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A study on a new design of semi-automatic crepe machine to improve Small Medium Enterprise (SME) productivity

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Abstract: This paper presents a study on a new design of semi-automatic crepe machine to improve Small Medium Enterprise (SME) productivity. Currently, the SME's using the manual method to make crepes layer. This method is low efficient because the speed and output production completely depends on human effort and skill. Therefore, a semi-automatic machine has been designed to improve productivity that focusing on crepe layer making process. This machine parts and assembly model were designed in virtual by using SolidWorks 2019. Then, power transmission results have been obtained through analytical referring to specification data of this machine's component such as DC motor, bevel gear and spreader. The output speed, torque and power have been transmitted from motor to spreader during spreading batter on a pan is 50.01RPM, 41.24 Nm, 216 Watt respectively with assumed 90% efficiency. Next, a simulation of transient thermal finite element analysis (FEA) was conducted on spreader with heating to 100°C the contact surface in different temperature by using Solidwork 2019. The variable heating times of 1, 60, 120, 240, 360 and 480 minutes respectively have been used. The simulation result has determined that the maximum heating period for spreader is allowed contact on a hot pan as continuously is a limit to 120 minutes (2 hours). Following the crepe cake process time analysis between of manual, expertise and this semi-automatic machine, the production speed by using Semi-automatic machine contributes 36.8% increase and output in 8 hours production run will provide a 66.7% increase compared to the manual method by a beginner. These results proven this new design of semi-automatic crepe machine able to improve the Small Medium Enterprise (SME) productivity. The added value, this machine proven heat resistant and safe use for the user.

Keywords: Semi-Automatic, Improve, Productivity, Speed, Manual

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1. Introduction

Crepe is a kind of fried bread originated from Brittany, France in the 13th century. Crepes are very flat, thin and round. Currently, crepes are commercialised and sold around the world [1]. Making crepe requires a simple recipe and it is also versatile. The step process starts to prepare the crepe batter. Next, pouring batter on a hot pan and spread the batter forming a thin and even layer using spreader as shown in Figure 1(a). After that, cook the crepe until the top is set then use a spatula to help reverse the flip. Once both sides of the crepe are cooked, remove the crepe from the hot pan for use overcooked. finally, arrange the crepe layers alternately with any spread cream [2] as shown in Figure 1(b). In Malaysia, Small Medium Enterprise (SME) is specialised in making crepes exclusively. It has a high potential to produce high profit as the cost of ingredient is low. Table 1 shows the comparison of characters between traditional, SME such as crepe cake kiosk and Industrial machine. This comparison contributes a gap study to generate the best idea to design a machine or equipment that can help Small Medium Enterprise (SMEs) increase productivity. The making crepe cake process had run by SMEs is similar to the traditional process which is using the manual method. The advantage the SMEs worker is more expertise because they value high productivity for commercial purposes. However, the manual method still requires a lot of manpower energy and skill but productivity results can not be increased. This problem has been identified through observations at Marion Crepes and Crepes21 which is specialised in making crepes and Miles Crepe cake exclusively as well as various small cafes. Besides, a review of crepe cake making process by industrial machine shows the highest production speed. This is because the industrial machine had used automated methods for their entire production process for the large scale industrial production [3]. This method requires high costs and large workspace. It is also very expensive and difficult to move anywhere because of its large size and heavyweight. The weakness from the industrial machine in crepe cake making process unable resolving the SMEs. However, the advantages of using automated industrial machines can partly be used as a reference for generating ideas to create a new machine design. The advantages of this new machine should be lightweight, portable, reasonable cost and use a semi-automatic method. Therefore, a new design of semi-automatic crepe machine has been designed. The characteristic of this Semi-Auto machine is obtained from the design and analysis results in this study.

