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Research Article

An Experimental Study on Transient Heat Transfer Effect for Waste Extruded Aluminium Collectors Using Computational Fluid Dynamics Method

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Abstract

This paper reports the study of transient heat transfer effects using Conduction heat transfer method for waste extruded aluminium collector. The structural design of the extruded waste aluminium collector was executed using Catia V5 Computer Aided Design software. Upon designing, finite element analysis conducted to analyze the transient effect of conduction heat transfer method using Ansys R2 2021 Computer Aided Manufacturing software. The materials selected for the simulation are Titanium and Aluminium 7075. A low-cost experimental solution identified for the problem stated. By identifying the variation of contours for transient rate of heat transfer surrounding the surface of extruded waste aluminium collector, the results obtained achieved the objectives.

Keywords: Heat transfer; Material science; Finite element method; Computational fluid

Introduction

Aluminium Alloy has highly opted for structural applications. 7075 grades have been a mutual choice of raw material selection for heavy-duty manufacturing sectors and construction industries. The advantages are low density, highest tensile strength, ductile and huge fatigue resistant [1]. Heat transfer is a well-known everyday phenomenon. People intuitively connect it to the properties of materials for example, to cooking or insulation of houses, even without being familiar with the underlying physics. Heat transfer strongly depends on the material, characterized by its coefficient of thermal conductivity λ [2] (Figure 1).

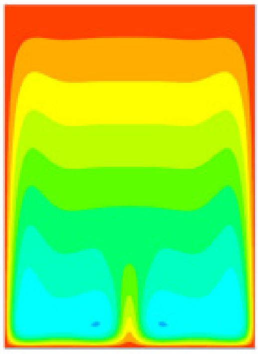

Figure 1: Transient temperature distribution in a sealed aluminium can [3].

Literature Review

Influence of viscosity on the thermal behaviour of fluids in a sealed can

This research focuses on the importance of the effect of viscosity on thermal behaviour in a sealed container. CFD simulation is used to experiment this research. CMC solutions were utilized as a model foodstuff for this research. They found that viscosity rises accordingly with increasing concentration. Somehow, the remaining physical and thermal properties didn't significantly change.

The researchers [3] performed couple of different simulations to identify the thermal behaviour. Those are activated natural convection and pure conduction simulation respectively. Besides, it was successfully captured the time-temperature history of different concentrations of CMC solution.

The transient thermal behaviour is estimated based on the averaged wall heat flux, volume-averaged temperature, averaged heat transfer coefficient, and slowest heating zone. The results show that the fluid viscosity significantly affected the thermal behaviour and heating time. Noticed that, until 700 s, no significant differences witnessed in thermal behaviour between the convective approach and pure conduction simulation for the high viscosity fluid used in this study.

Followed by a mild difference between them due to significant viscosity reduction. As a result, if the liquid in the container is highly viscous and less temperature dependent, pure conduction simulation may capture the thermal behaviour. Hence, more studies are sufficient to minimize the heating time by operating at higher temperatures for high-viscous liquids (Figure 2).

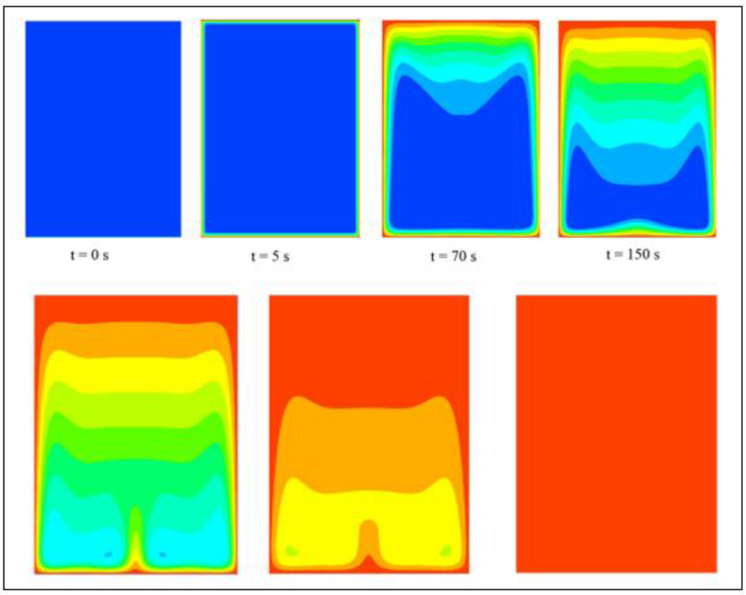

Figure 2: Contours of sintered wick heat pipe using CFD method.

