KAUNAS UNIVERSITY OF TECHNOLOGY
MECHANICAL ENGINEERING AND DESIGN FACULTY

Dinesh Manickam

INJECTION MOLDING OF ABS PLASTICS

Final project for Master degree

Supervisor
Assoc. Prof. Dr. Regita Bendikiene

KAUNAS, 2015

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Assoc. Prof. Dr. Regita Bendikiene

Reviewer
Assoc. Prof. Dr. Rasa Kandrotaite Janutiene

Project made by
Dinesh Manickam

KAUNAS, 2015

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MECHANICAL ENGINEERING AND DESIGN FACULTY

(Faculty)

Dinesh Manickam

(Student's name, surname)

Mechanical Engineering (code 621H30001)

(Title and code of study programme)

Injection molding of ABS plastics

DECLARATION OF ACADEMIC HONESTY

1 June 2015

Kaunas

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SUMMARY

Injection molding is the process used to produce products of desired shape and size and normally parts made in injection molding process can have their own distinctive set of possible defects like sink marks, weld lines, war page, shrinkage, shot shorts, etc. due to the complex technology involved. To minimize these defects and to obtain good quality of product, optimization of parameters must be carried. In this project Acrylonitrile Butadiene Styrene (ABS with grade IM14GM) thermoplastic was used and ANSYS 14.5 software has been used to optimize the parameters like temperature and pressure to reduce the shot short defect which means incompletion filling of mold and to produce good quality of ABS products and in addition, fabrication was carried out with the results obtained in the analysis and then these fabricated materials was subjected for thermal testing to determine quality of the product. Generally, ABS plastics have various applications that include electrical and electronic equipment, as well as widespread applications in automobiles, communication instruments, and other commodities. Among these applications, the motor cover of the table top grinder was the ABS plastic product chosen that was produced using injection molding machine since motor cover has many applications. The injection molding machine has different zones of which the optimization was carried out. The optimized temperatures of nozzle, zone 1, zone 2, zone 3, zone 4, with which the good quality motor cover was produced is 100°C 180°C, 160°C, 150°C, 140°C respectively and the injection pressure was optimized as 100 bar. The obtained result was proven by fabricating the product using these parameters.

Keywords: Injection molding, ABS, Shot short defect, optimization, ANSYS, fabrication.

Manickam, Dinesh. **Abs plastikų liejimas slegiant.** Final Master's Degree Project / vadovas Assoc. Prof. Dr. Regita Bendikiene; Kauno technologijos universitetas, Mechanical Engineering and Design Faculty, Department of Manufacturing Engineering.

Kaunas, 2015. 53 p.

SANTRAUKA

Plastmasės liejimas įpurškimo būdu yra procesas skirtas norimos formos ir dydžio gaminiams išlieti. Deja, tokia technologija turi savitų trūkumų, kaip įdubimų susiformavimas, plastiko susilydimo linijų susidarymas, gaminio išlinkimas ar susitraukimas, nepakankamas įpurškiamo plastiko kiekis ir kiti trūkumai. Gaminio defektams atsirasti tikimybė yra didelė, nes gamyboje naudojamas platus technologijų spektras. Trūkumų sumažinimui ir geros kokybės išgavimui reikia optimatizuoti gamybos parametrus. Šiame projekte buvo naudojamas Akrilnitrilo Butadieno Stireno (ABS IM14GM klasės) termoplastikas bei ANSYS 14.5 programinė įranga, kuri leidžia optimatizuoti temperatūros ir slėgio parametrus, sumažinant gaminio nepakankamo išliejimo tikimybę, taip išgaunant kuo geresnę kokybę. Gamyboje buvo remtasi analizės duomenimis, kurie buvo gauti bandant gamybos medžiagas terminiu būdu. ABS plastikas turi platų panaudojimo spektrą - elektros ir elektronikos prietaisų, automobilių dalių, komunikacijos prietaisų ir kitų gaminių gamyboje. Projektui buvo pasirinkta virtuvės kombaino korpuso danga, nes ji turi daug panaudojimo būdų kituose buitiniuose prietaisuose. Liejimo įpurškimo būdu aparatas, naudotas projekte, turi skirtingas zonas, kuriose buvo vykdoma optimatizacija. Optimatizuota purkštuko temperatūra, pirma, antra, trečia ir ketvirta zonos, kuriose geros kokybės virtuvės kombaino danga buvo pagaminta 100 ^{O}C, 180 ^{O}C, 160 ^{O} C, 150 ^{O} C, 140 ^{O} C temperatūrose, optimaliu pasirinkus 100 bar purškimo slėgį.