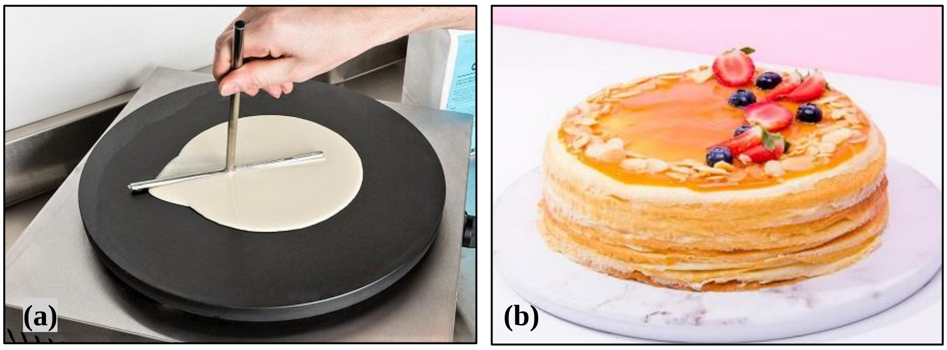

Figure 1: Manual making process for (a) crepe layer and (b) cake [4]

Table 1: Comparison of characteristics for different crepe cake making process

Crepe cake making process / Characteristics	Traditional	Commercial by SME/Restaurant/ Kiosk [1]	Industrial machine [2-4]	Semi-Auto machine
Method	Manual for beginner	Manual for expertise	Automatic	Semi-Automatic
Production location	Home	SME/Kiosk / Restaurant	Industry	SME/Kiosk /Reastaurant
~~Perpose~~ (purpose)	Personal use	Business	Business	Business
Drives	By hand	By hand	DC motor	DC motor
Capacity/ layer (second)	60	50	0.75	41.2
Manpower (person)	1	3 to 4	1	1
Tool Cost (RM)	20	20	252,285	150
Height (meter)	0.175 (total height of pan and spreader)	0.175 (total height of pan and spreader)	1.57 (heigh of machine)	0.3 (height of machine)
Weight	136.5 gram (Spreader)	136.5 gram (Spreader)	1000 kilogram (machine)	5 kilogram (machine)

2. Materials and Methods

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study. In this paper, the methods only presenting for virtual design and suggestion material for fabrication.

2.1 Suggestion of materials

Table 2 shows the suggested materials for future fabrication for Semi-auto crepe machine. These materials were selected referring their ability and suitability to each machine part in terms of character and function.

Table 2: The suggested materials for machine part

Item	Materials	Machine Part	Characteristic and function
1	Stainless Steel	Spreader and bowl	High corrosion resistance and safety for food contact
2	PLA Plastic	Centrifugal pump, Casing	Safety for food contact
3	Silicon	Tube	Safety food contact. Appropriate as batter transferring tube
4	Carbon Steel	Bolt and nut	Good toughness and ductility for part joining
5	Mild Steel	Square bar, Support rib and frame	Good ductility and weldability.

2.2 Method to design the machine part by using SolidWorks 2019

The virtual parts design of semi-automatic crepe machine's parts were established by using SolidWorks 2019 software [5] as shown in Figure 3.1 (a-f). The virtual design is categorised into two main parts, the machine and the batter dispenser. The part design of the machine starts by drawing the spreader as shown in Figure 3(a). The spreader was sketched using circle and use extruded features to a certain thickness. Then, a direct current motor part is added as shown in Figure 3(b). Next, the casing used to encase the motor and gear as shown in Figure 3 (c). Furthermore, the support parts such as a square bar with diagonal support rib and base have been drawn. Figure 3 (d) shows a square bar is drawn by sketching lines to form a square shape then use extrude feature to a certain height. Holes are added on the square bar by using the extruded cut feature. Then, the bevel gear is drawn by using the template provided by the software toolbox library feature. The specifications of the gears are also edited such as a number of teeth, module, face width and so on as shown in Figure 3 (e-f). Figure 3(h) shows the diagonal support rib is drawn by sketching a base and use extruded features to a certain thickness. Figure 3(i) shows a box as a frame for the pump was created by sketching a rectangle shape then extrude feature to a certain height. Holes are added to the top and front surface with a position that corresponds to holes from part of the shell of the centrifugal pump by using the extruded cut feature. Next, Figure 3(j) shows a bowl was designed by sketching line and also spline to form a shape with the edges and the bottom forming a seamless curve then use revolve feature. Shell feature used to create a thin-walled. The hole is added on the surface of the bowl by using the extruded cut feature. Then, the transferring tube part is drawn by using circle and spline with appropriate size then use swept boss to create a solid feature. Next, use a swept cut feature to cut a solid model to get a certain size thin-walled. Next, the tube was changed into the transparent surface as shown in Figure 3(l). Next, the part design of the batter dispenser starts with the motor of the pump. The methods used to draw the motor of the pump is the same as the motor for the machine. Then, the centrifugal pump is drawn. The outer part of the pump is drawn by drawing circles and use extruded features to a certain thickness as shown in Figure 3(m). Lastly, the impeller fan is added from the template SolidWorl library tool as shown in Figure 3(n).

