RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING VOL. 2 NO. 1 (2021) 101-108

RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN: 2773-4765

Simulation Study of BACM Mold Respect to Temperature Distribution

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DOI: https://doi.org/10.30880/rpmme.2021.02.01.012
Received 26 Feb. 2021; Accepted 01 April 2021; Available online 15 April 2021

Abstract: The Bladder Assisted Composite Manufacturing (BACM) technique is one of the method to produce hollow product. Mostly, issue in design, research and development effort are requirement to overcome the challenge in mold design. Another that, for selecting the bladder material, controlling the pressure and temperature of the heated air inside the bladder in BACM method is most important thing to make sure the successful of the process. In this work, the focus is to design the mold of BACM, starting with getting the accurate dimension of cylinder hollow of the final product. In addition, a good selection of material mold is essential to withstand the maximum processing temperature. This research requires the use of SolidWorks software to design mold of BACM, and it is easier to design the mold and the quality of the design can be improved. The analysis and simulation of the mold is representing in thermal analysis and pressure analysis. The process of simulation used 200 °C, 400 °C, and 600 °C temperature and 3 bar, 5 bar, 7 bar pressure in the studied. Since the operating system of BACM process of temperature between 100 °C to 250 °C, so the part is secure to use under 600 °C temperature because melting point of material about 600 °C. The simulation result for thermal analysis and pressure analysis shown the mold is secured.

Keywords: BACM, Complex Geometry, Thermal Analysis, SolidWorks Simulation.

1. Introduction

BACM technique is another promising method to produce hollow product with high quality and this technique can eliminate traditional applications of bladder moulding. However, traditional of bladder manufacturing method require several steps and a master geometry that increases costs and production times [1]. BACM process has feasibility for current fabrication method and this method is for the production of components with varying geometric complexity. In BACM system to fabricate geometrically complex, hollow parts made of composite materials [2]. Another that, BACM method has advantages over conventional bladder molding application and it is because it heats the component from the inside during the curing process and can control the cure pressure.

A hollow product may can be made by different methods such as pultrusion process, filament winding, bladder moulding and more. The BACM consist of four main components which are mold, heater,

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bladder and manifold. This project is focusing to design the mold and perform simulation analysis respect to temperature and pressure.

2. Literature Review

2.1 Overview of mold

The metal products like car body panels, home appliances, and industrial fixtures have been produced by molding in a long time ago. The larger companies most often can afford to build, operate and maintain these tools. Composite materials offer a practical path for anybody to make even enormous creation runs of identical parts in molds they can deliver themselves.

The considerable number of interest points offered by composite materials, their capacity to be molded to complex shapes is maybe the most famous. At the point when a shape should be replicated various occasions, it is generally proficient to manufacture a device or form inside which the part can be created. Formed parts develop completely molded without fail and require little post-completing work.

2.1.1 Material of mold for mold

Material mold for this BACM is aluminium alloy. Before starting the development of any shape, set aside the effort to consider the ideal final products. Plan to create mold in any event multiple times thicker than the parts to pull from it. This will prevent warping and damage form during the de-shaping procedure. The development of the mold will be an exchange off among the physical properties of the form, cost of development and time required to construct the mold. Advantage of composite aluminium alloy combination molds is cost. It is far more affordable to create and keep up a composite shape than to buy a form made of aluminium or steel. The aluminium mold was protected by in casing it in 20 mm of gypsum (plaster of paris) which has a thermal conductivity of 0.6 W/m-°C [2]. Al is principally done by alloying it with elements like copper, zinc, manganese, magnesium, silicon, and lithium and processing its alloys.

