DESIGN AND SIMULATION OF PLASTIC INJECTION MACHINE FOR PET (POLYETHYLENE TEREPHTHALATE)

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Abstrak

Material PET (Polyethylene Terephtalate) banyak digunakan untuk beberapa industri, khususnya industri elekronik. Penelitian ini melakukan desain dan simulasi untuk pembuatan casing untuk smartphone dengan menggunakan mesin injeksi plastik untuk proses manufakturnya. Pada hasil simulasi didapatkan bahwa proses pengisian, suhu dan tekanan mempunyai persamaan yaitu distribusinya di mulai dari titik pusat pengisian sampai ke bagian ujung desain casing. Kecacatan pada hasil manfuktur merupakan salah satu kegagalan proses produksi dan pada penelitian ini sangat jarang terdapat hasil penelitian yang menganalisa prediksi kecacatan pada proses manufaktur casing. Pada simulasi ini terdeteksi kecacatan dalam hasil simulasi dari desain casing ini diantaranya cacat garis dan cacat karena ada gelembung udara. Penelitian ini sudah berhasil membuat gambaran mengenai proses pengisian, suhu, tekanan, dan deteksi dini kecacatan dalam proses injeksi.

Kata Kunci: *Desain, PET(Polyethylene Terephtalate), Peleburan, Injeksi, Plastik*

Abstract

PET (Polyethylene Terephthalate) material is widely used for several industries, especially the electronics industry. This study conducted a design and simulation for the manufacture of cases for smartphones using plastic injection machines for the manufacturing process. On the simulation results, it is found that the filling process, temperature and pressure have similarities, namely the distribution starting from the filling center point to the end of the casing design. Defects in manufacturing results are one of the failures of the production process and in this study, it is very rare to find research results that analyze predictions of defects in the smartphone case manufacturing process. On this simulation, defects were able to be detected in the simulation results of the casing design such as line defects and defects due to air bubbles. This research has succeeded in making an overview of the filling process, temperature, pressure, and early detection of defects in the injection process.

Keywords*: Design, PET(Polyethylene Terephthalate), Smelting, Injection, Plastic*

INTRODUCTION

In 1941, John Rex Whinfield and James Tennant Dickson who worked for calico printers association company in England discovered the synthesis of linear polymers that can be produced through ester exchange between ethylene glycol (eg) and dimethyl terephthalate (dmt) which produces polyethylene terephthalate, and is currently known by the mention of pet and used as the base material of bottled beverage containers [1-3].

PET Plastic (Polyethylene Terephthalate) is classified as a type of plastic (Thermoplastic) that can be recycled and has high mechanical strength, transparent, non-toxic, and does not affect taste and permeability that can be ignored for carbon dioxide. PET plastics have good tensile strength and impact strength, as do their chemical resistance, clarity, processability, color capability and thermal stability. PET (Polyethylene Terephthalate) has specifications: it has a density of 1,420 kg/m^3, Elasticity Modulus 2800-3100 MPa, Tensile Strength 55-75 MPa, melting point 260-300 °C [4-6].

PET consists of polymerization of ethylene terephthalate monomer units with repeating $C_{10}H_8O_4$ units. PET easily dissolves in sulphuric acid, nitric acid, trifluoro acetate, phenol, meta cresol and tetrachlororotan. PET excels due to high relativity melting point, good dimensional stability, mechanical rigidity-high impact resistance, low thermal expansion coefficient. PET (Polyethylene Terephthalate) is generally recycled, and given the number 1 which indicates the symbol can be recycled [5-7]. Due to these desirable properties, PET seems to be suitable material for mobile phone casing. Injection molding is usually used to produce plastic based products as well as for smartphone casing. And during injection molding process, thermal expansion of materials will definitely affect the filling process and possibility of defects. Lacking of results presented on simulation of manufacturing process of casing design using PET is one of main reasons to do this research. Defects detection is very important aspect to study to prohibit any manufacturing failures and with simulation, defects will be able to be predicted early [8-11].