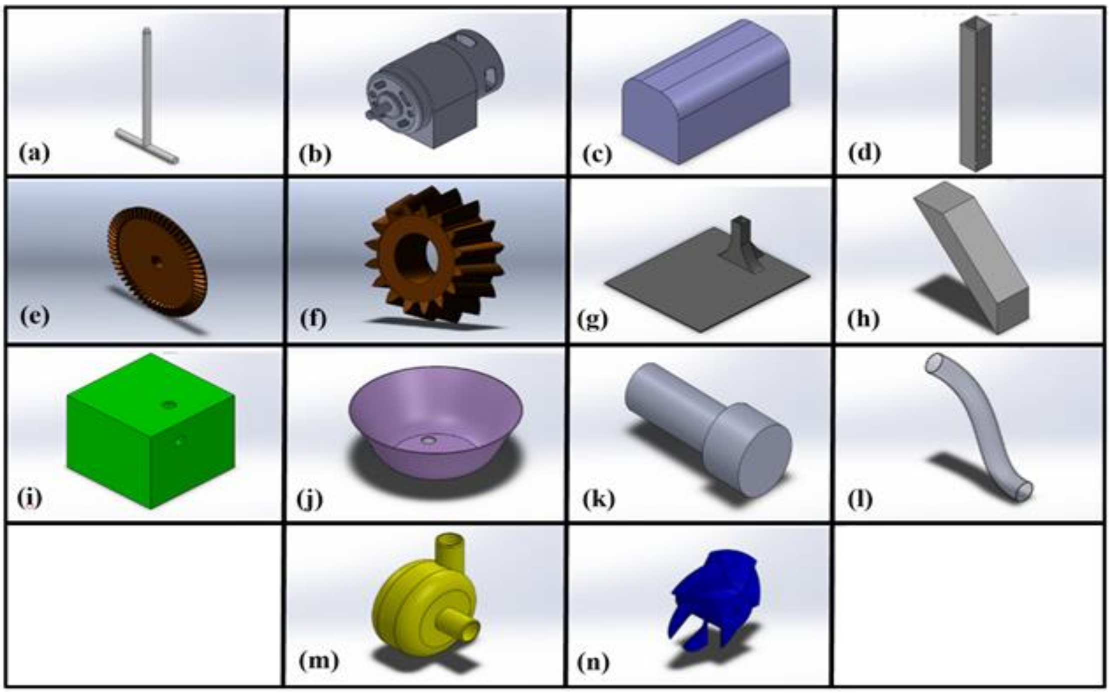

Figure 3: Machine parts by Solid Work 2019 (a)spreader, (b) DC motor, (c) Casing, (d) Square bar, (e) Bevel gear, (f) Pinion bevel gear, (g) Base, (h) Support rib, (i) Frame, (j)Bowl, (k) Fastening pin, Transferring tube, (m) Centrifugal pump, (n)Impeller fan

2.3 Assembly part of Semi-auto crepe machine

Figure 4 shows the assembly part and exploded view of Semi-auto crepe machine in SolidWorks 2019. Then, the parts function were described according to Table 3

