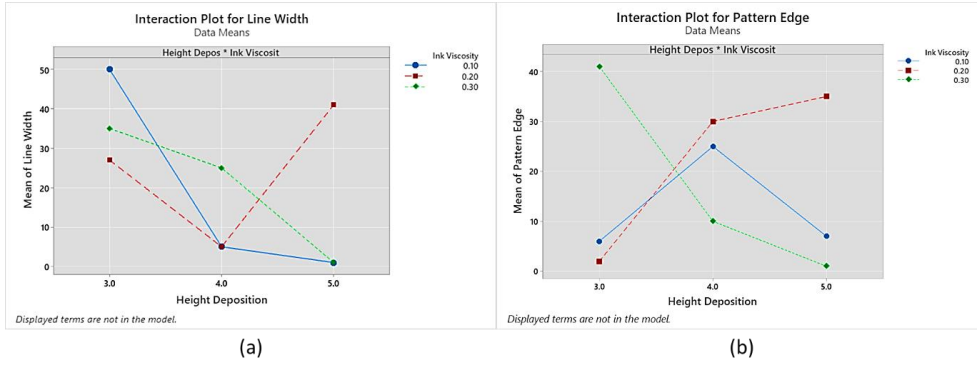
(a)   (b)

Figure 9: Interaction plot of constant parameter for printing process (a) response of line width (b) response of pattern edge

3.2 Result of simulation: Selection of significance level of printing parameter.

Based on the Pareto chart below using the Minitab software, the standardized effect value of number of pass and printing speed both do not exceed the reference line that indicates as statistically insignificant for the response of line width and pattern edge on the 4 levels of experiment.
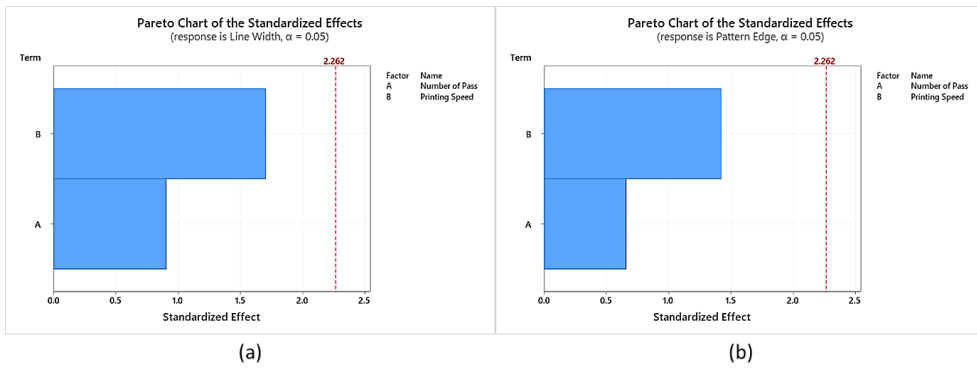

(a)   (b)

Figure 10: Pareto Chart of 4 level of experiment for printing process (a) response of line width (b) response of pattern edge