Transient thermal analysis on convection process of circular plate used in hot surface deposition test rig

The main objective of this research is to investigate the transient thermal behaviour of the convection process of a circular-shaped aluminium alloy plate utilized in the Hot Surface Deposition Test (HSDT) rig. The temperature distribution and its characteristics over time are investigated by applying certain thermal load and time dependence. Real deposition test using HSDT executes the process of detaching the aluminium alloy circular plate from the heater block, the transient thermal analysis creates a medium to estimate the duration required for the hot plate to cool down to room temperature (25°C-27°C) and feasible handling.

The process of modelling the geometry, meshing, applying the boundary conditions, and evaluating results are conducted experimentally using ANSYS Release 16.2 software. The analysis results portrayed that the aluminium alloy circular plate with higher internal temperature underwent a lengthy convection process to cool down to room temperature.

The transient thermal analysis study on the convection process for aluminium alloy circular plate was successfully conducted by using ANSYS Release 16.2 software. As a result, the highest temperature produced is at the center of the hot plate. The center portion of the hot plate also needs a lengthy duration to cool down to room temperature compared to other parts and this is caused by the thicker dimension on the bottom of the plate. For the time taken for the aluminium alloy circular plate to cool down to room temperature after being heated to a certain temperature, the results show that the convection process duration is longer for a hot plate with a higher internal temperature.

However, the maximum total heat flux generated after the hot plate reached room temperature is different regarding the temperature applied on the analysis, which is higher maximum total heat flux for higher applied temperature and vice versa [4] (Figure 3).

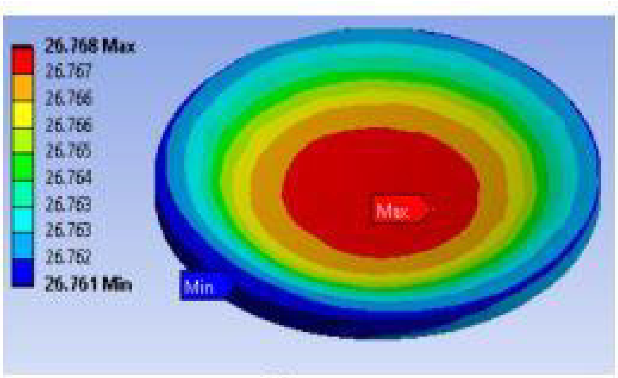

Figure 3: Contours of transient thermal analysis on convection process of circular plate using computational fluid dynamics method.

Problem Statement & Objectives

Problem statement

Conventional methods of manufacturing extruded aluminium 's is considered as risky job till date. This is due to the working environment which is extremely hot and dusty. Currently, the method of releasing extruded aluminium is still manually done using high temperature resistant conveyor belts. This unsafe practice is causes difficulty in disposing the melted or deformed aluminium rods from the hot furnace. In order to solve this circumstance, a low cost and feasible solution is proposed [5,6].

Research objectives

i. To propose a design using Catia V5 which has feasibility of collecting extruded aluminium waste safely from the heating furnace.

ii. To conduct simulation test using ANSYS R2 2021 for the designed waste collector by applying mechanical properties Titanium and Aluminium T6 7075.

iii. To observe and identify the transient flowrate of heat distribution on solid surfaces of simulated results.

iv. To analyse and understand the root causes of differences among flowrate of heat distribution.

Methodology

Design of extruded waste aluminium collector

(Figure 4) To achieve the first objective, an extruded waste aluminium collector in the form of mug shape were designed using CatiaV5 software. The reason of designing in mug shape is to ensure a smooth and feasible extraction of malfunctioned extruded aluminium rods. The designed aluminium collector consists numerous chamfers and curves due to ensure a smooth flow of fluid and pressure (Table 1).

Table 1: Tabulation of Dimensions for designed sintered heat pipe.