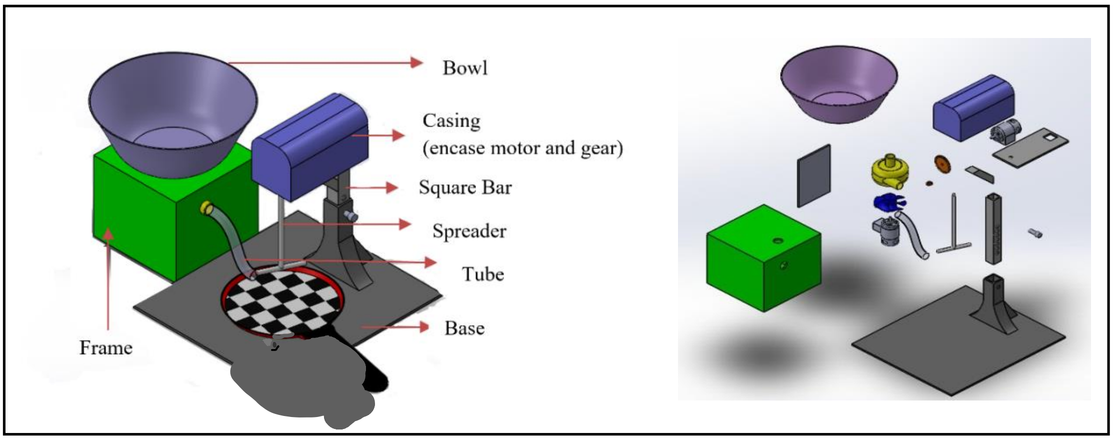

Figure 4: Assembly part of Semi-auto crepe cake machine

Table 3: Parts description of Semi-auto crepe machine

Item	Parts	Description
1	Bowl	To store batter
2	Casing	Encase the gear and direct current motor
3	Square Bar	Provide support to the casing
4	Spreader	To spread the batter on the pan
5	Base	Provide support to the machine
6	Tube	To transfer batter from bowl to hot plate
7	Frame	To encase the centrifugal pump and direct current motor

2.4 Equations

The following equations are used to obtain the result of the value of rotational velocity, torque and power [6] of Semi-auto crepe machine.

$$\text{Circumference one layer crepe, } s = 2\pi r \qquad \text{Eq. 1}$$

Linear velocity,

$$\text{Linear velocity, } v = \frac{circumference\ plate}{time} \qquad \text{Eq. 2}$$

$$\text{Angular velocity, } \omega = \frac{\theta}{t} = \frac{2\pi r\,(rev)}{t\,(s)} \qquad \text{Eq.3}$$

$$\text{Rotation speed, } N = \frac{60 \times \omega}{2\pi} \qquad \text{Eq.4}$$

$$\text{Gear ratio, } n = \frac{\text{Number of teeth Gear}\,(t_g)}{\text{Number of teeth Pinion}\,(t_p)} = \frac{\text{Speed Pinion}\,(N_p)}{\text{Speed Gear}\,(N_g)} \qquad \text{Eq.5}$$

$$\text{Power, } P = \tau\omega \qquad \text{Eq. 6}$$

$$\text{Percentage of Power Efficiency, } \eta = \frac{\text{Output Power}}{\text{Input Power}} = \frac{P_{out}}{P_{in}} \qquad \text{Eq.7}$$

3. Results and Discussions

3.1 Power transmission result

Power transmission result of Semi-auto crepe machine was obtained by analytical referring to machine components specification such as DC motor, bevel gear and spreader as shown in Table 4. In this study, the DC motor and gear are considered as input drive, while pinion and spreader as output drive. During the crepe making process, the spreader with 18.9 cm length is rotated 360º (2θ) on a hot pan. The time is taken for the spreader to spread batter in one rotation until it becomes a layered crepe is 1.2 second. Following eq. 1, the 0.595m value of circumference crepe layer has been obtained. The output linear and angular velocity of spreader was computed from eq.2 and eq. 3 gives a value result of 0.486 m/s and 5.237 rad/s respectively. Next, eq.4 was used to determine the output rotation speed of spreader and the value is 50.01 RPM. In the determination of power transmission result, a set bevel gear is used with the number of teeth for gear and pinion is 40 and 15 respectively. Following that, the 2.5 gear ratio has identified from eq.5 and it was used to obtain the input rotation speed. Hence, the required value of the input rotation speed of the motor is 20 RPM. Knowing that in the power of the motor is 240 watt. Therefore, the input torque can be calculated by eq.6 and gives 114.59Nm of the result value. In this situation, the motor efficiency was assumed at 90%. Referring eq.7, the 216 Watt of power has been transmitted to spreader during rotation. Meanwhile, the output torque value is 41.24 Nm. Table 5 shows all these power transmission results has been specified. Following this result, the Semi-auto crepe machine must require a speed controller to reducing the input speed. It happened because, during batter spreading, it required relatively low speed to spread the batter evenly and also avoid splashing.

