CHAPTER 4 RESULTS AND DISCUSSION

In this chapter, so as to comprehend the consequence during plastic filling stage the simulation results of filling stage in injection molding process model performed by ANSYS CFX software are discussed in 4 sections. First part discusses about the melt temperature effect on viscosity and shear rate. Next, the flow behavior and temperature profiles of molten PLA plastic are predicted and visualized for each scenario in the section. Finally, the pressure distribution along melt flow advancement is criticized in this chapter as well.

4.1 Effect of melt temperature on viscosity and shear rate

From the Cross-WLF (Eqn. 2.1), which was the applied viscosity model for this simulation, shows that the viscosity is the function of melt temperature, shear rate. There are 3 melt temperature values are used to verify the melt temperature effect on viscosity and shear rate as displayed in Figure 4.1.

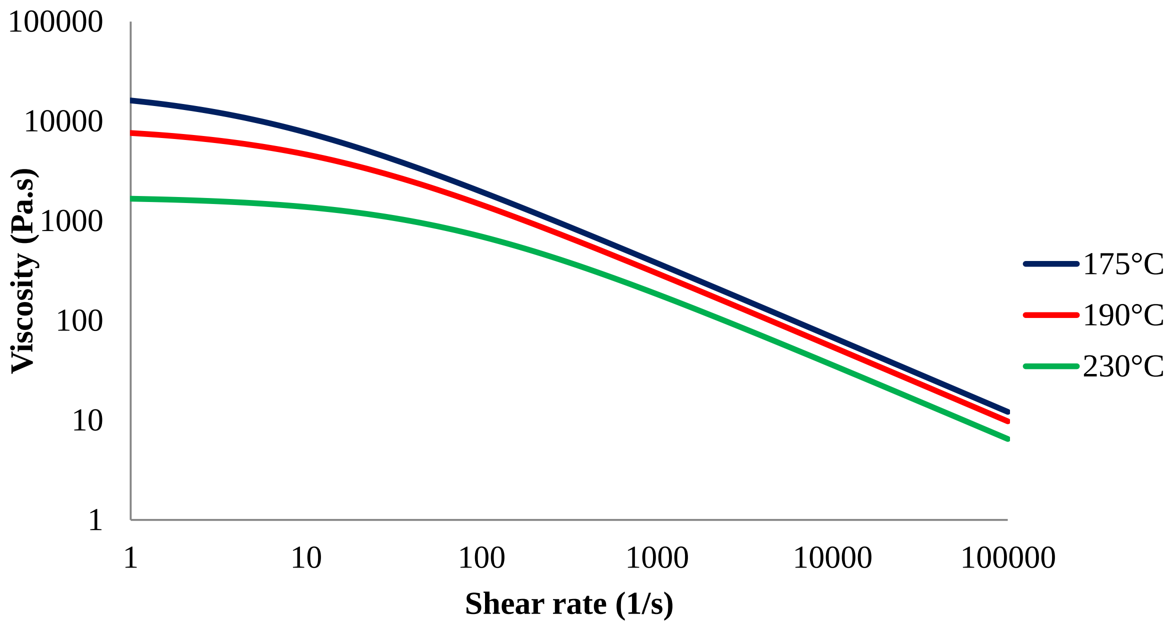

Figure 4.1 Consolidated plot of viscosity versus shear rate at different temperatures

Figure 4.1 presents the consolidated plot of viscosity versus shear rate at different temperatures, 175°C, 190°C and 230°C. The viscosity in this graph was calculated from the Non-Newtonian viscosity model, Cross-WLF. This figure clearly expresses the fact that as temperature increases, viscosity decreases. At the same time, viscosity decreases with increasing shear rate and the curvature of isotherm never cross over the other curves which are in line with the theory.

These curves further show that there is a smaller effect at higher shear rates, when the curves come to be closer to each other or these may be concluded that at higher shear rates the temperature dependence of viscosity is almost negligible. Furthermore, this result also points that the strength of Cross-WLF viscosity model can handle with non-Newtonian fluid in this simulation.