Parameters	Dimensions
Total Height	100 mm
Total Thickness	250 mm
Internal Diameter	97 mm
External Diameter	100 mm

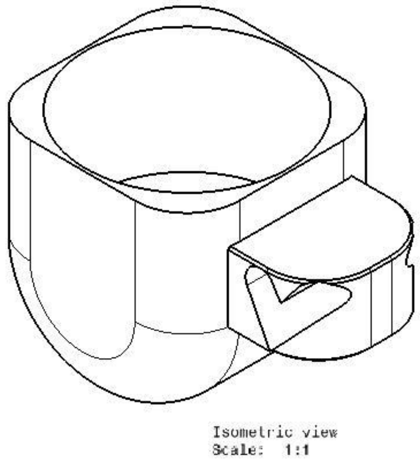

Figure 4: 3-dimensional extruded waste aluminium collector.

Chronology of finite element analysis

To achieve the second objective, simulation based on finite element analysis conducted using ANSYS R2 2021 software. Fluent analysis method chosen to proceed the analysis. Initially, the design was loaded in the geometry database. Upon loading, the data updated (Figure 5).

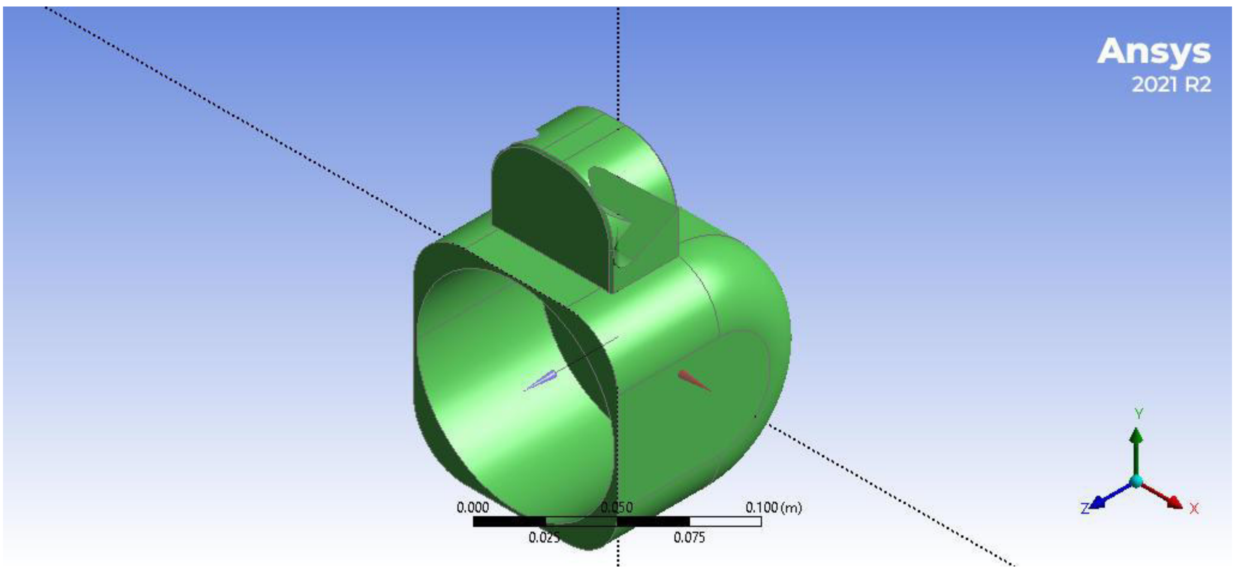

Figure 5: Uploaded design geometry database.

Meshing process successfully accomplished whereby entire finite elements are captured and eligible for evaluation (Figure 6).

At setup database, Energy icon activated. At create and edit materials icon selected the desired materials for the applied geometry design. Titanium (Ti) was selected. Converted the material type to solid and followed by filling the properties column according to given data (Figure 7-10) (Table 2-5).