In this research, filling time, filling temperature, thermal expansion and defects will be investigated to determine suitability of the design. This research studied how filling process during injection molding could affects temperature, pressure distribution which are very important aspect to obtain high quality injection molding products.

RESEARCH METHODOLOGY

Flow Chart

This research was started by analyzing the problems of the manufacturing of smartphone case. The analyzing is starting to explore PET material for smartphone case using injection molding process. Injection molding process was chosen as a manufacturing process as commonly used in plastic industry. Building design concept of injection molding machine and case design was done as preliminary steps before simulation. Parts were designed with an actual size. Simulation was run to calculate and investigate during injection molding process. Analyzing the results was done to observe any scientific phenomena during simulation.

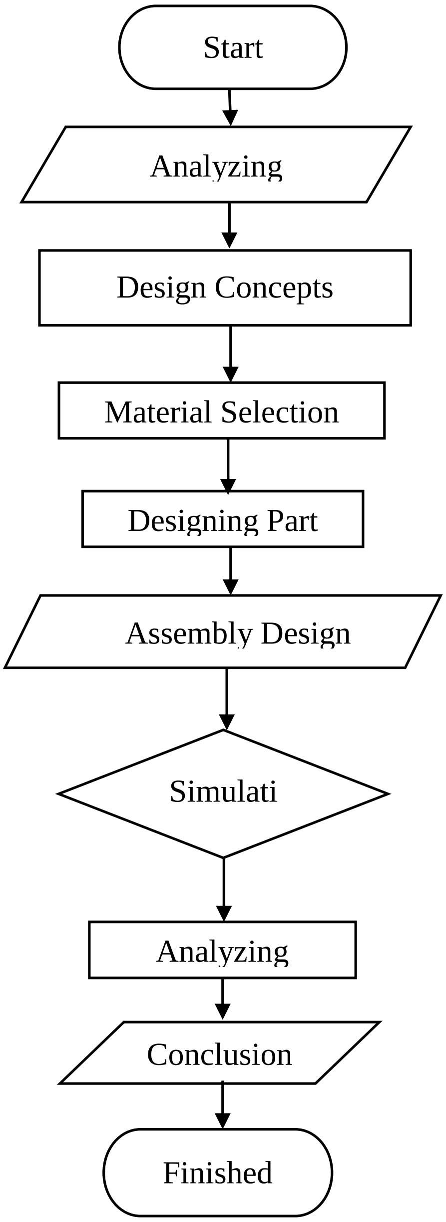

Figure 1. Flow Chart of Research Methodology

Simulation and Design

In this work, Solidworks was used to design and simulate the plastic injection machine as well as casing part. The Samsung A 6 casing was used as a model using PET (Polyethylene Terephthalate) material. In this research injection pressure was set to 18702 N/mm^2 with clamping force of 28471 N/mm^2 and melting temperature of 270 °C. And the injection molding machine and casing model were shown in Figure 1 and 2 respectively.

Plastic injection machine design in Figure 2 contains execution rod, hammer, top connection, plastic section, electronic box, plastic tunnel, band heater, cable, nozzle and base frame. And for casing design with 10 mm thickness has 145 mm length and 65 mm width and center hole with 23 mm length and 13 mm width as shown in Figure 3.

