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ORIGINAL ARTICLE

SIMULATION OF HEAT GENERATION IN FRICTION SURFACE CLADDING (FSC) OF MULTILAYER AA2024

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ABSTRACT – Friction surface cladding (FSC) is a solid-state cladding process that produces a thin metal layer on the substrate. It can be utilised at the surface to change the mechanical and corrosive properties of structural materials. There is a lack of retaining between the clad material and the substrate, resulting in loss of retaining between the clad material and the substrate. In this project, to estimate the heat generation during friction surface cladding (FSC) process for multilayer AA2024 using comsol multiphysics 5.5. The process parameter with different layer thickness has been investigated. Clad layer thickness 0.4mm -1.6mm (0.4mm each layer) with constant rotation speed 600rpm and translation speed 30mm/min was tested in this simulation to detect heat distribution. From the simulation result, the temperature increases significantly when cladding process started. With the thickness layer 0.4mm, the simulation shows the highest temperature which is same as the experimental result. For the conclusion, the clad layer thickness can affect the heat generation during friction surface cladding. As a result, the rate of heat generation is inversely proportional to the thickness of the clad layer. The thicker the clad layer, the lower the rate of heat distribution.

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KEYWORDS
COMSOL Multiphysics
Friction Surface Cladding
Aluminium alloy

INTRODUCTION

The friction surface cladding (FSC) method is comparable to the friction surfacing (FS) and friction stir welding (FSW). The FSC system consists of an in-house created tool mounted on a modified planer machine with a hydraulic pumping unit that supplies the FSC tool with regulated amounts of hydraulic fluid [1]. Heat is generated by friction between the tool, clad material and the substrate. The FSC approach combines elements of both techniques to enhance the surface properties of the substrate. The interaction between the rotating consumable rod and the substrate generates heat during the cladding procedure, figure 1. Furthermore, the presence of the tool is required to provide adequate clad material distribution and attachment to the substrate. The gap between both the tool's bottom and the substrate, for example, determines the thickness of the clad layer. To optimise heat generation and allow mixing of the substrate and clad materials, the tool axis can also be changed in relation to the substrate normal.

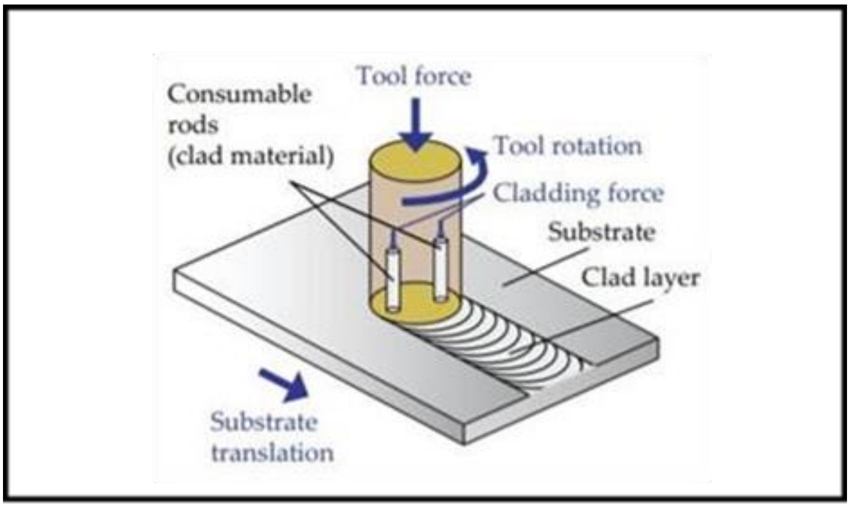


Figure 1: Schematic of friction surface cladding

In this research project, the case of heat generation simulation was set up to predict the multilayer behavior of AA2024. The FSC method involves applying a clad material to a substrate with a rotating hollow tool, which allows for the formation of a thin clad layer at elevated temperature. The tool rotation rate **Ω**, clad material supply speed V_f, layer thickness h, translation speed, V_t are process parameter in the FSC process.