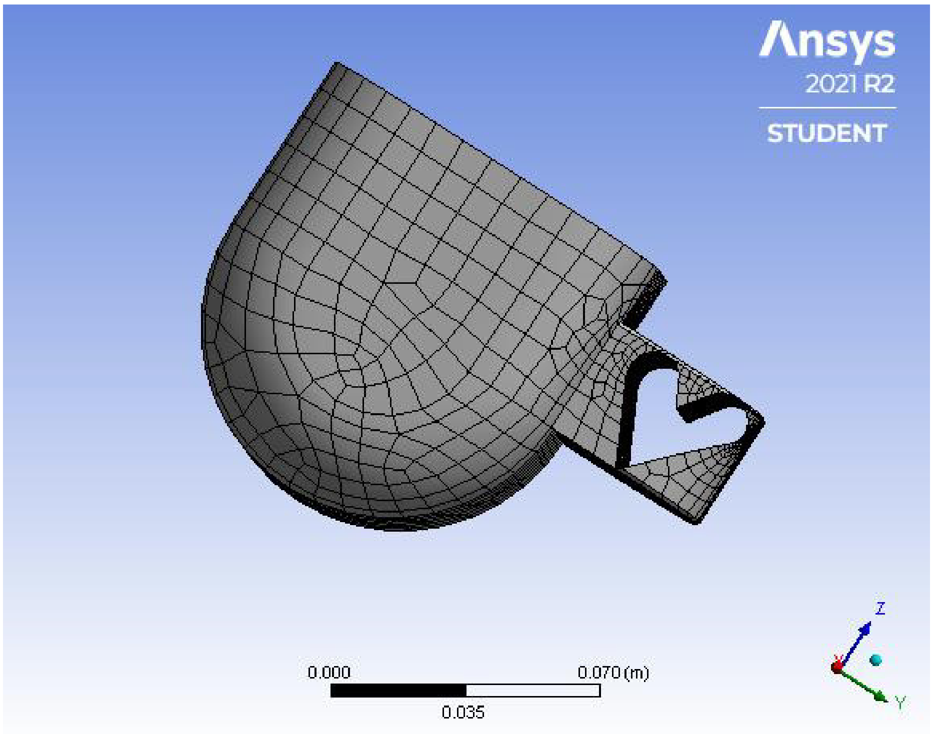

Figure 6: Shows successfully meshed extruded waste aluminium collector.

Table 2: Tabulation of specifications for waste collector wall properties.

Material Name	Titanium
Applied Density	0.0045 kg/m3
Applied Specific Heat	670 J/kg-k
Applied Thermal Conductivity	19°C / 292 K

Table 3: Tabulation of applied specifications for fluid properties.

Material Name	Aluminium 7075
Applied Density	0.00281 kg/m^3
Applied Specific Heat	960 J/kg-k
Applied Thermal Conductivity	130 w/m-k
Applied Viscosity	1.72 x 105

Table 4: Tabulation of specifications for internal and external wall of aluminium collector.

Surface	Wall
Applied Temperature	200°C / 473 K
Wall Thickness	0.25m
Heat Generation Rate	130 W/m^3

Table 5: Tabulation of applied velocity at inlet.