As for the Interaction plot, the printing speed VSD_1 does not show a proper correlation with other printing speed for both the response of line and pattern edge. Therefore, the 4 levels of experiment are not suitable to be used for conducting the experiment.
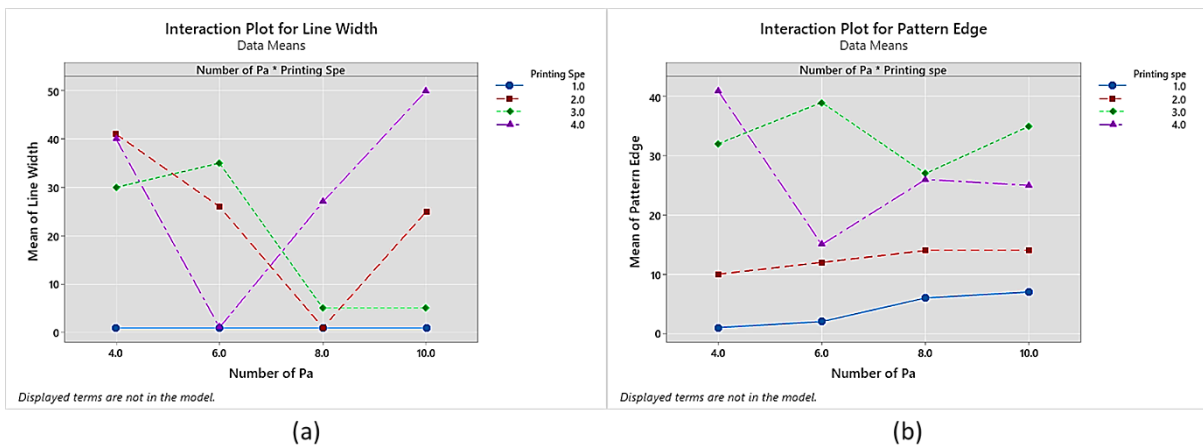

(a)   (b)

Figure 11: Interaction plot of 4 level of experiment for printing process (a) response of line width (b) response of pattern edge

Next, the simulation on 3 levels of a parameter is statistically significant in this experiment, as shown in Figures 4, 5 and 6. Therefore, the experiment will further proceed with the 3 levels of a parameter using pass and printing speed as the input printing parameter.

3.2 Experimental result

In this experiment, two primary printing parameters were chosen and focused on: the number of passes and the printing pass, with the remaining values were to kept constant. There will be 9 distinct samples will be used to conduct and test the parameter selected. The result of the reliability test which include the smear test and the morphological test that it has been done the analysis on the quality of image and by making the colour assessment. The quality of image is done by observing the line width and pattern edge using the optical microscopic image. In the samples, there were not be able to present the result of smear test, observation of colour assessment, and testing the quality of image as the experiment could not be completed due to the Covid-19 pandemic and the government-imposed the Movement Control Order (MCO) closing the industry and material science lab at UTHM. This had an effect on the experiment's outcome and it is recorded on the Table 4 below. It is expected that it will be completed in future study.

Table 4: Table of experiment

Run	Number of Pass	Printing Speed (VSD)	Smear Test (Smear/ not smear)	CYMK Level	Morphological Analysis	
					Line Width (mm)	Pattern Edge (mm)
1		2	N/A	N/A	N/A	N/A
2	4	3	N/A	N/A	N/A	N/A
3		4	N/A	N/A	N/A	N/A
4		2	N/A	N/A	N/A	N/A
5	6	3	N/A	N/A	N/A	N/A
6		4	N/A	N/A	N/A	N/A
7		2	N/A	N/A	N/A	N/A
8	8	3	N/A	N/A	N/A	N/A
9		4	N/A	N/A	N/A	N/A

4. Conclusion

In conclusion, the second objective of determining the optimum variance and parameter for experiment was achieved. However, the first objective is not met due to a constraint to complete and conduct a feasibility study on the ink and printer head that would be used to print patterns on synthetic leather directly. The restrictions caused by the COVID-19 pandemic and the government-imposed the Movement Control Order (MCO) throughout the country resulted in the closure of the industry and material science lab at UTHM. According to the analysis performed with simulation via Minitab, the factor of parameter for printer height deposition and ink viscosity has been adjusted to be a constant variable due to their statistical insignificance. Meanwhile, the other two parameters are configured as the input printing parameters, which include the number of passes and printing speed. The optimal number of passes discovered is 4,6, and 8, while the optimal printing speed is VSD 2, VSD 3, and VSD 4 for printing PVC synthetic leather using eco-solvent ink on a Delone M2-1800 printer.

The study highlighted three main fundamental components of sustainability development: social equity, environmental protection and economic growth. The concept of sustainability was centred on developing solutions for economic and social advancement that avoided environmental deterioration, overexploitation, or pollution, while marginalising less productive disputes over whether to prioritise development or the environment.