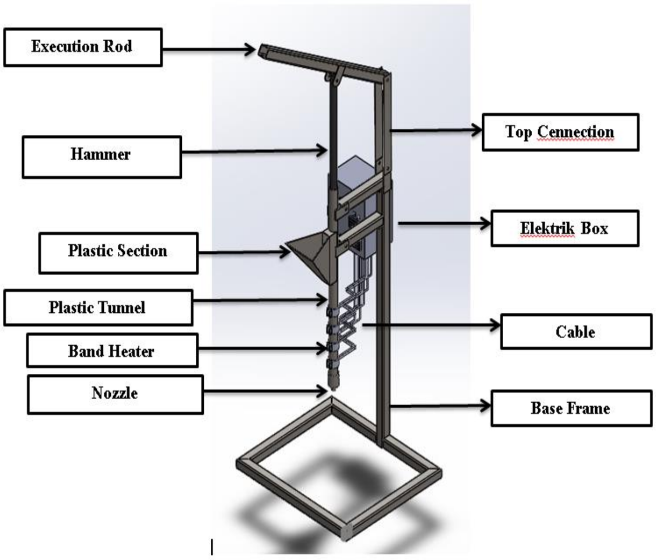

Figure 2. Plastic Injection Machine Design

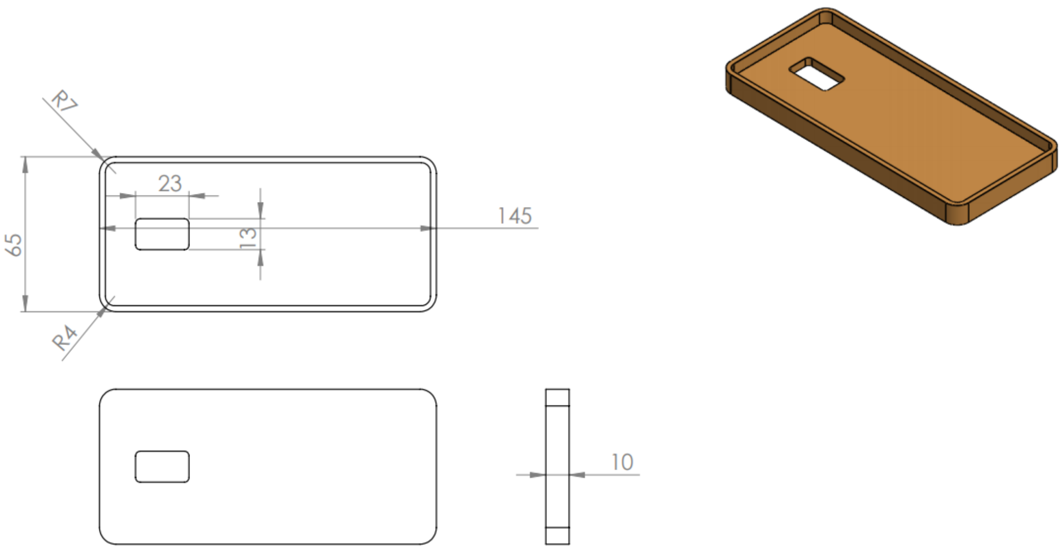

Figure 3. Casing Design

RESULTS AND DISCUSSIONS

Filling Time

In this simulation results show the charging time that has occurred in the plastic molding process as shown in Figure 4 below. The filling time displays the plastic melt profile as it flows through the molded part cavity during the injection molding process filling stage. The blue area indicates the beginning or beginning of the plastic inflow with a time of 0.0066 second. The red area indicates the final position of the plastic melt with a charging end time of 9.4 second [11].

