Optimisation of Printing Process Significant Parameter and Level via Simulation on Printing of Synthetic Leather Substrate

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Abstract: Synthetic leather materials includes polyurethane (PU), polyvinyl chloride (PVC) and microfiber leather is a low-cost material that performs similarly to actual leather in terms of function and orientation and Ultraviolet (UV) printing ink have been seen used widely to print pattern on synthetic leather substrates. However, some disadvantages were discovered, including an unpleasant odour and several health concerns induced by excessive UV radiation exposure. Therefore, research is required to resolve such issues based on the direct printing technique using eco-solvent ink. In this study, a simulation was conducted via Minitab software to characterise and optimise the significant and level of printing parameters for printing process on synthetic leather substrate. This involvement determines the optimal value for both the significant and level of printing parameters that correlate to the line width and pattern edge response values. Four input parameters were identified including number of pass, printing speed, the height deposition of the printer head and viscosity of the ink. The result obtained shows that only number of pass (6,8, and 10) and printing speed (VSD_2, VSD_3 and VSD_4) are statistically significant with 3-levels of design for printing process on synthetic leather substrate.

Keywords: Synthetic Leather, Printing, Simulation

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]. Due to this, 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]. Procedures that are additive direct printing techniques include inkjet printing, flexography, screen printing, gravure printing, offset printing, and UV printing [2][3]. The optimum technique needs to be chosen in order to obtain the best result on synthetic leather.

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It is important to know that when printing on synthetic leather material, the issues that evolved during the printing process must be identified and provide an adequate solutions. UV ink is one of the most versatile and extensively used alternatives, as well as one of the quickest methods of printing on a substrate. But, UV printing ink emits a strong and pungent odour that may be offensive to some and may cause health problems such as skin irritation, minor headaches, and respiratory system irritation [4]. Apart from that, excessive exposure to UV light can have a detrimental effect on our health, particularly on our skin, causing erythema [5]. As a result, this study is important to find the optimal parameter that is acceptable for printing and curing the PVC synthetic leather without compromising the quality of substrate surface.

The overarching aims of the study were twofold: (a) to characterise and optimise significant printing parameters including number of pass, printing speed, height deposition and viscosity of ink via simulation for printing pattern on synthetic leather substrate; (b) to determine the significant factor levels of printing parameters either 3-level or 4-levels of design via simulation for printing pattern on synthetic leather substrate. The significance of the study to determine the feasibility of using the eco-solvent ink for direct printing application on synthetic leather materials. The printing parameters' significance in determining the optimum parameters to be used when printing images on synthetic leather. Eventually, it benefits the production line in the industry by lowering the trial time and level of run, hence increasing productivity and the quality of the image on the substrate. The study is significant to find the optimum input parameter for the design of the experiment using Simulation of Minitab. 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. Designs and Methods

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 1. 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.
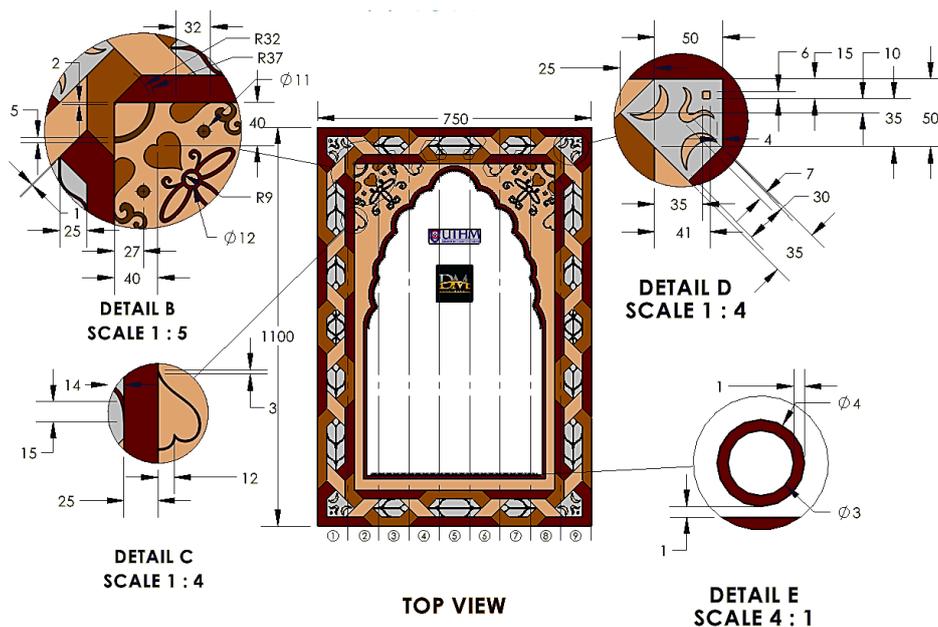