Raktažodžiai: *Liejimas purškimo būdu, ABS, nepakankamo išliejimo defektas, optimizacija, ANSYS.*

1. INTRODUCTION

Polymers are processed in different ways. Injection molding is one of the commonest methods used for the purpose where molten polymer is injected into the mold under high pressure and the part is ejected from the mold after being relatively cooled in a short time [1]. ABS is one of the industrial polymers and among the five most highly consumed polymers in the word and Acrylonitrile–butadiene–styrene terpolymer (ABS) is one of the most successful engineering thermoplastics. High level of strength, rigidity, toughness and impact strength of ABS has led to its good mechanical properties [2].

ABS is a thermoplastic material and due do which it is easily plastic injection molded. The Acrylonitrile–Butadiene–Styrene (ABS) polymers are based on three monomers: Acrylonitrile, Butadiene and Styrene. Because of its good balance of properties, toughness/ strength/temperature resistance coupled with its ease of molding and high quality surface finish, ABS has a very wide range of applications. These include electrical and electronic equipment, as well as widespread applications in automobiles, communication instruments, and other commodities [3].

In this project, motor cover of table top grinder was taken as ABS plastic product. The grade of ABS plastic used in this project is IM14GM and it was shown in figure 1.1.

Figure1.1 ABS (with grade 1M14GM)

Initially, parameters are analyzed using ANSYS and then was optimized accordingly which was then fabricated and then subjected to quality testing to determine the exact parameters with which defect (shot short) free and good quality product can be produced.

Table top grinders have various applications in day to day life to grind stuffs to prepare food like dosa, idli, etc. In the company, motor cover of wet grinder is produced and during production there were multiple defects occurring in the product such as shrinkage, warpage, shot shorts, etc. The motor cover of table top grinder was shown in figure 1.2.

Figure 1.2 Table top grinder

In this industry more work pieces gets rejected with the defect of shot short. Since it is temperature related defect employees just were approximately changing the temperature and producing the product which does not give expected quality of the product. All that needed is to analysis the parameters and among these defects, this project concentrated only on shot short defect to minimize that defect by optimizing the parameters like temperature and pressure using ANSYS software in which CFD and THERMAL is used to analysis.

PROBLEM IDENTIFICATION

When the parameters are altered manually, they are still getting defects so that the product gets rejected as shown in figure 1.3. When the temperature is maintained less, the material will not get melted completely so that only half molded product is produced and if the temperature is increased, complete product can be obtained but with some defects like shrinkage, moisture, incomplete finishing at the end.

Figure 1.3 shot short defect

In this product, the completion of the product end is important since the clamping hole is present at the end to screw it covering the motor.

The **main aim** of this project is to find solution to eliminate shot short defect (incomplete filling of the mold) that occurs in the motor cover of the table top grinder produced in the injection molding machine using ABS material by optimizing the parameters used during the injection molding process. The **tasks that were raised to reach main aim** are to,

1. Select an equipment for the production of motor cover of table top grinder.
2. Select the material for the motor cover production.
3. Perform ANSYS analysis to determine the optimized parameters for the production of good quality ABS plastic motor cover.
4. Produce the motor cover using the ANSYS experimental results (using optimized parameters).
5. Test the produced motor cover to determine the working temperature.

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2. ABS PLASTICS AND EQUIPMENT USED TO PRODUCE IT

2.1 PROPERTIES OF ABS PLASTICS

Acrylonitrile-butadiene-styrene (ABS) is one of the most important synthetic engineering resins, due to excellent properties on impact resistance, heat resistance, and chemical resistance along with characteristics of easy to fabricate, stable in finished size and good surface glossiness. ABS has achieved wide applications in machinery, vehicles and electric products now a day [4]. It consists of an amorphous phase of styrene–acrylonitrile copolymer (SAN) and a polybutadiene (PB) rubber phase. ABS is widely used in electrical and electronic equipment, in the automotive industry, telecommunication instruments, and other commodities [5], [6].

ABS (acrylonitrile-butadiene-styrene) is an engineering thermoplastic composed of an elastomer (butadiene) dispersed as a grafted particulate phase in a thermoplastic matrix of styrene and acrylonitrile copolymer referred as SAN [7]. ABS is the most usually plated plastic because of its excellent toughness, good dimensional stability, good process ability, chemical resistance and cheapness [7], [8].