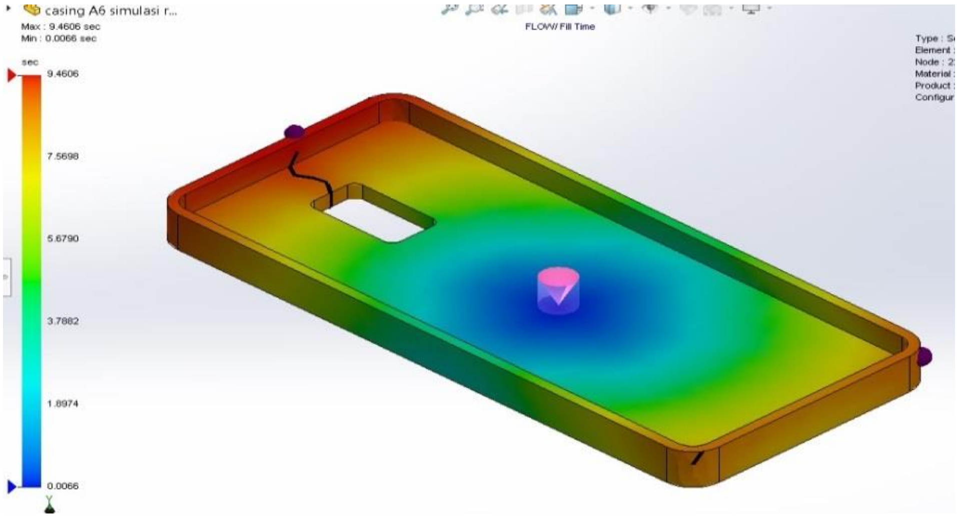

Figure 4. Filling Time Simulation

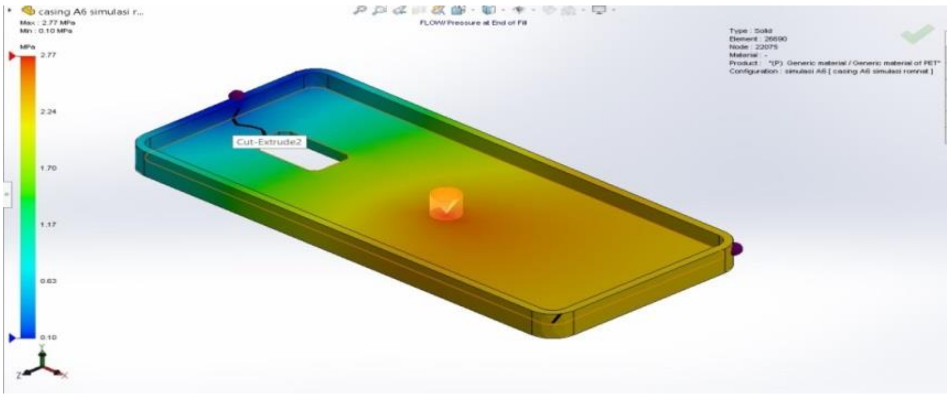

Figure 5. After Filling Pressure

At the time of injection of plastic into the mold it will form pressure inside the mold. Injection pressure input of 18,702 N/mm^2 in simulation settings, resulting in a pressure on the red-marked graph of 2.77 MPa and a blue final pressure of 0.10 MPa as shown in Figure 5. Injection pressure is propagated through liquid plastic and produces a decrease in pressure distributed throughout the flow. The pressure at the end of the filling is an excellent indication of how evenly the cavity is filled.

Filling Temperature

In the process of filling the plastic mold, it will form a temperature distribution graph in the mold filling process as shown in Figure 6. It indicates that the highest filling temperature is located at the center of casing design which has similar distribution with filling time and after filling temperature as shown in Figure 4 and 6 respectively.