Table 1: AA Designation and classification of wrought aluminium and its alloys [4] [5]

Alloying elements	Series designation	Classification
Pure aluminium	AA1XXX	Non-heat treatable
Copper	AA2XXX	Heat treatable
Manganese	AA3XXX	Non-heat treatable
Silicon	AA4XXX	Non-heat treatable
Magnesium	AA5XXX	Non-heat treatable
Magnesium and silicon	AA6XXX	Heat treatable
Zinc	AA7XXX	Heat treatable
Lithium	AA8XXX	Non-heat treatable

2.1.2 Properties of aluminium alloy (AA5083)

Alloying is enhanced the mechanical strength of pure aluminium. The properties of unalloyed aluminium are high electrical and thermal conductivities, good corrosion resistance, high ductility, low density, and low melting temperature around 600 °C. The BACM process has a maximum operating temperature of 343 °C, was used to produce of the composite cylinders [3]. It's process suitable for aluminium alloy because the processing temperature not reaches the melting point of AA. In non-ferrous metal aluminium and magnesium have low melting point but aluminium more suitable in this

BACM process because have low density and easy to shape. The AA5XXX series is chosen since its non-heat treatable alloys contains magnesium that are strengthened by elements in solid solution and dislocation structures introduced by cold rolling [5]. Although 5XXX has the highest strength of the non-heat treatable alloys compared to another series of non-heat, aluminium alloy 5083 have good formability, weldability, and highly resistance to attack by chemical environment [6].

2.2 Characteristic of mold

2.2.1 Support/leader pin

Leader pin is for accurately locate in flange core and cavity (male and female) side of mold, make them match perfectly and move smoothly. Larger flanges are worth incorporating to make both these procedures easier. Locating pins along the perimeter flange should also be planned for complex molds with multiple pieces requiring precise alignment.

2.2.2 Gasket

These matched of male and female mold have a mating surface and it's suitable add gasket to prevent leakage while under compression process. Gasket also allow for less than perfect mating surfaces on mold where they are can fill irregularities. In BACM process, mold must going into compression process, so the presence of gasket can prevent friction on both surface of mold. The compressive forces used resulted in the laminates experiencing consolidation pressures equivalent to the bladder pressures used in fabricating the cylinders [2]

2.2.3 Parting line

The parting line called the point where the mold pieces that joint together. The imaginary line divided into a negative and positive draft. The many parting planes as needed for complete separation for built molds but in this design that provide use one parting line. It is more economical for mold design, mold development, mold maintenance and for part production to use sharp edges on the parting lines of a section.

3. Methodology

3.1 Concept design of mold

Concept sketches are done using SolidWorks after all the ideas have been combined. The sketching was done after identifying all the advantages to develop the mold.

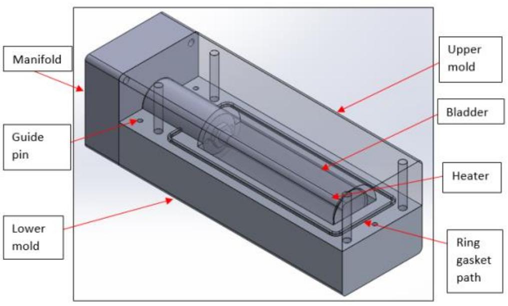


Figure 1: Concept 1

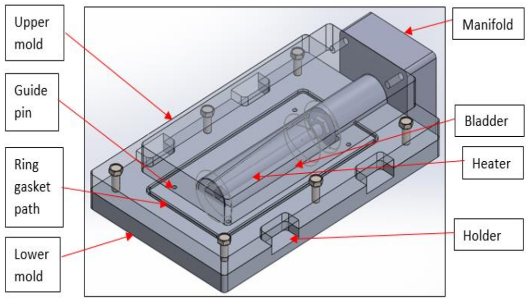


Figure 2: Concept 2

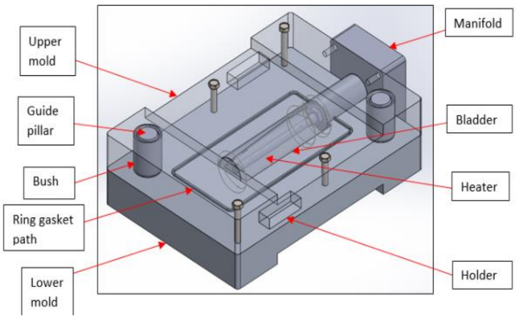


Figure 3: Concept 3

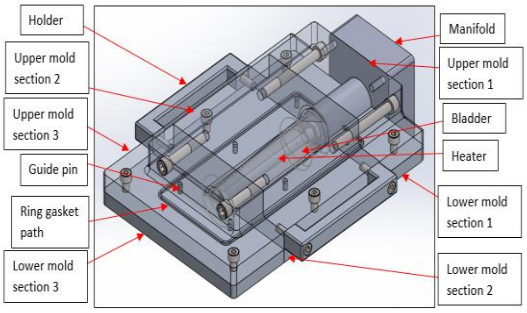


Figure 4: Concept 4

From the four conceptual designs, the design concept 4 is chosen as the best design for BACM mold referring to the Quality Function Deployment (QFD) and the Product design specification.