Table 4: Semi-auto crepe machine component specifications

Item	Part	Specification	Symbol	Value or Type		Unit or Dimension or material
1	DC Motor	Power	P	240		Watt (W)
		Voltan	V	24		Volts(V)
		Current	A	10		Ampere(A)
		Mass		500		grams(g)
		Maximum Speed		1000		Revolution/minute (RPM)
2	Bevel Gear	Material		-		Steel BS970
		Model		Straight moulded		MB 10-2.5X-S
		Module	m	1		-
		Face width		6		millimeter (mm)
		Pressure angle		20		Degree (º)
		ratio	n	2.5		
				Gear	Pinion	
		Number of teeth	t_g, t_p	40	16	millimetre (mm)
		Outside diameter,	$\varnothing_{out}$	17.86	40.74	millimetre (mm)
		Pitch diameter	$\varnothing_{pitch}$	40	16	millimetre (mm)
		Reference cone angle	δ	68.199	21.801	Degree (o)
		Cone distance	R	0.675		millimetre (mm)
3	Spreader	Height		25		centimetre (cm)
		Length		18.9		centimetre (cm)
		Diameter		0.75		centimetre (cm)
		Weight		136.65		gram (g)

Table 5: Power transmission value result of machine

Item	Parameter	Symbol	Input (Motor)	Output (Spreader)	Unit
1	Linear velocity	v	-	0.496	Meter per second (m/s)
2	Angular velocity	ω	2.094	5.237	Radian per second (rad/s)
3	Rotation Speed	N	20	50.01	Revolution per minute (RPM
4	Torque	τ	114.59	41.24	Newton meter (Nm)
5	Power	P	240	216	Watt (W)

3.4 Transient Thermal FEA Analysis of Heating ~~up~~ Spreader.

Through finite element analysis (FEA) using Solidwork simulation, transient thermal analysis of heating the spreader on a pan with different time has been run. AISI 321 Annealed Stainless Steel (SS) was selected as spreader's material. The material properties have been generated after applied the material on the solid part of the spreader. All the parameter value is automatically computed by SolidWorks referring on a part designed and material applied. After meshing part, the parameter value was generated as shown in Table 6.

Table 6: Material properties of AISI 321 Annealed Stainless Steel (SS) in Linear Elastic Isotropic Model type

Item	Parameter Name	Variable Value	Unit or Dimension
1	Thermal conductivity	16.1	W/(m.K)
2	Specific heat	500 J	J/(kg.K)
3	Mass density	8,000	kg/m^3
4	Mass	0.136589	Kilogram (kg)
5	Volume	1.70736×10^5	m^3
6	Weight	1.33857	Newtons (N)

The transient thermal finite element analysis (FEA) by using the simulation study feature in SolidWorks 2019 was conducted on spreader with heating to 100℃ the contact surface in a different time. In this study, the variable heating times of 1, 60, 120, 240, 360 and 480 minutes respectively have been used. Figure 5(a-f) shows the profile image results of the heat distribution of spreader after running on the heat in a variable time. The temperature 100ºC was applied along the lower part of the spreader, which is the contact surface on the pan. Next, the changes in temperature value have been plotted and analysed at eleven points apart from bottom to top of the spreader and it is called as the elements of plot level. This data is measured at the same distance because the spreader material of AISI 321 Annealed Stainless Steel (SS) was considered in linear elastic isotropic. In this situation, the mechanical and thermal properties are the same in all direction. [7]. Therefore, the temperature is consistently changing by the distance along the part body. Table 7 shows the result data of this analysis in FEA simulation and for a graph. Following that, the temperature changes is 35.52, 13.73, 14.59, 0.51, 0.06, 0.001 (ºC) for different heating time of 1, 60, 120, 240, 360 and 480 (minutes) respectively has been obtained.