4.2 Melt front predictions

In this section, the predictions of plastic flow advancement are displayed and discussed. The melt front prediction is generally used to explain how the molten plastic flow and fill up into the mold cavity during plastic injection molding process. The contour plot of PLA volume fraction represents the predictions of flow characteristics from simulation at different filling time for melt temperature 175, 190 and 230°C in XY plane at Z=0.15 cm of the model of mold are shown in Figure 4.2.

From Figure 4.2, it may be concluded that the flow front at temperature of 230°C is sequentially faster than 190°C and 175°C, respectively. This makes sense because the injection temperature or melt temperature of 230°C is higher than the other cases. This implies that the viscosity is lower and then makes the molten PLA flow easier. Nevertheless, at the initial filling time namely 0.5 to 1 second, all the flow characteristics are relatively not different since the molten PLA was just started injecting into the mold cavity and the cooling effect due to mold temperature is insignificant. While the filling time passes the molten plastic flow behaviors clearly present the flow deviations according to the change in melt temperatures.

According to the above reasons, the molten PLA plastic at 230°C approximately takes only 1.7 seconds to completely fill up plastic in mold cavity and the total filling time of 190°C and 175°C are 2.6 and 3.0 seconds, respectively.

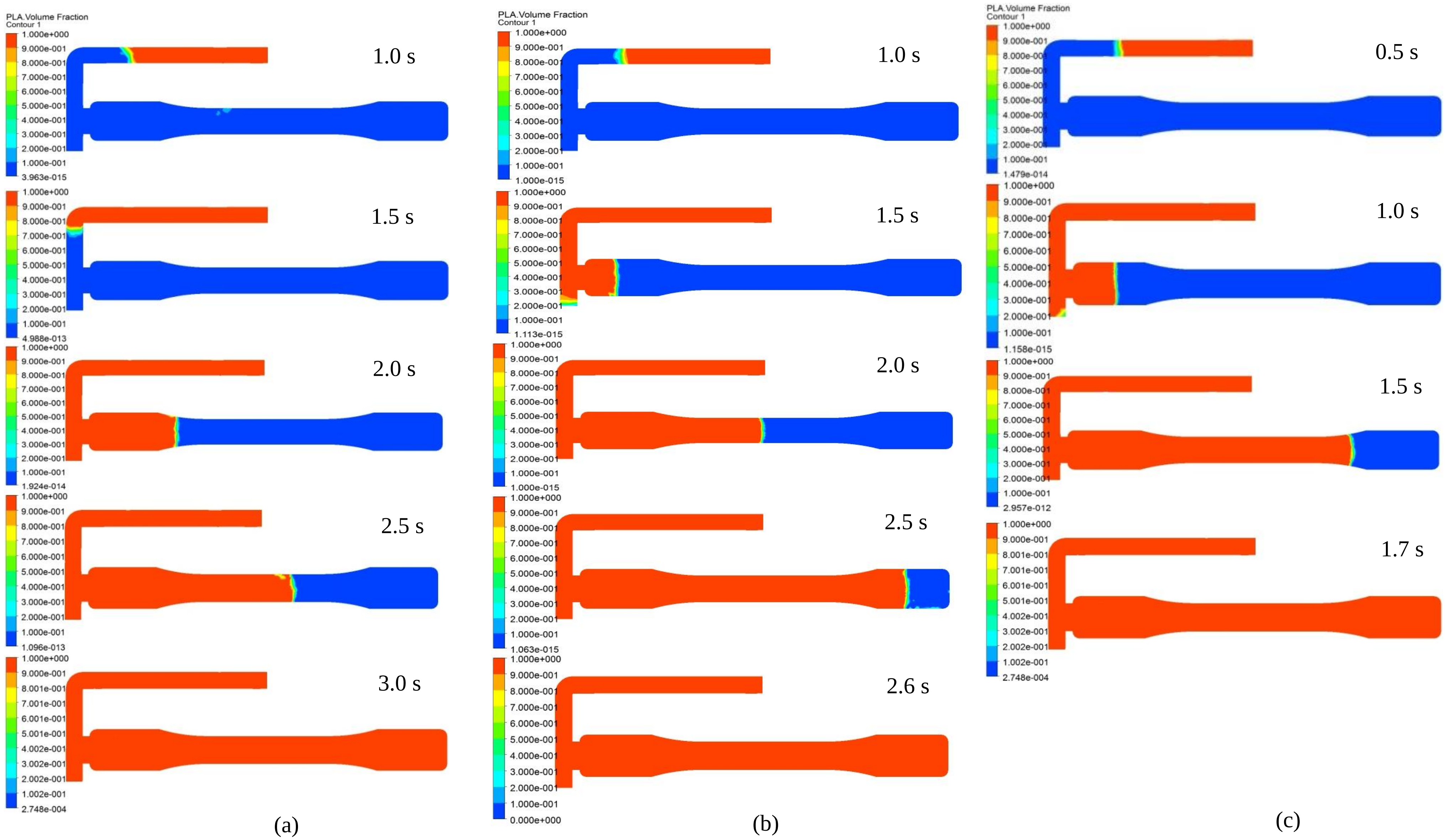

Figure 4.3 Flow front predictions at different filling time for melt temperatures (a) 175°C (b) 190°C and (c) 230°C

4.3 Temperature profiles