Thus, additional research is necessary to gain a better understanding of the printing process. It is recommended that to gain additional exposure on the subject and undertake an experiment to verify the data and conclusions obtained through Minitab simulation by using the response surface design methodolody to refine the models significant factor.

Acknowledgement

Appendix A: Sejadah Design (9 Area Samples)
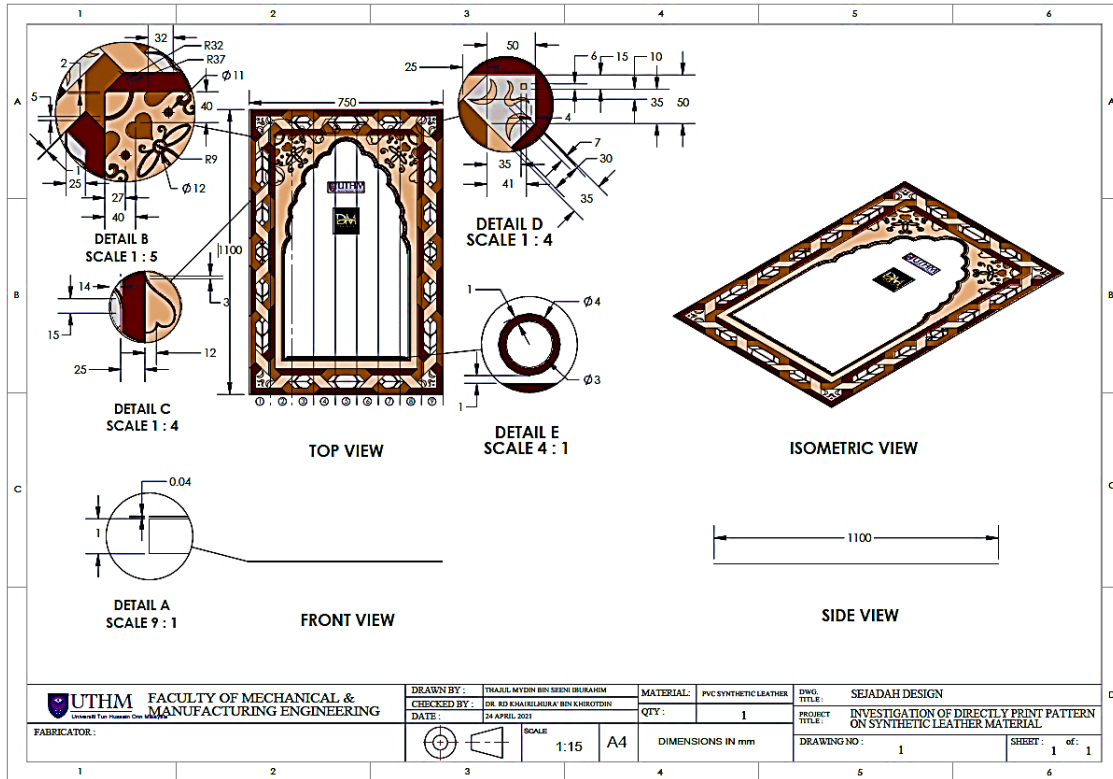
Appendix B: Input parameter ANOVA Table (a) Line width (b) Pattern edge

(a)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	4	2457.8	614.44	7.16	0.041
Linear	4	2457.8	614.44	7.16	0.041
Number of Pass	2	477.6	238.78	2.78	0.175
Printing Speed	2	1980.2	990.11	11.54	0.022
Error	4	343.1	85.78		
Total	8	2800.9			

(b)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	4	1670.4	417.61	7.89	0.035
Linear	4	1670.4	417.61	7.89	0.035
Number of Pass	2	736.9	368.44	6.96	0.050
Printing Speed	2	933.6	466.78	8.82	0.034
Error	4	211.8	52.94		
Total	8	1882.2			

Appendix C: Constant parameter ANOVA Table (a) Line width (b) Pattern edge

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