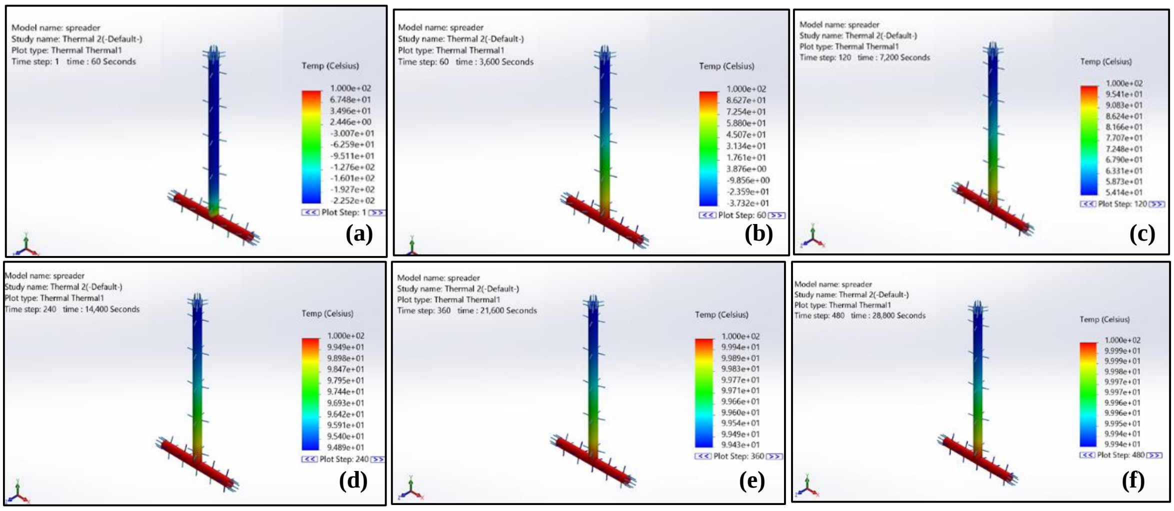

Figure 5: Thermal transient FEA analysis of image profile for 100°C heating up on pan in a different time, (a) 1 minute, (b) 1 hour, (c) 2 hours, (d) 4 hours, (e) 6 hours, (f) 8 hours

Table 7: Data of FEA analysis in Solidwork simulation and for graph

Stage	Variable Time (minutes)											
	1		60		120		240		360		480	
	FEA	Graph	FEA	Graph	FEA	Graph	FEA	Graph	FEA	Graph	FEA	Graph
1	100	100	100	100	100	100	100	100	100	100	100	100
2	67.48	67.48	86.27	86.27	95.41	95.41	99.49	99.49	99.94	99.94	99.999	99.999
3	34.96	34.96	72.54	72.54	90.83	90.83	98.98	98.98	99.89	99.89	99.999	99.999
4	2.446	2.446	58.8	58.8	86.24	86.24	98.47	98.47	99.83	99.83	99.998	99.998
5	-30.07	0	45.07	45.07	81.66	81.66	97.95	97.95	99.77	99.77	99.997	99.997
6	-62.59	0	31.34	31.34	77.07	77.07	97.44	97.44	99.71	99.71	99.997	99.997
7	-95.11	0	17.61	17.61	72.48	72.48	96.93	96.93	99.66	99.66	99.996	99.996
8	-127.6	0	3.876	3.876	67.9	67.9	96.42	96.42	99.6	99.6	99.996	99.996
9	-160.1	0	-9.856	0	63.31	63.31	95.91	95.91	99.54	99.54	99.995	99.995
10	-192.7	0	-23.59	0	58.73	58.73	95.4	95.4	99.49	99.49	99.995	99.995
11	-225.5	0	-37.32	0	54.14	54.14	94.89	94.89	99.43	99.43	99.994	99.994
Temperature changes value	32.52		13.73		4.59		0.51		0.06		0.001	