Figure 1: The intricate and simple pattern design on PVC synthetic leather substrate

The Figure 2 below shows the flow chart of the experiment developed to achieve the objective of the investigation. The flow chart begins with the design of experiment (DoE) using the full factorial technique simulation in Minitab software. Thus, before that, the printing parameter has to be identified first to find the optimum value to use in the experiment. The software helps researchers to characterise and determine the optimal input parameter to use as a guideline for executing the experiment and obtaining the required response parameter. Next, the printing parameter of number of pass, printing speed, viscosity of ink and height deposition of the printer head were analysed its significance using the simulation. Then, it was continued with the significance of level of parameter to identify whether the 4-level of design or 3-level of design is suitable for the printing process on PVC synthetic leather. The flow of the study is then ended by obtaining the optimum parameter and level of parameter for the printing process.
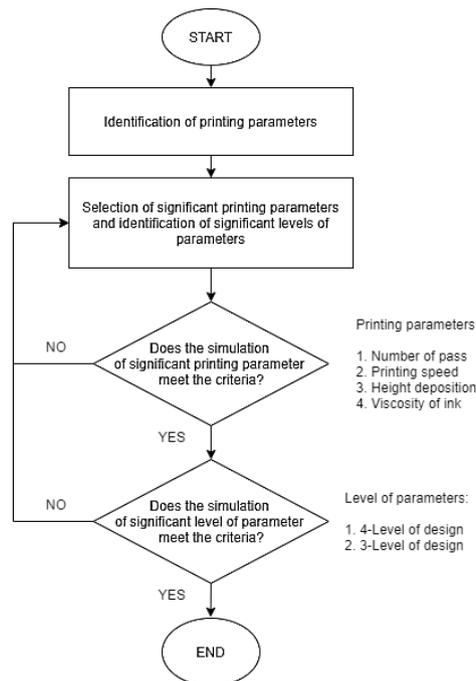
Figure 2: Flow chart

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 [6][7]. 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 [8]. Minitab can handle many tasks, from creating graphical and numerical summaries for a set of data to more complex statistical procedures [9]. 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

3.1 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 [10]. Figure 3 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.
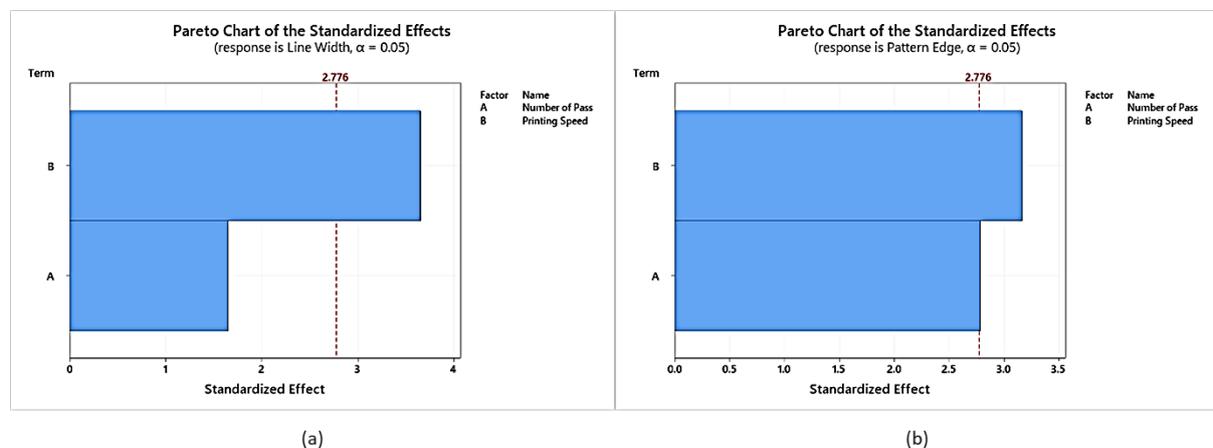

(a)   (b)

Figure 3: Pareto Chart of input parameter for printing process (a) response of line width (b) response of pattern edge