METHODOLOGY

Experimental setup

The material applied in this research AA2024 as a clad material and substrate. Table 1 indicated the chemical properties of AA2024. The substrate dimension with thermocouple inside 300mm x 141mm x 4mm and clad material with 10mm diameter. Figure 2 show the tool of H13 hardened steel with a diameter of 10mm for the centre opening. Table 2 show the process parameter that used in this experiment with different layer thickness and the rotation rate tool around 600rpm based on control temperature substrate approximately 350℃.

Table 1. Chemical properties of composition AA2024.

Material	Composition%	Material	Composition%
Aluminium	90.7-94.7	Magnesium	1.2.1.8
Chromium	0.1	Manganese	0.3-0.9
Copper	3.8-4.9	Silicon	0.5
Iron	0.5	Titanium	0.15

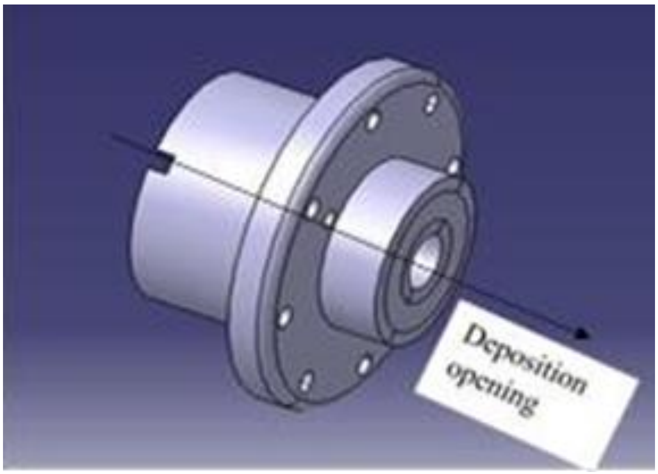


Figure 2. H13 hardened steel tool

Table 2. Process parameter for the experiment.

Layer	layer thickness h (mm)	Rotation rate, Ω (rpm)	translation speed, V_t (mm/min)
First layer	0.4	600	30
2nd layer	0.8	600	30
3rd layer	1.2	600	30
4th layer	1.6	600	30

Comsol implementation

The process for implementing COMSOL is similar to that of a standard nonlinear finite element analysis. Pre-processing, processing, and post-processing are the three steps in this technique. The Model Builder is broken into several parts to showcase the different distinct tasks that are completed under each job. The following significant points are taken from the Model Builder sections. Figure 3, show the Pre-processing, processing and post-processing task in the comsol. Comsol simulation require a lot of parameters that need to be solve. For a specific simulation setting, the FSC process is influenced by a number of process parameter. Table 3 depicts the parameter that been used in comsol multiphysics.

The parameter in Table 3 including translation speed, V_t, Tool rotation rate **Ω**, clad material supply speed V_f, layer thickness h, radius clad rod, height clad according to conducted experiment.