4. Results and Discussion

4.1 Analysis and simulation

Analysis and simulation carried out to observe the condition of mold during BACM process.

4.1.1 Thermal analysis

The thermal analysis could be a methodology that discovered the result or response to the component because of the part has critical section in this system. In different words, the impact of an amendment to the half will be detected and calculated while no related to extended time response. The thermal load set at 200 °C, 400 °C and 600 °C for the cavity part and 27 °C (300 K) for environment temperature and 50 W/m^{2}K for the coefficient of the heat convection corresponds to free convection with air [7]. After setting the thermal loads, the thermal study was successfully performed. Figure 5, Figure 6, and Figure 7 shown the thermal analysis results for 200 °C, 400 °C, and 600 °C respectively.

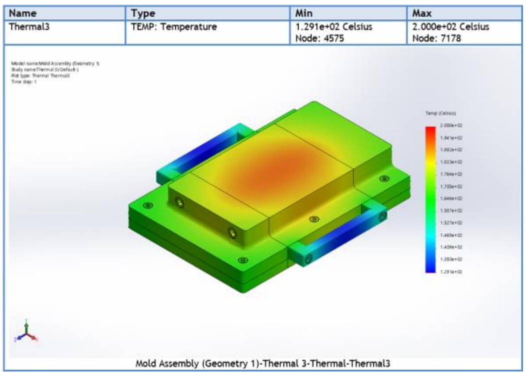


Figure 5: Thermal analysis result for the 200°C temperature

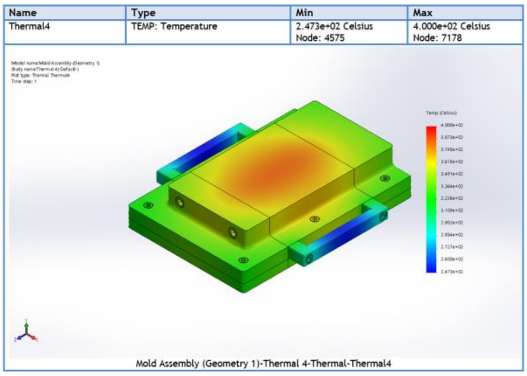


Figure 6: Thermal analysis result for the 400°C temperature

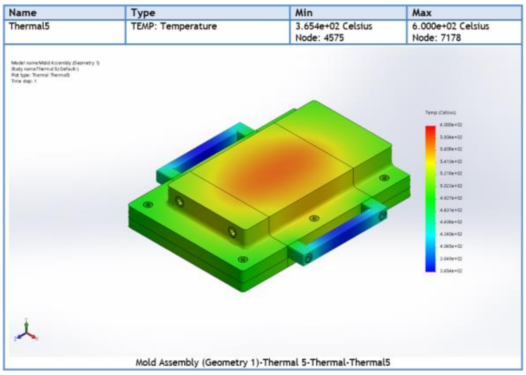


Figure 7: Thermal analysis result for the 600°C temperature

The Figure 5 shows the result of thermal during temperature calculating. It shows the value of 200 °C (2.000e+2 °C) for the maximum temperature and value of 129.1 °C (1.291e+2 °C) for the minimum temperature. Figure 6 show the value of 400 °C (4.000e+2 °C) for the maximum temperature and value of 247.30 °C (2.473e+2 °C) for the minimum temperature. Figure 7 show the value of 600 °C (6.000e+2 °C) for the maximum temperature and value of 365.4 °C (3.654e+2 °C) for the minimum temperature, which theoretically still meets the design requirement for the sake of safety. Table 2 show the temperature difference between maximum and minimum for all the setting process temperature.

$$Different\ (\%) = \frac{Max.Temperature - Min.Temperature}{Max.Temperature} \times 100\%$$