Based on Figure 4, 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.
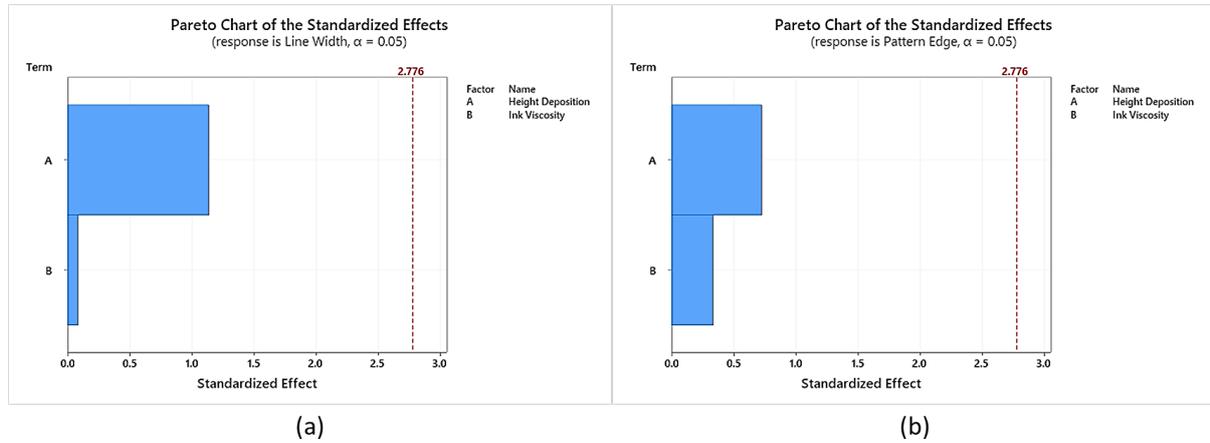

(a)   (b)

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

Figure 5 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.
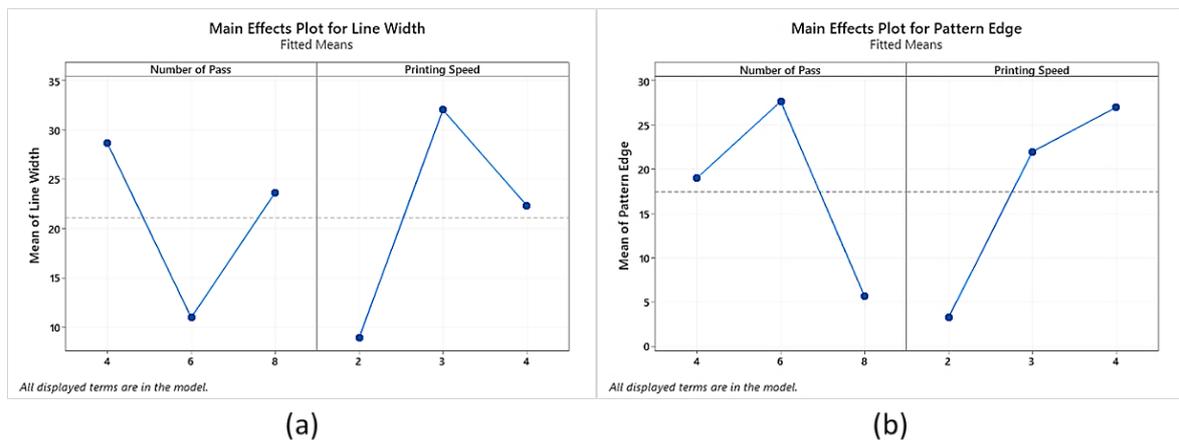

(a)   (b)

Figure 5: 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 6. Hence, the result from the main effect plot is not statistically significant.
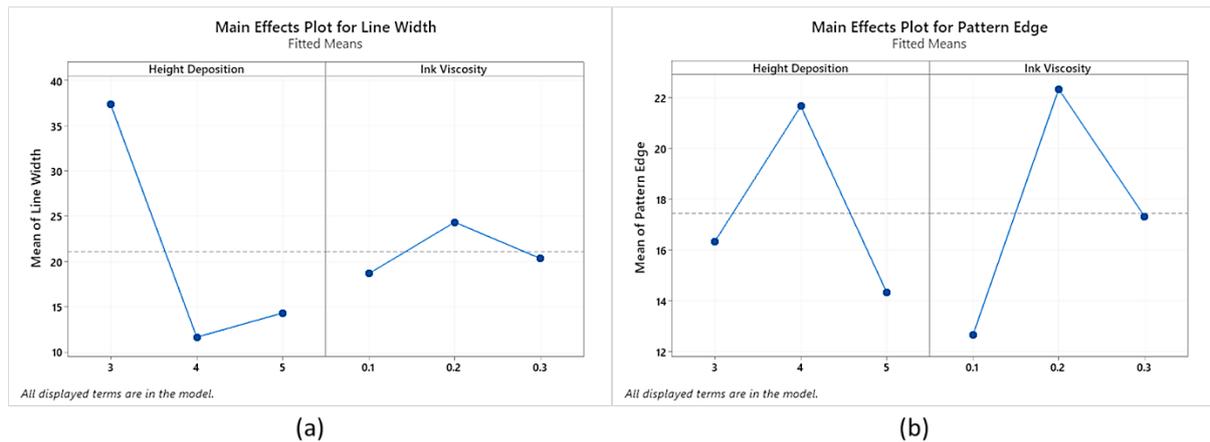
Figure 6: Main effect plot of constant parameter for printing process (a) response of line width (b) response of pattern edge