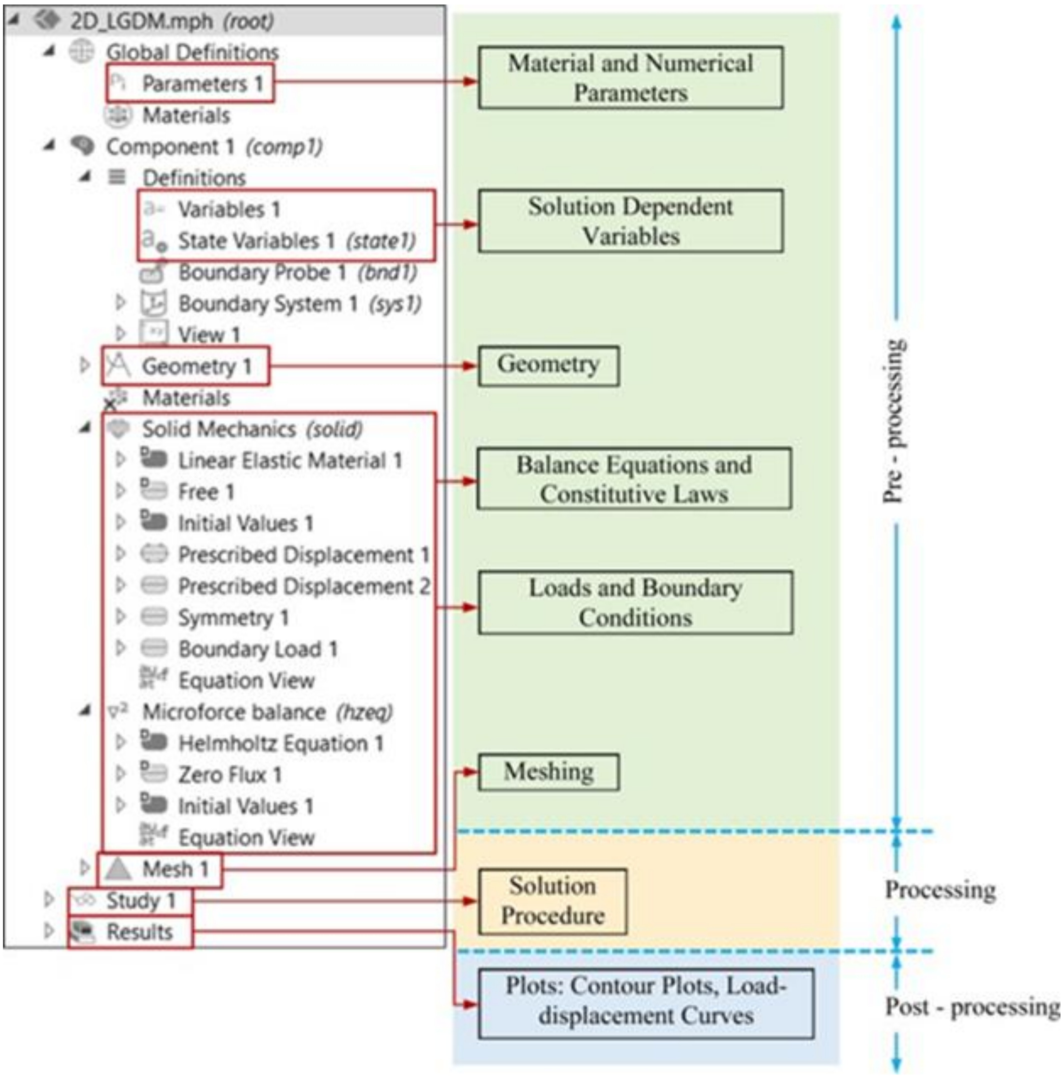


Figure 3. Pre-processing, processing ad post-processing task in comsol.

Table 3: List of parameter inserted in Comsol Multiphysics.

No.	Name	Expression	Description
1	F_n	50[kN]	Normal force
2	v_t	30[mm/min]	Translation Speed
3	R_s	600[1/min]	Rotation speed (RPM)
4	F_c	0.4[1]	Friction coefficient
5	htc1	10[W/m^2/K]	Heat transfer coefficient 1
6	htc2	200[W/m^2/K]	Heat transfer coefficient 2
7	T_melt	919.15[K]	Melting temperature
8	omega	2*pi[rad]*Rs	Angular velocity
9	$x0$	100[mm]	x=0 Tool
10	$y0$	127.5[mm]	y=0 Tool
11	$z0$	83[mm]+h0	z=0 Tool
12	t	4[mm]	Material thickness
13	R_{rod}	5[mm]	Radius Rod
14	H_{rod}	10[mm]	Height Rod
15	D_{rod}	20[mm]	Diameter Rod
16	h_0	0.4[mm]	Clad layer thickness
17	R_{disk}	10[mm]	Radius Disk
18	D_{disk}	20[mm]	Diameter Disk
19	W	20[mm]	Clad Layer Width