In this topic, the temperature profiles for molten polymer at different melt temperatures were exhibited. The temperature profiles may show the effect of the colder mold wall on the temperature of molten as it flows in filling stage. This phenomenon is illustrated by using the temperature contours at 190 °C in different locations e.g. (a)sprue part,(b) runner part and (c) the middle of dogbone section as reviewed in Figure 4.5 and 4.6 because the temperature profile at 175 °C and 230 °C are the same trend as 190 °C.

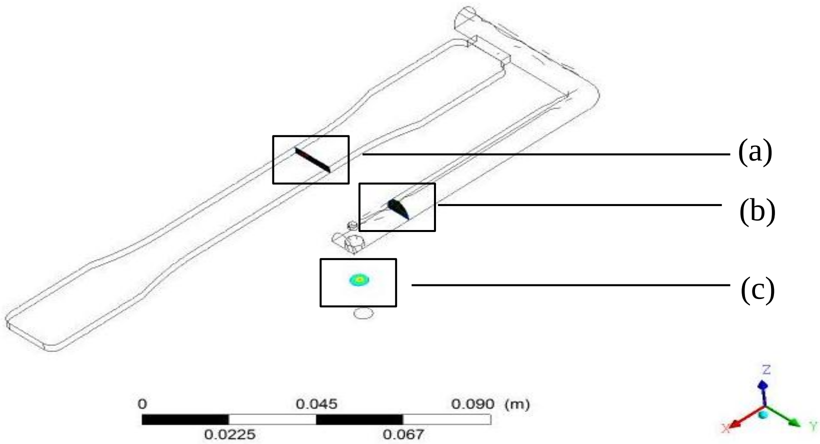

Figure 4.5 Example positions of temperature contours

From Figure 4.6, the different temperatures in the molten PLA can be expressed in the contrast color as labeled in the legend tabs. This result revealed that; while the flow keeps moving, the hot PLA is deposited on the sides of mold walls and then it will be cooled and formed a thickness according to the cooling effect of lower mold wall temperature. Thus, the coldest area is near the mold wall where the frozen layer is constructed. At the center of the mold, the PLA temperature comes to be hotter and covers the larger region in the mold cavity than the coldest layer at the mold wall.

Furthermore, the PLA temperature near the mold wall is around 30°C which is close to the mold temperature. This may conclude that the PLA was solidfied according to the lower mold temperature which actually makes sense in practical. However, in this study, the solidifying of molten PLA was ignored as mentioned in the model assumption. Thus, this result may be explained that the molten PLA is not solidified near the mold wall, it was just infinitely viscous so it might behave like a solidified polymer.