Surface	Inlet
Velocity Magnitude	100 m/s

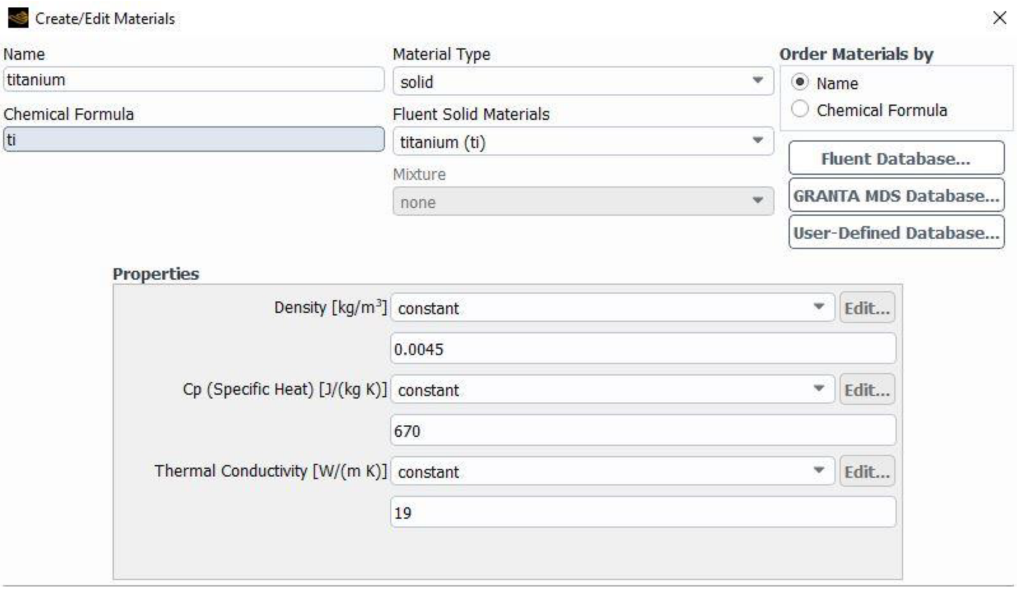

Figure 7: Database of create/edit materials with specifications for extruded waste collector surface.

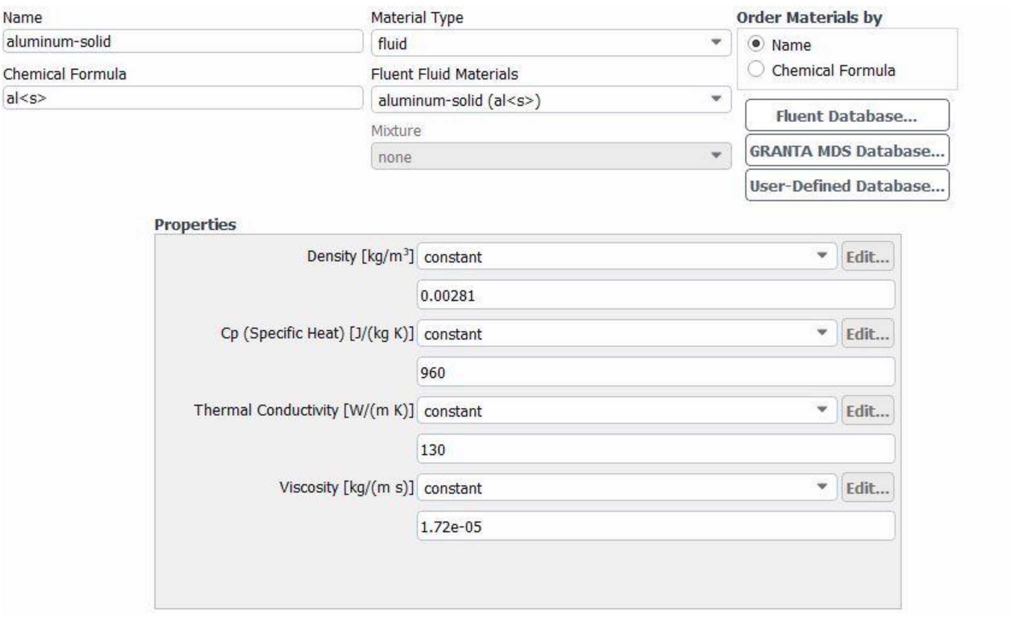

Figure 8: Database of create/edit materials with specifications for extruded waste aluminium solid in liquid form.