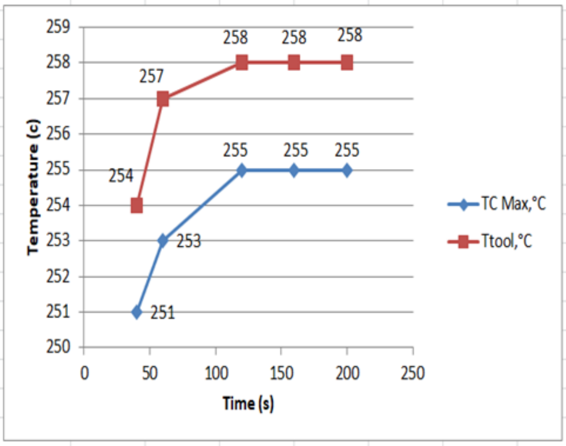
RESULTS AND DISCUSSION

Heat Input and temperature distribution

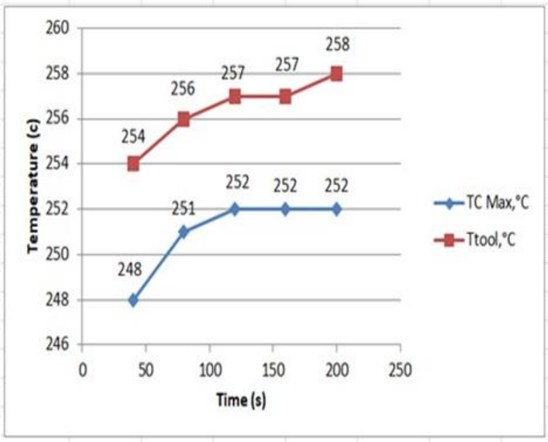
Progress | Log | Probe Table 1

t (s)	h0 (mm)	Rs (1/min)	Temperature (degC), Domain Substrate	Temperature (degC), Domain Backing Table	Temperature (d
5.6288	0.40000	600.00	237.34	237.34	242.35
7.1529	0.40000	600.00	239.89	239.89	244.71
10.201	0.40000	600.00	243.25	243.25	247.83
13.249	0.40000	600.00	245.13	245.13	249.56
16.297	0.40000	600.00	246.31	246.31	250.64
19.345	0.40000	600.00	247.16	247.16	251.43
25.441	0.40000	600.00	248.49	248.49	252.65
31.538	0.40000	600.00	249.44	249.44	253.53
43.730	0.40000	600.00	250.84	250.84	254.83
55.922	0.40000	600.00	251.82	251.82	255.70
75.922	0.40000	600.00	253.13	253.13	256.68
95.922	0.40000	600.00	253.96	253.96	257.28
115.92	0.40000	600.00	254.49	254.49	257.66
135.92	0.40000	600.00	254.84	254.84	257.90
155.92	0.40000	600.00	255.08	255.08	258.06
175.92	0.40000	600.00	255.23	255.23	258.17
195.92	0.40000	600.00	255.33	255.33	258.24
215.92	0.40000	600.00	255.39	255.39	258.28