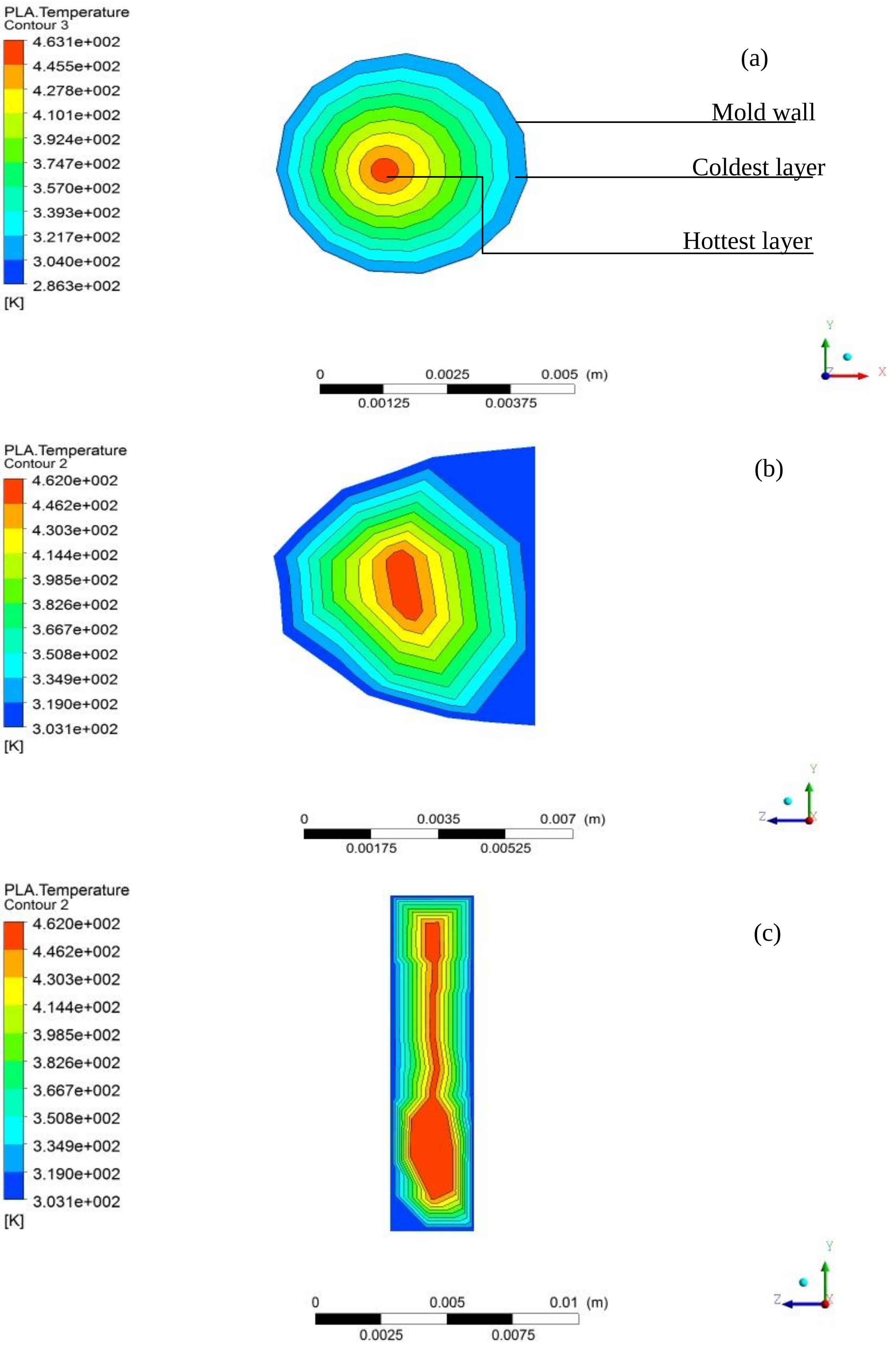

Figure 4.6 Temperature contours at different locations in mold cavity for 190°C

4.4 Pressure distribution along melt flow advancement

In this section, the pressure distribution along the melt flow advancement in filling stage is discussed. Figure 4.7 demonstrates the pressure distribution along melt flow advancement at 2.5 seconds for 175°C and 190°C, at 1.5 seconds for 230°C in XY plane at Z=0.15 cm. which are close to the total filling time of each case.

The results describe that each case gives the same pattern of the pressure distribution which is the pressure decreases from the inlet position to the end of the mold cavity. This result is taken place by the fact that the flow of molten plastic is driven by pressure that overcomes the melt's resistance to flow. It may be summarized that the molten plastic flows from high pressure regions to