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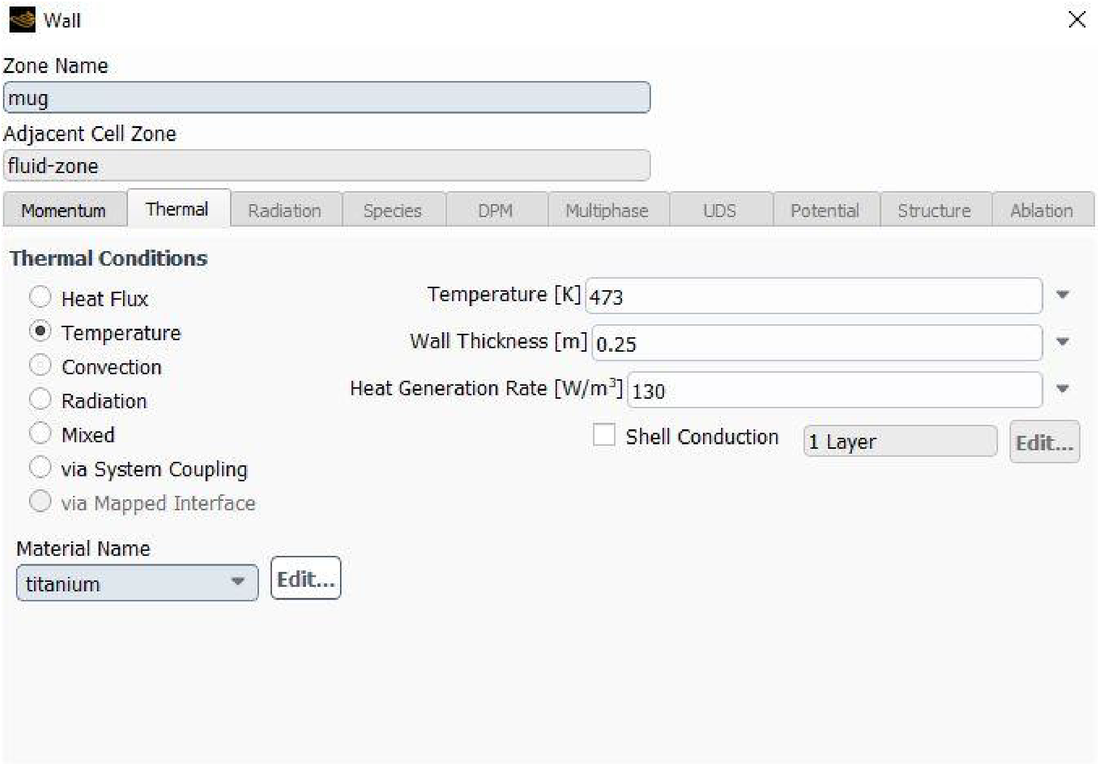

Figure 9: Database of create/edit materials with specifications for internal and external wall.

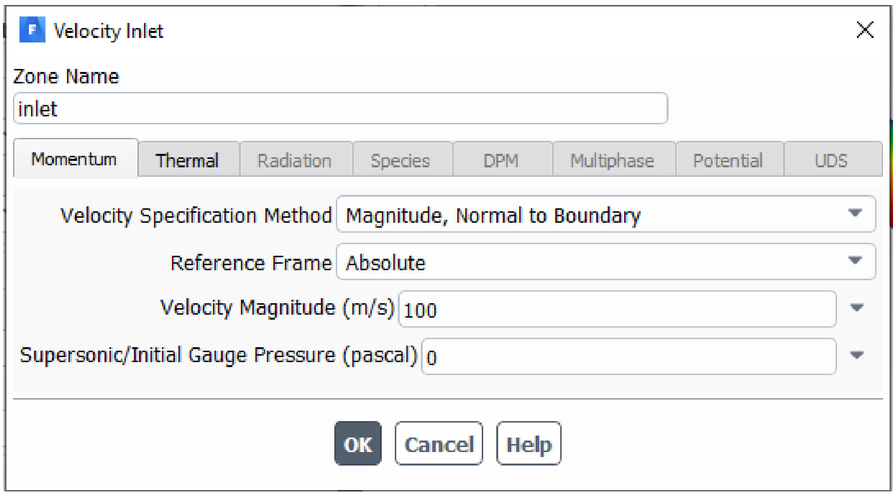

Figure 10: Database of velocity for internal wall.

Analysis Method

Upon completion of data applications, proceeded to solution process to evaluate. Determined the level of iterations at 1000 to evaluate the computational fluid dynamics solutions. As per increase in iterations well noticed the changes occurs in simulation of graph during the calculations in progress. As the calculations accomplished, clicked the contours icon to view the 3-Dimensional results upon simulation. Selected the named surfaces and click Save/Display to obtain the output (Figure 11).