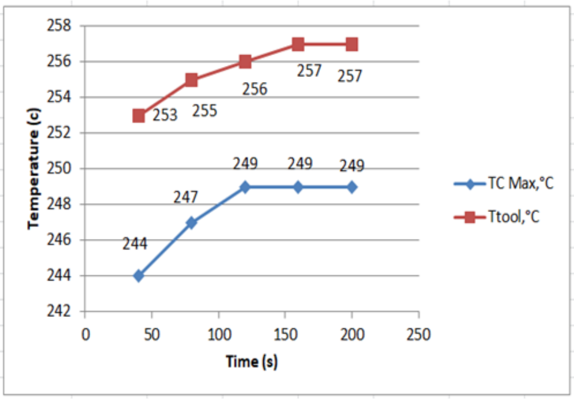
Figure 4: Simulation data



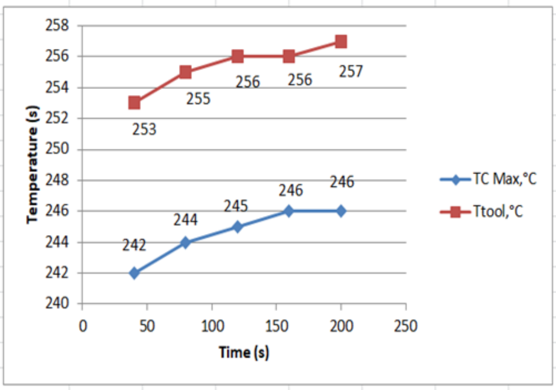
(a) h_0 = 0.4mm



(b) h_0 = 0.8mm



(c) h_0= 1.2mm



(d) h_0= 1.6mm

Figure 5: Temperature distribution of Tc and Tt for each layer.

Figure 4 shows the simulation data was chosen between 0 and 200 seconds. The temperature substrate (T_C) and temperature at tool (Tt) while adjusting the translation speed around 30(mm/min) and tool rotation speed 600 rpm. According to Figure 5, the value of Tc Max obtained from the maximum value at the substrate at each thermocouple point for the experiments with different layer thickness.

Comparison with experimental result

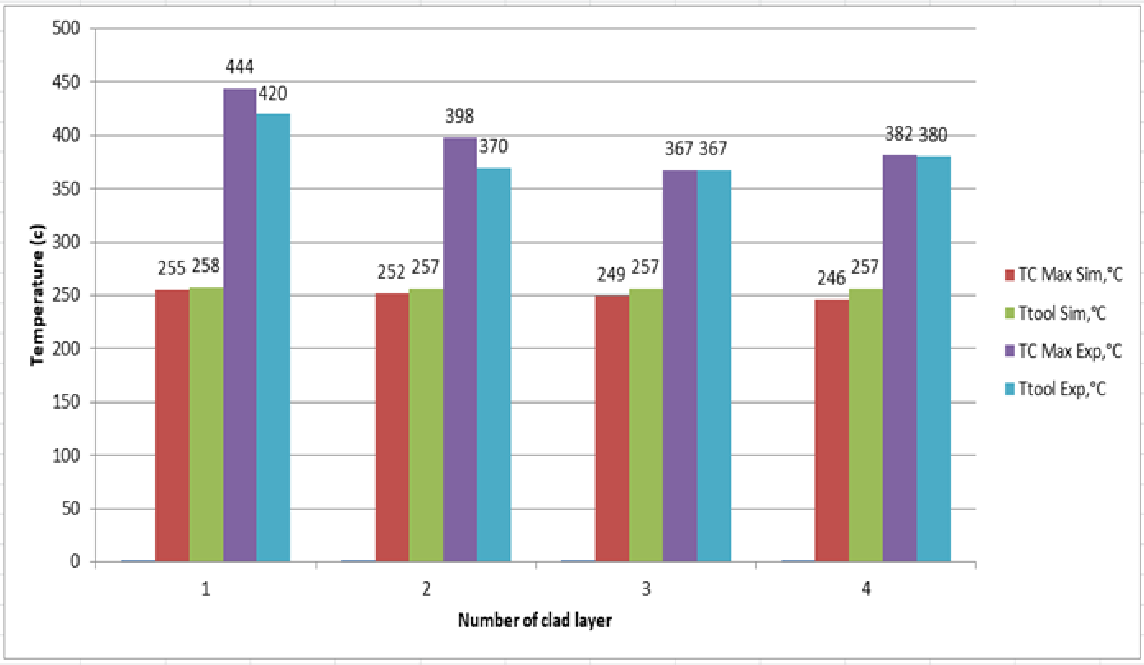


Figure 6: Comparison of Temperature distribution in simulation and experiment.

Graph from Figure 6 show the results of the temperature distribution measured form the experiment and simulation. The temperature result for the experimental result is significantly different from the simulation result. All the simulation temperature shows higher than experimental temperature. Tc has a temperature differenceof 62.9% between experimental and simulation results, whereas Tt has a temperature difference of 66.9%. In this case, there was an error during parameter setting for simulation or experimental setup.