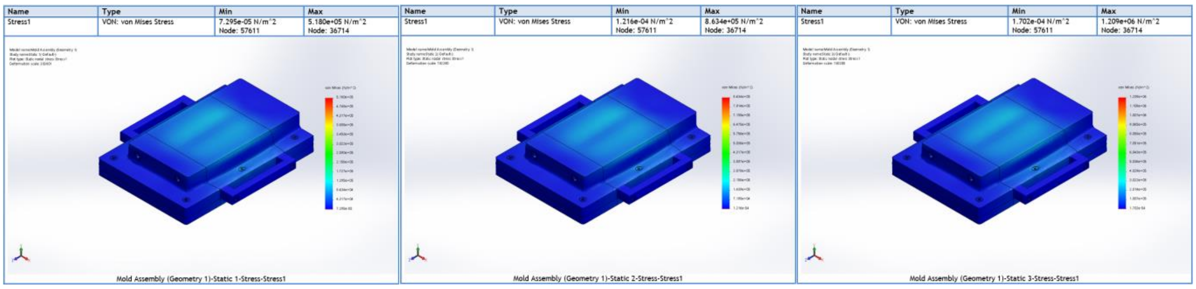
Table 2: Temperature difference between maximum and minimum

Process Temperature (°C)	Result		Difference (%)
	Maximum Temperature (°C)	Minimum Temperature (°C)	
100	200	129.10	35.45
150	400	247.30	38.18
200	600	365.40	39.10

Based on the simulation result, there is a different value between maximum and minimum temperature. The difference between maximum and minimum temperature for 200 °C, 400 °C, and 600 °C processing temperature are 35.45%, 38.18%, and 39.10% respectively. It can be seen, the temperature differences increase when the process temperatures increase.

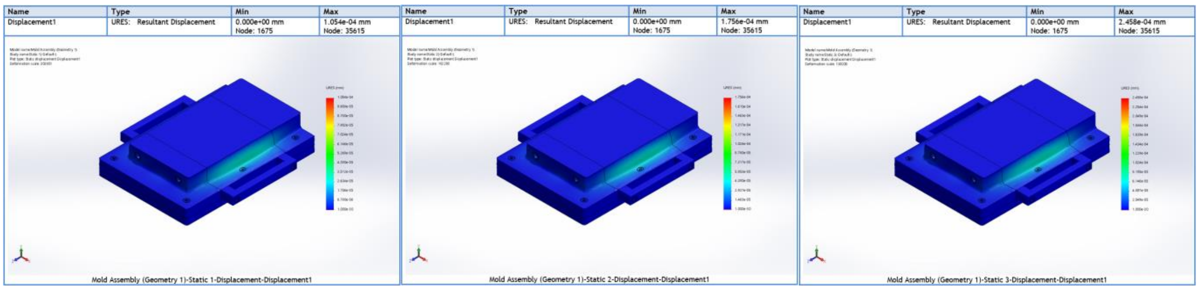
4.1.2 Pressure analysis

The pressure analysis evaluates the displacement, stresses, and strains in the product when force or pressure is applied. Pressure is applied 3 bar (300000 N/m^2), 5 bar (500000 N/m^2) and 7 bar (700000 N/m^2) for the cavity part. After setting the load and fixtures, the static study was successfully performed. Figure 8, Figure 9, and Figure 10 shown the results of the stress, displacement, and strain result, respectively. When the pressure is applied to the cavity part, the part deformed and the pressure is transmitted throughout the part. From the result, Table 3 show the maximum and minimum value for stress, displacement and strain for three different pressure process.



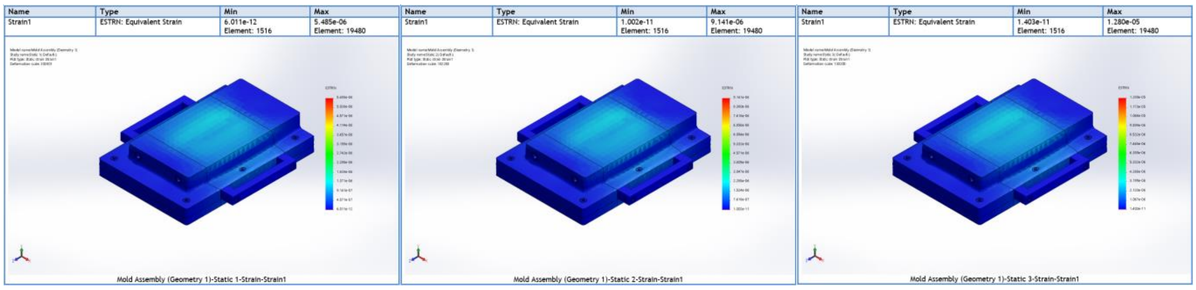
(a) (b) (c)