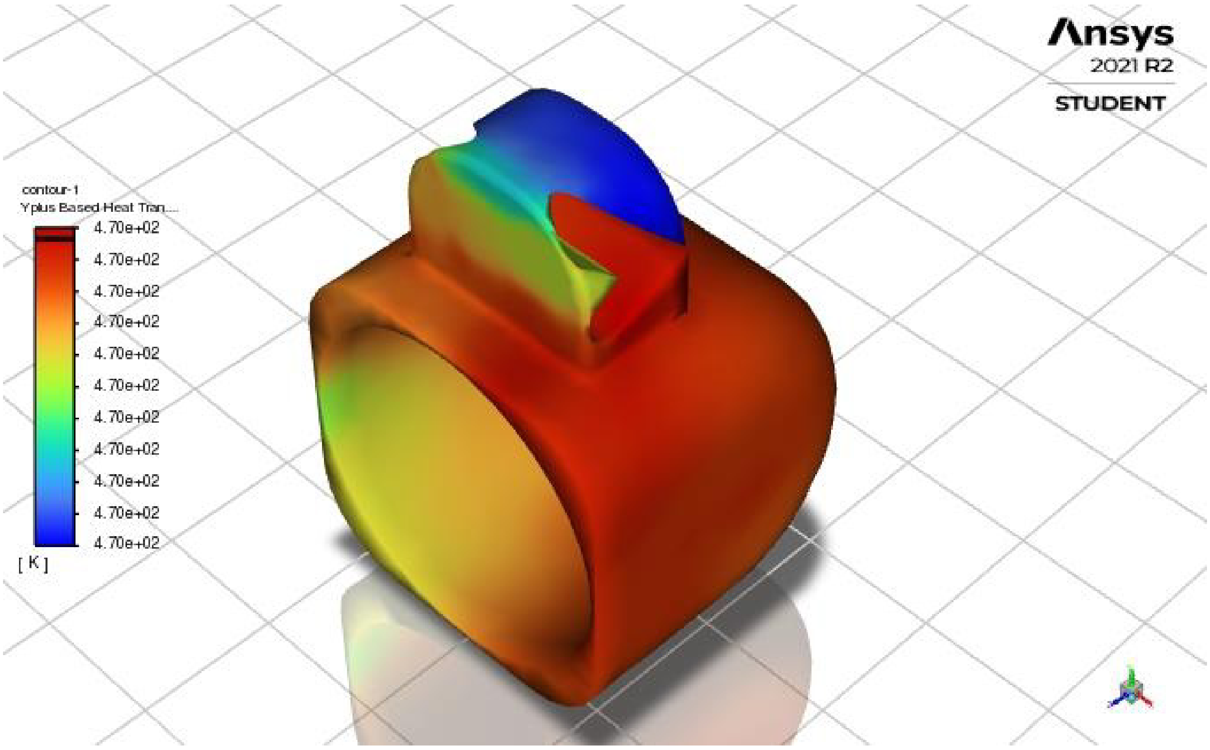

Figure 11: Result of colour contours upon successful finite element analysis.