the low pressure regions. Then, the pressure will be converted to flow energy in filling stage of injection process and resulting in the pressure loss.

Even this simulation gives the good pattern of pressure distribution along flow front that pressure decreases along the flow length toward the polymer melt front that was in agreement with the theory but the pressure results are not practically precise. Since the pressure at vent or outlet position of mold cavity should be reached the atmospheric pressure which implies that the pressure distribution results of this simulation may not be actually used to explain the pressure variation in the actual process. The unacceptable results might be came from the design of vent channel of mold model was not modeled properly.

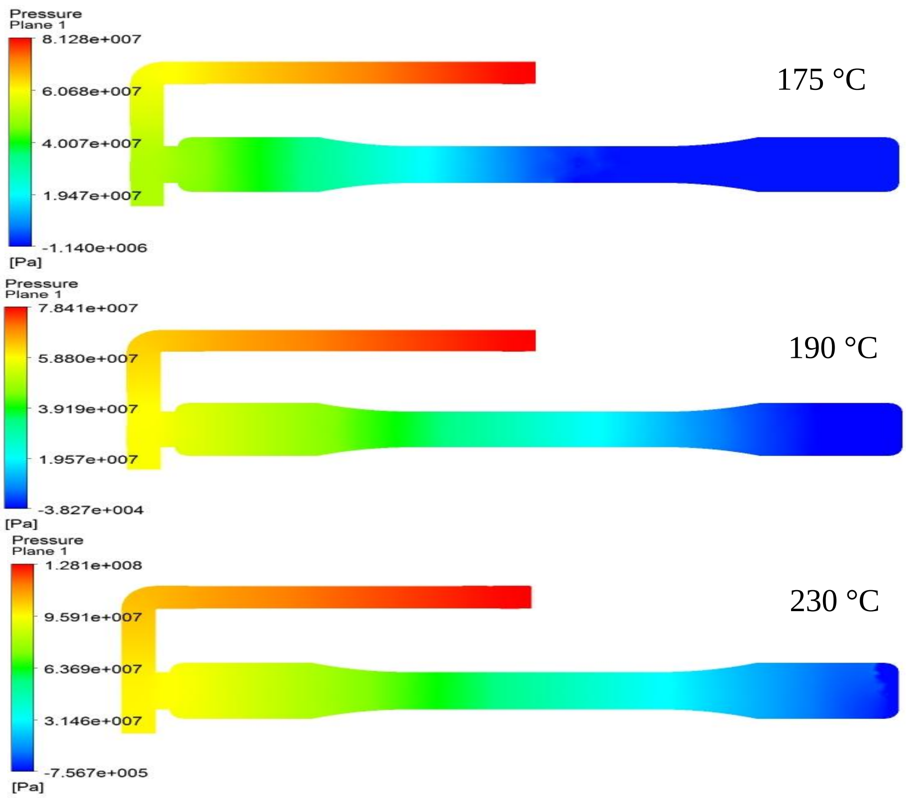

Figure 4.7 Pressure distributions along melt flow length at different melt temperature