Figure 6 shows the temperature changes at a different time as graphically. The graph shows the temperature changes is fell drastically from 1 until 120 minutes heating period. While, from 240 to 480 minutes, it shows remained flat. Therefore, these can confirm that after 240 minutes (4 hours) the spreader is heated on 100°C, the temperature changes were found to decrease. This implies that the heat is almost completely transferred at the top of spreader. Figure 7 shows a graph of temperature changes at the elements plot level of spreader from the lower part (contact surface) to top (end of the rod). The graph displays the temperature is shrank drastically to 2.446°C at plot level 4 and then levelled off. This is because, in a short period of heating time, a lot of temperature changes has been occurred, however only a small part the heat is an able transfer on the spreader. Hence, at plot level 5 to 11 it was found that no heat transfer occurs. This condition continues to happen when the heating period increases to 120 minutes (2hours). The minimum temperature for 60 minutes heating period was recorded 3.879°C at plot level 8. While, at the 120 minutes heating period, the 54.14°C minimum temperature was recorded at the end of plot level. After that, the result shows the above 240 minutes heating period, the temperature seems to be constant along with the elements plot level. This happens because the heat is completely transferred to the top of spreader. Consequently, the temperature reaching to maximum can be read at the 11^{th} plot level. Base on these analysis results, the maximum heating period for spreader can contact on a hot pan as continuously is only limit to 120 minutes (2 hours). However, the making process of one layer crepe just taking time only 1.2 seconds. Thus, the continuously heating condition on spreader has not occurred. Nevertheless, these results managed to generate a specification on this machine in future in terms of temperature resistance limit.

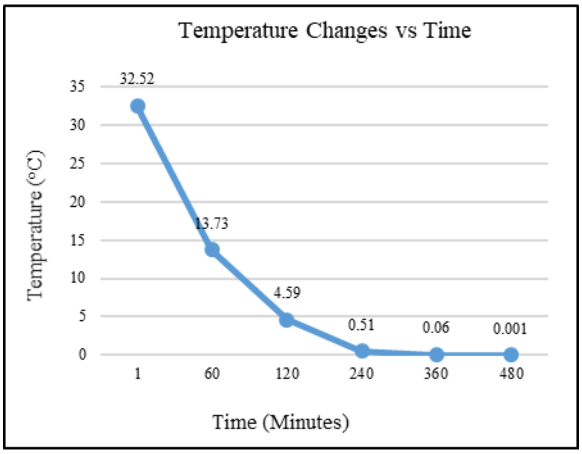

Figure 6: Temperature Changes vs Time

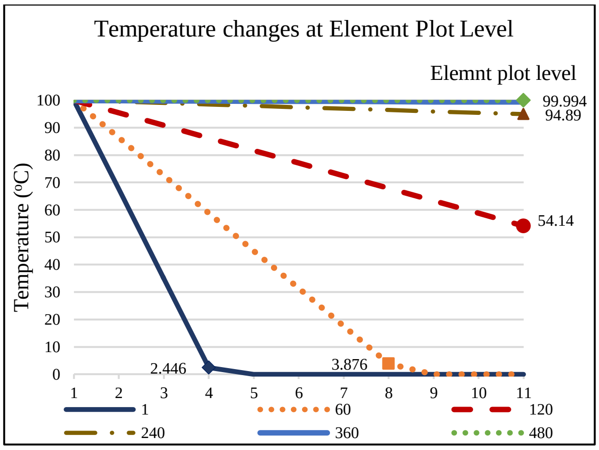

Figure 7: Temperature changes at the elements plot level

3.2.Improvement of production speed and output by using the Semi-automatic crepe machine.

Table 8 shows the output characteristic that consists of cepe cake making proses time and spreader speed in the different method can contribute to increases in production speed and output quantity. This comparison was established between of manual method by beginner and expertise as well as Semi-Automatic machine. The final result of this data notify the production speed by using Semi-automatic machine was contributes 36.8% increase compared to the manual method by a beginner. While the crepe cakes output in 8 hours production run will provide a 66.7% increase when using the semi-automatic machine compare to the manual method by a beginner. This comparison is also illustrated in Figure 8 and Figure 9.