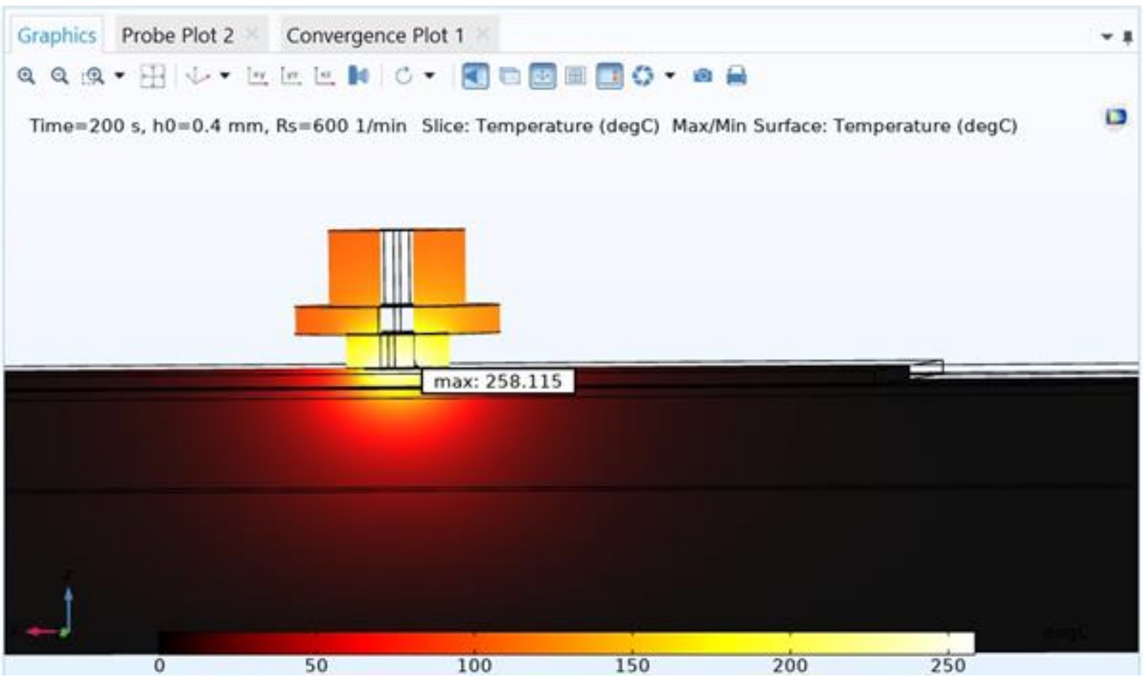


Figure 7: Heat generation

Figure 7 shows the temperature distribution of the FSC tool, the substrate and the backing table for the simulation of thickness of layer h0= 0.4mm, translational speed 30mm/min and rotation speed 600rpm when the tool is located exactly above the location of the middle substrate. The Maximum temperature approximately 258°C near the input region that is the cladding/ processing zone.

CONCLUSION

The study of the friction surface cladding (FSC) process depositing multilayer AA2024 in the solid state has been presented. A part from that, the heat generated is shown to be strongly related to the thickness of the clad layer. From the simulation software Comsol Multiphysics, it shows that the highest using temperature recorded for clad layer is 258°c with the thickness 0.4mm, translation speed 30mm/min and rotation tool is 600rpm. The simulation provides a way to determine the heat generation rate from temperature data recorded during the experiments. The rate of heat generation is inversely proportional to the thickness of the clad layer. The thicker the clad layer, the lower the rate of heat generation.

RECOMMENDATION

i. Use variety value of the rotation tool speed to compare for friction surface cladding process.
ii. There are some parameter could be consider to add in this experiment such translation speed, normal force to increase the accuracy of the result.
iii. To investigate different material such as steel, iron and copper.

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