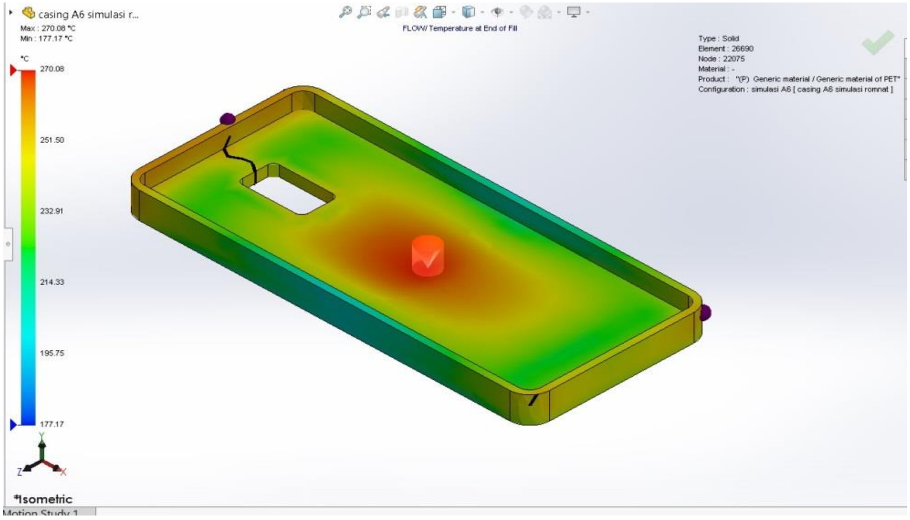

Figure 6. After Filling Temperature

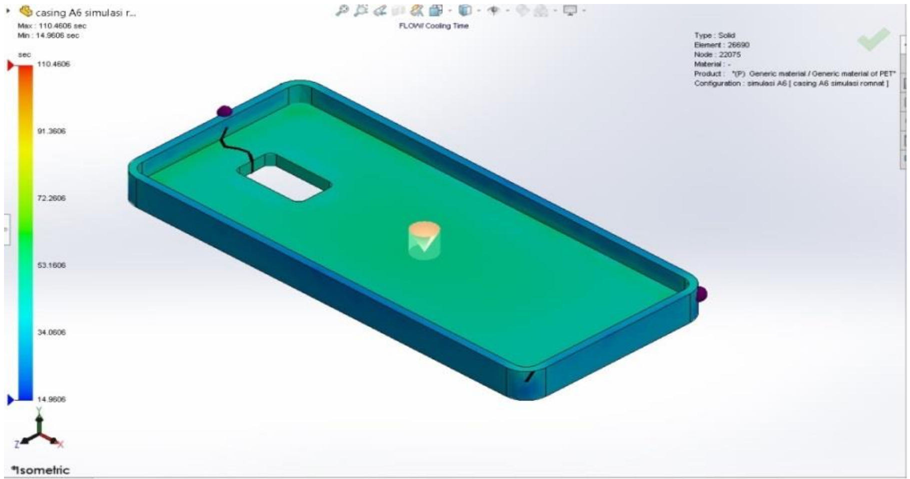

Figure 7. Cooling Time

At the end of the filling, the plastic coming into contact with the walls of the cavity freezes into a very thin frozen layer and has cooled to the point of reaching mold temperature. The thickness of this frozen layer does not depend on the thickness of this part of the wall. Thickness depends on the difference in melting temperature and mold as well as thermal conductivity of the material [11-13].

Cooling Time

In this injection process cooling time is the time of change of liquid objects into solid objects, this change in shape is influenced by cooling time.

The two factors that influence cooling time are melting temperature and mold temperature. Increasing one of the temperatures can result in an increase in cooling time. Plastics require a long cooling time because they are good insulators with low thermal conductivity. From the figure 7 above shows that the cooling process of melting temperature takes 95.5 seconds or 1.5 minutes.

Thermal Expansion

In general, a material will expand when the temperature is raised. Thermal expansion is defined as a change in the size of a material due to the increase of one unit of temperature. The thermal expansion of a material is determined by the initial size of the material, the change in temperature and the coefficient of material expansion.

Linear expansion is the increase in the length of a material due to the increase of one unit of temperature. In figure 8 it shows an expansion rate of 0.00007 in the material (PET), and occurs constantly and fixed to the variation in melting temperature.

In figure 9 above explaining the rate of increase in injection pressure every half a second.

Defects

After the simulation is done and get some simulation results, such as cooling time, final temperature of charging, final pressure of charging and charging time, in this result occurs two defects of print results namely weld line defects and air trap. Weld lines are when two streams of melt meet at both ends of the material melt flow as shown on figure 10. The causes of weld lines include the point between injection and transfer too close, the cooling time is too short and the material temperature is too low.