Results and Conclusion

Results of heat distribution in waste collector surfaces

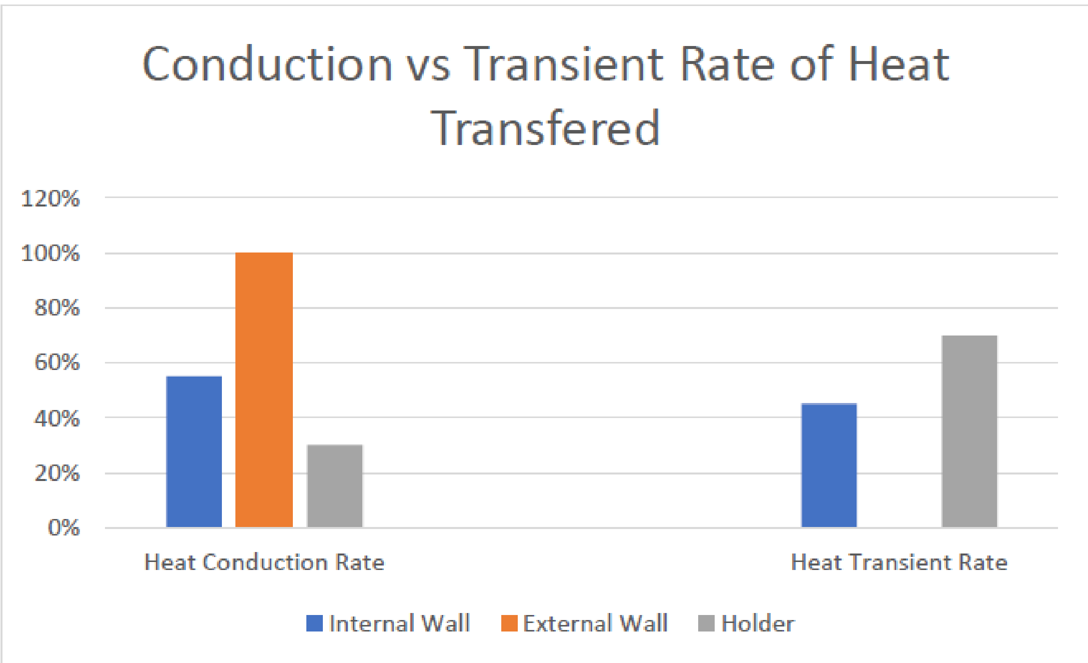

Figure 12: Shows the chart of heat conduction vs heat transient rate.

Surface	Heat Conduction Rate	Transient Rate
Internal Wall	55%	45%
External Wall	100%	0%
Holder	30%	70%

Discussion

i. External wall

According to the observation from results obtained, the experiment has successfully achieved the objectives. The variations among heat flow rate have been successfully witnessed. The result shown in Figure 13 explains that accumulation of heat fluxes from 130 Watts per meter kelvin temperature produced by the collected waste aluminium, tend to fully absorb by the external wall. As the wall consist of 200-degree Celsius or 473 Kelvin thermal resistivity, the red-hot contour clearly portrays that expedited rate of conducted heat is merely 100%. Hence proved that Titanium is a good heat resistant metal.

ii. Internal wall

As observed in Figure 14, as the contour of internal wall displays a yellowish contour at the internal wall, the heat flowrate is assumed to be partially transient about 45%. From this observation, noticed that duration of heat absorption seems to be temporary due to immediate absorption by external wall whereby the designated velocity of air is 100m/s as stated in Figure 10.

The root cause of this sustainability rate is due to wide flat space on the edges. This provides an advantage for the heat particles to release immediately in laminar flow. As a result, the heat particles rapidly dissolve in air along with the designated air velocity. In practical, possibly the concentration of inconsistent room temperature may also cause a difference in heat distribution surrounding the waste collector. This may occur especially if the boundary is facing humidity. The factors that cause humidity are probably from the cooling devices such as fan used in the production area to regulate the extreme hot temperature.

iii. Holder

As observed in Figure 15, as the contour of Holder Bottom Surface Boundary displays a blue contour at the internal wall, the heat flowrate is assumed to be mostly transient nearly at rate of 70%. From this observation, noticed that duration of heat absorption is very less at respective portion.

The root cause of this due to minimal exposure rate to the heat released from the extruded aluminium. In practical, possibly the holder is mounted with any support devices such as gripping sticks or rods for the flexibility of holding. So, possibly it will produce a gap of duration for the concentration of heat to absorb the surface of the Holder Bottom. Repeatedly, this may occur especially at if the boundary is facing large scale of humidity. The factors that cause humidity are probably from the cooling devices such as fan used in the production area to regulate the extreme hot temperature.

Conclusion

Predominantly, I would confidently mention that the research objectives achieved without any technical flaw. Computational Fluid Dynamics (CFD) method to conduct Finite Element Analysis turned successful. Results obtained for experimental study on transient heat transfer effect for waste extruded aluminium collectors are according to standard specifications and parameters. Through the results, I witnessed that conduction heat transfer method impacts the sustainability rate of transient level in each boundary of the designed waste collector. The results almost resembled the practical scenario in industry. Besides, the knowledges from the literature reviews guided me more in conducting the methodology. The output of simulations proved that CFD simulations are unique and reliable to explain the performance of prototypes applies thermodynamics theories and applications.

To conclude my research, I endorse that Computational Fluid Dynamics method is unique invention to learn thermal behaviour of any designed prototype using heat transfer mechanisms. The effect of core elements during heat transfer at boundary conditions such as conduction is well investigative, through simulations of extruded waste aluminium collector device under different conditions. These measures provide more advantages to improve the extruded aluminium waste disposal method in future with more added features.

Acknowledgement

None.

Conflict of Interest

No conflict of interest.

Reference

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