For the Interaction plot as shown in the Figure 7, 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 7 (a), the interaction plot gives much better relation compare to the interaction plot on the Figure 7 (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 [11][12]. According to the result from ANOVA table for the following simulation that proves the both linear for the response of line width and pattern edge are significant as their p-values are below 0.1.
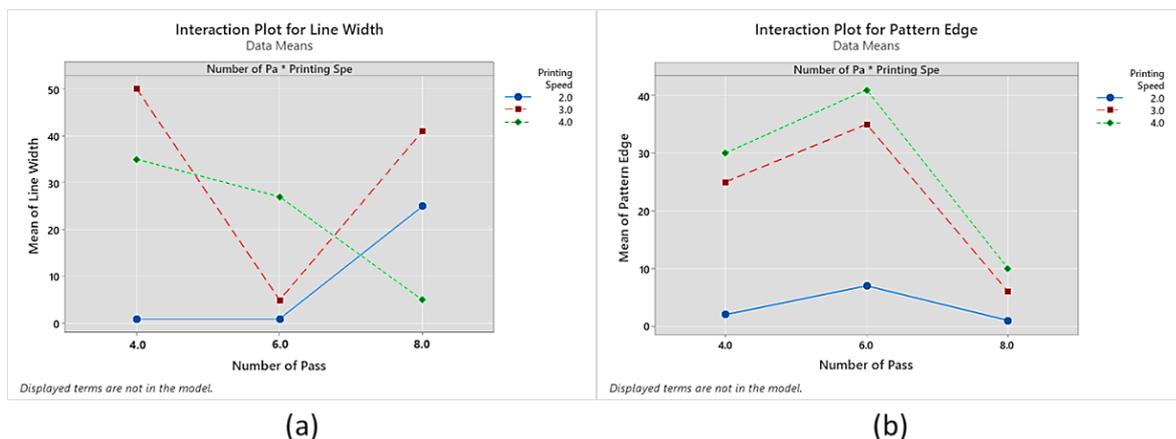

Figure 7: Interaction plot of input parameter for printing process (a) response of line width (b) response of pattern edge

Meanwhile, for the factor of height deposition and viscosity of ink both the Figure 8 (a) and 8 (b) shows a numerous relation between the printing parameters. According to the result from ANOVA table for the following simulation that proves the both linear for the response of line width and pattern edge are insignificant as their p-values are above 0.1.
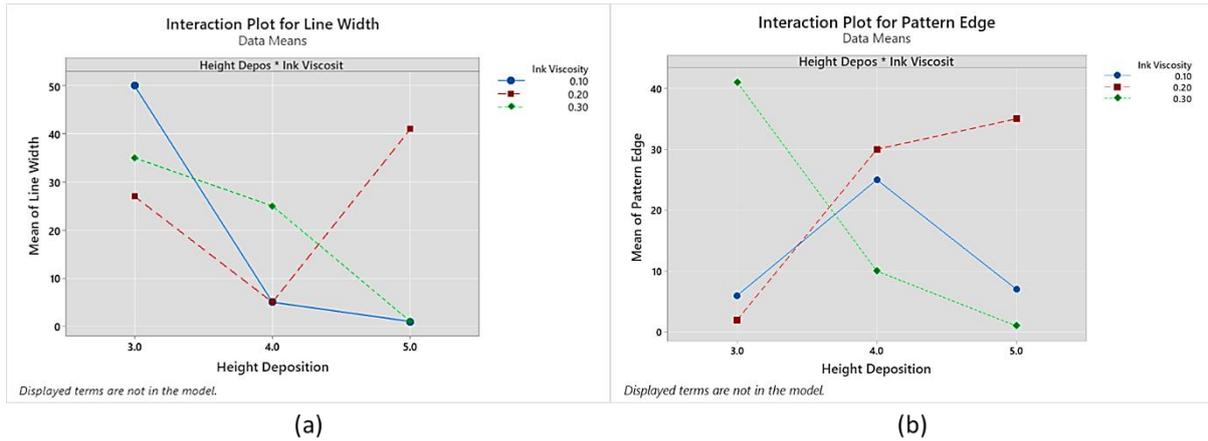
(a)   (b)