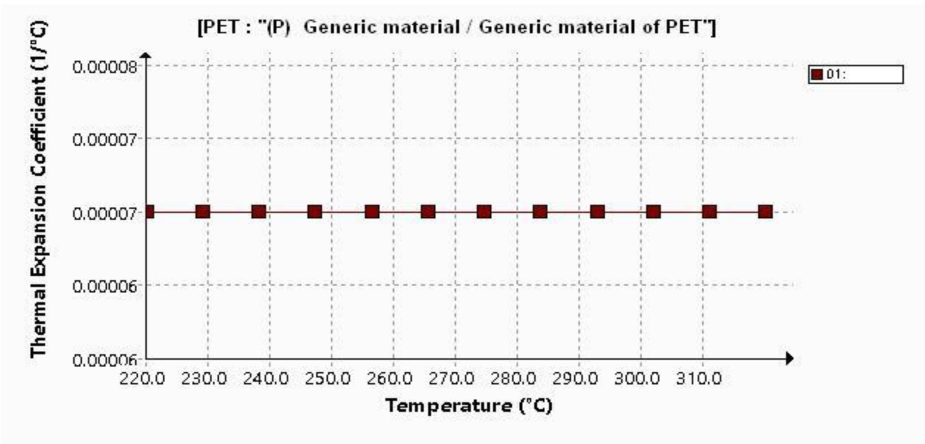

Figure 8. Thermal Expansion Graph

Incoming Pressure

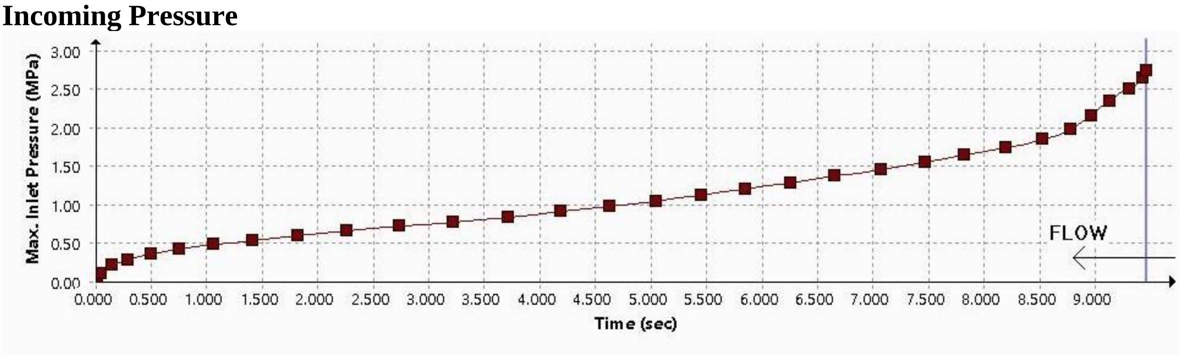

Figure 9. Incoming Pressure Graph

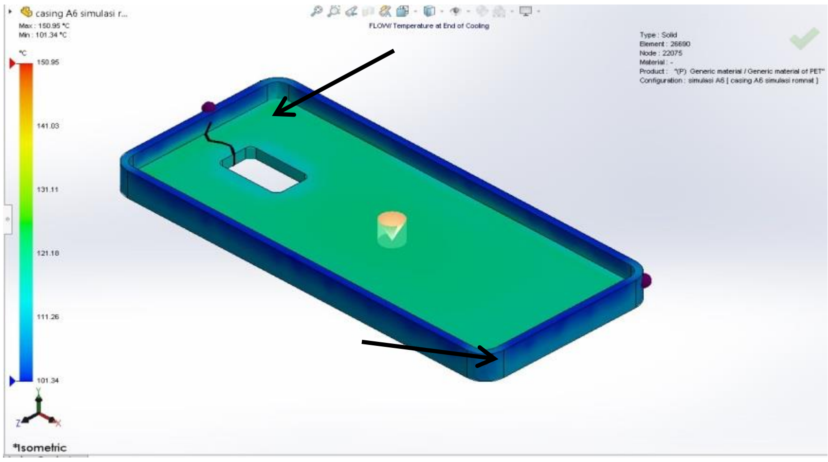

Figure 10. Weld Line Defects

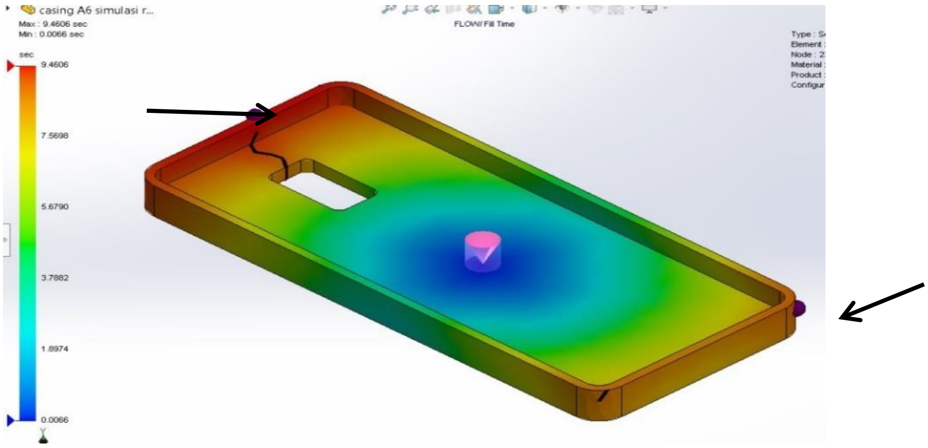

Figure 11. Air Trap Caused Defects

In theory this defect cannot be eliminated, therefore it can only be minimized or moved. When seen by the naked eye then this happens like a crack, if the position of the weld line in the area of voltage concentration can cause strength problems. Therefore, the countermeasures must be implemented as soon as possible [7].

Air trap can be said also as blisters or air bubbles trapped in the product. It usually occurs during the process of injection of material into the cavity as shown on figure 11. The air does not have time to get out through the air vent by the time the plastic material enters the cavity. It can also be by gas mixed with liquid material in cylinder.

In the water trap defect this occurs in the area near the weld line defect and occurs in the corner of the mold. The cause of the water trap is gas that is still trapped in the cylinder, air that is still trapped in the cavity that has not had time to get out through the air vent.

Based on calculations done by simulation above, the results were summarized at table 1 and 2 to shows about plastic injection machine design capacity and processing results including charging time, final pressure, charging end temperature and cooling time.

Table 2. Plastic Injection Machine Capacity

No	Plastic Heat	Power Heater	Heating Rate	Energy Consumption	Efficiency	Plastic Tunnel Mass
1	1333,2 J	920 Watt	1,3 ℃	55,2 Kwh	39%	1,6 kg

Table 3. Simulation Results

NO	Simulation Results	Early	End
1	Charging Time	0,0066 s	9,4 s
2	Final Pressure	2,77 MPa	0,10 MPa
3	Charging End Temperature	270,06 ℃	177,17 ℃
4	Cooling Time	110,4 s	14,9 s

CONCLUSION AND FUTURE RESEARCH

Based on calculations that have been done starting from the simulation of load, injection force, heating power, plastic heating, machine capacity volume and energy consumption in this research, it shows that the distribution of filling process including temperature and pressure starting from the center of the casing design. Defects were found as results from simulation especially around top and bottom edges caused by uncompleted weld lines and air trap during injection molding process. It is assumed that for the better surface finish of the injection molding products, setting more suitable parameter such as filling process, temperature and pressure is encouraged to eliminate defects during and after manufacturing process. Exploring different type of materials for smartphone case is also encouraged to be able to expose possibility of new smartphone case materials.

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