Table 8: Comparison of production speed and output in a different method of crepe cake making process

Production Speed and Output	**Method**				
	Manual (beginner)		Manual (Expertise)		Semi-Automatic
One layer of crepe					
Duration time to make one layer of crepe on a hot plate, *Ts* (second)	Min	Max	Min	Max	1.2
	25	20	15	10	
Duration time for one layer of crepe cooked, *Tc* (second)	40		40		40
Total time for one slice crepe cooked, *Tt* = *Ts* + *Tc* (second)	Min	Max	Min	Max	41.2
	65	60	55	50	
Spreader velocity, *v* (m/s)	0.0238	0.0297	0.0397	0.0595	0.4957
Angular speed for spreader, ω = *θ/t* (radian/second)	0.2519	0.3143	0.4201	0.6296	5.237
Speed spreader in revolution per minute, N = 60ω /2π (rpm)	2.4055	3.0013	4.0117	6.0122	50.01
A set of crepe cake (35 layers with 7 cm of height)					
Total of duration time to make 35 layers of crepe cake =35 x Tt (minutes)	Min	Max	Min	Max	Semi-Automatic
	38	35	32	29	24
Number of crepe cake can produces for a working day (8hours) operating	12	13	15	16	20

Percentage Increases in production speed between automatic and manual method for beginner, (%)	0	0.8	15.8	23.6	36.8
Percentage increases of crepe cakes output in 8 hours between the automatic and manual method for a beginner, (%)	0	13.3	26.7	33.3	66.7

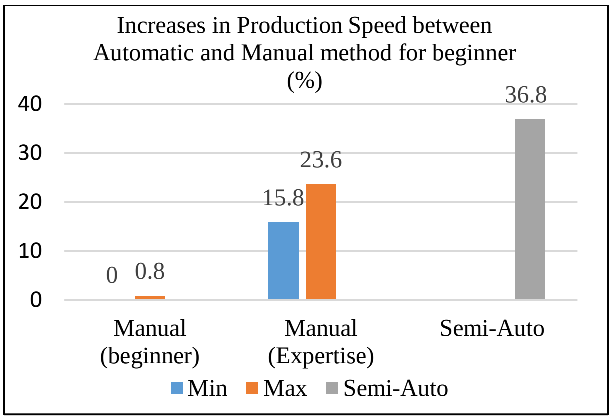

Figure 8: Production Speed comparison

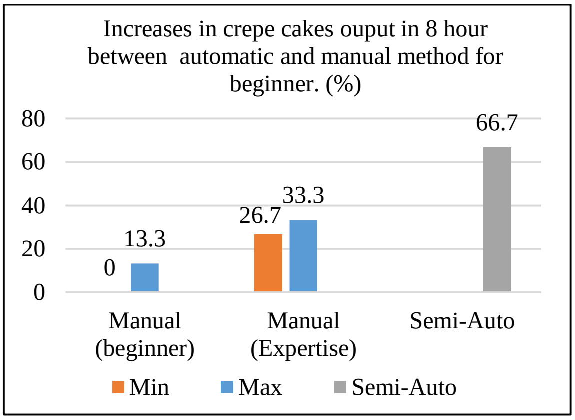

Figure 9: Production output comparison

4. Conclusions

In conclusion, the objectives of this study are achieved. This new design of semi-automatic crepe machine able to improve the Small Medium Enterprise (SME) productivity. The power transmission results have been obtained through analytical referring to specification data of this machine's component such as DC motor, bevel gear and spreader. The result was found the output speed, torque and power have been transmitted from motor to spreader during spreading batter on a pan are 50.01RPM, 41.24 Nm, 216 Watt respectively with assumed 90% efficiency. Following the output speed result and component specification, the production speed has been analysed. The result shows, the speed production is 36.8% increase by using Semi-automatic machine compare to the manual method by a beginner. While the crepe cakes output in 8 hours production run will provide a 66.7% increase when using the semi-automatic machine compare to the manual method by a beginner. Next, a simulation of transient thermal finite element analysis (FEA) was conducted on spreader with heating to 100℃ the contact surface in different temperature by using Solidwork 2019 has determined that maximum heating period for spreader is allowed contact on a hot pan as continuously is limit to 120 minutes (2 hours). It is proven that this semi-automatic crepe machine has heat resistant and safe use for the user.

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