Figure 8: 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.
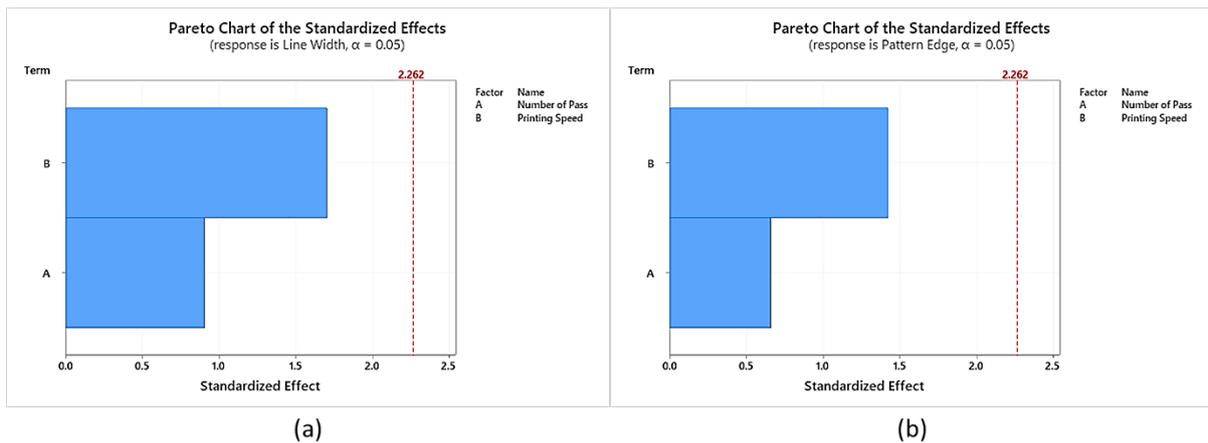

(a)   (b)

Figure 9: 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.
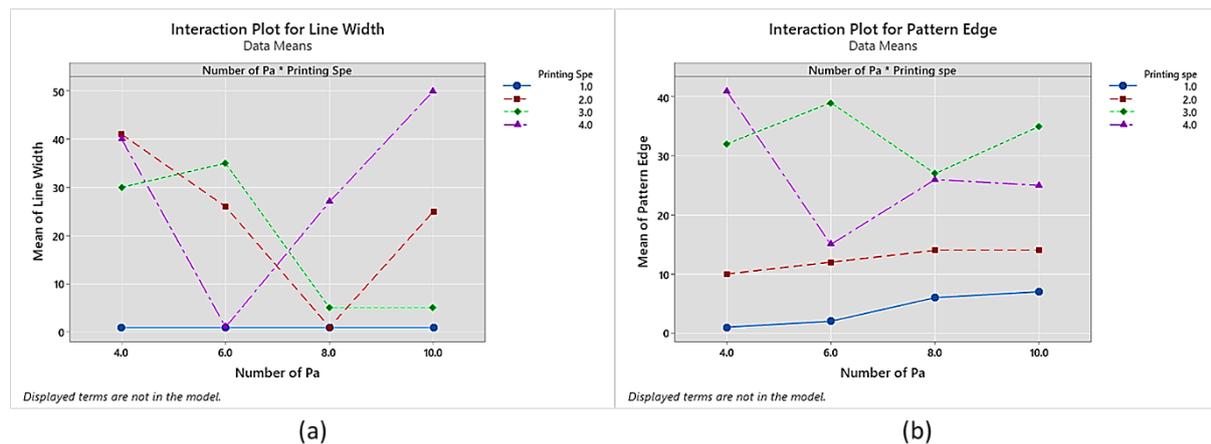
Figure 10: Interaction plot of 4 level of experiment for printing process (a) response of line width (b) response of pattern edge

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.

4. Conclusion

In conclusion, both the objectives of the study were accomplished. The study managed to characterize and optimize the significant printing parameters including the number of pass, printing speed, height deposition and viscosity of ink via simulation for printing pattern on synthetic leather substrate. Besides, the second objective is also met by determine the significant factor levels of printing parameters either 3-level or 4-levels of design via simulation for printing pattern on synthetic leather substrate. According to the analysis performed by simulation, 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. 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 actual 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

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