Figure 8: Pressure analysis result of the stress for (a) 3bar (b) 5 bar (c) 7 bar



(a) (b) (c)

Figure 9: Pressure analysis result of the displacement for (a) 3bar (b) 5 bar (c) 7 bar



(a) (b) (c)

Figure 10: Pressure analysis result of the strain for (a) 3bar (b) 5 bar (c) 7 bar

Table 3: Pressure analysis result

Process Pressure (bar)	Result					
	Stress (N/m^2)		Displacement (mm)		Strain	
	Max	Min	Max	Min	Max	Min
3	5.180e+05	7.304e-05	1.054e-04	0	5.485e-06	6.011e-12
5	8.634e+05	1.217e-04	1.756e-04	0	9.141e-06	1.002e-11
7	1.209e+06	1.704e-04	2.458e-04	0	1.280e-05	1.403e-11

The results of the pressure analysis as tabulated in Table 3, show the maximum stress for 3 bar, 5 bar, and 7 bar processing pressure are 5.180e+05 N/m2, 8.634e+05 N/m2, and 1.209e+06 N/m2 respectively. From the analysis, the design of the mold is sustainable and safe to use for BACM process. Therefore, the mold design is considered to be successful.

5. Conclusion

In conclusion, the objective of this research have been achieved by successfully develop the BACM mold. The simulation result for temperature and pressure analysis show the mold sustain at the processing parameters.

Recommendation

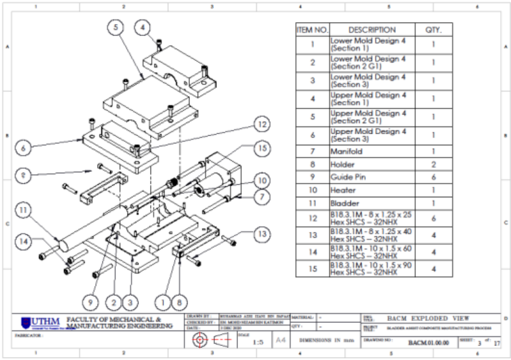
In this research, even though the objectives have been achieved there is still some weakness that can be improved for further investigation as follow:

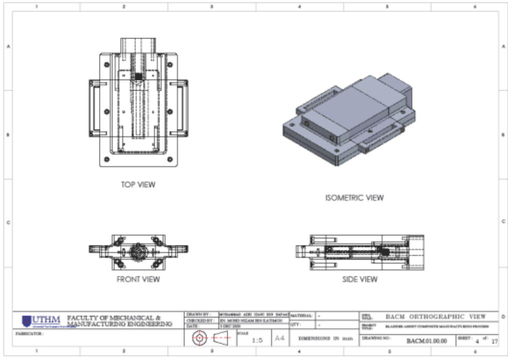
1. The design of the mold can be improve by changing into another good design and make the mold only one piece not in separate pieces. This can save wastage of the material used to make the mold.
2. It is better to use a 3D projector to get accurate geometry of the cylinder composite sample that is more easy and simple to make the cavity mold design without validation. This method can saves more time compared to this study.
3. It is better if do inspection for all of the geometry by the dial test indicator or the dial indicator so it can do the inspection clearance geometry for all mold.
4. In the future, next researcher should be able to develop mold and complete the BACM system with assembly the four main parts which are mold, heater, bladder and manifold.

Acknowledgement

This research was made possible as a requirement for graduate by the Ministry of Higher Education, Malaysia. The authors would like to thank all the staff of Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for the support. The authors also wish to thank The Universiti Tun Hussein Onn Malaysia for the funding support through Research University Grant Scheme (TIER 1) vot H266.

Appendices





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