However, its application is limited because it is non-conducting and easily fretted. Metallized ABS can be widely used in many fields since its outstanding properties of engineering plastic and metal. For many years, activation process for metallization of non-conducting substrates has attracted increasing attention [9-12].

ABS is a well-known terpolymer over the past decades. It has been used as a homo polymer or matrix of the composite materials. The tribological properties of ABS have been in studies over the years, whereas neat ABS has its limitations in tribology due to high friction coefficient and wear rate [13].

Metallized ABS with both outstanding properties of engineering plastic and metal can be used widely in electronic industry, petrolic industry and national defense field [14]. An attractive property of ABS is its processing temperature of around 200 ºC which allows for compounding with wood particulates without thermally degrading the wood [15].

Brennan et al. studied the effects of the recycling and blending of ABS and high impact polystyrene on the mechanical properties. They found that changes in glass-transition temperature, tensile strength, and tensile modulus in reprocessed ABS were negligible, but strain to break and impact strength were considerably reduced [16]. Boldizar and Möller studied the properties of ABS subjected to a series of seven combined cycles of extrusion and ageing in air at an elevated temperature. They observed large changes in the tensile and flow properties. Moreover, they reported that from the second to the sixth cycle, the elongation at break decreased markedly and attributed this result to the physical ageing of the SAN phase and to thermo-oxidative ageing of the polybutadiene phase [17].

High level of strength, rigidity, toughness and impact strength of ABS has led to its good mechanical properties and it is shown in table 2.1. Its low shrinkage has made it to be used for producing parts with high accuracy and products of exceptional dimensional stability. Shrinkage is an unwanted phenomenon in injection molding process which leads to changes in dimension and low part quality [2].

Table 2.1 Properties of ABS material [18]

MATERIAL PROPERTIES	***ABS***
Tensile strength – yield (psi)	5300-6500
Flexural strength – yield (psi)	9400-11000
Modulus of elasticity (psi)	3.40e+0.5 to 3.77e+0.5
CTE (ppm/ºC)	100-140
Deflection temperature at 0.46 MPA (ºC)	90
Deflection temperature at 1.8 MPA (ºC)	85
Max. continuous service temperature (ºC)	85
Thermal conductivity (W/m-K)	0.14-0-30
Specific heat (J/g.ºC)	1.2-1.4

IMPACT PROPERTIES

The izod impact strength values (thickness of3 .175 mm) of commercial ABS products range from 75 J/m (1.2 ft-lb/in.) to 640 J/m (12 ft-lb/in.) [19]. The major factors for the impact strength of ABS include rubber matrix adhesions, rubber particle size and size distribution, rubber level, crosslink density of rubber particles, matrix molecular weight, matrix composition, glass transition temperature of the rubber, test temperature, strain rate and orientation. To achieve reasonable impact strength, the rubber matrix adhesion needs to be sufficiently high to transfer stress from the matrix to the rubber [20].

Good adhesion between rubber and matrix is achieved by the presence of an optimized graft structure and graft level. The ABS polymers with small rubber particles (about 0.1 µm in diameter) tend to have shear deformation rather than initiate crazes. The shear deformation is promoted by rubber particle cavitation, which becomes the major toughening mechanism [21]. On the other hand, ABS with large particles (about 0.5 µm size) favored crazing.

TENSILE PROPERTIES

The tensile modulus, yield strength, tensile strength at break, elongation at break of commercial ABS products are in the ranges of 0.9-2.9 GPa, 18-51 MPa, 17-55 MPa, 1.5-100%, respectively [19].

A typical ABS yields at a strain equal to about 2.5-3.5%. Yield stress and modulus increases with higher strain rate and lower temperature and elongation at break decreases. The yield stress of ABS was found to increase linearly with the logarithm of the strain rate [22].

ELECTRICAL PROPERTIES

Electrical properties of ABS are fairly constant over a wide range of frequencies and are unaffected by changes in temperature and humidity level. Electrical property values for ABS polymers are: dielectric constant 2.4-5.0 over frequency range of $60\text{-}10^4$ Hz, dielectric strength 200-140 V/cm^{-1} (360-508 V/mil), arc resistance 50-85 sec [23]. ABS is good insulators.

THERMAL PROPERTIES

Heat distortion, softening, and glass transition temperature can be measured by using number of methods and the most common method of ABS is ASTM D-648 and ISO 75.

The deformation temperature of sample to 0.25 mm can be said as heat distortion temperature under three point bending when heated at 2ºC/min. It is satisfactory measure of ABS ability of withstanding deformation [24].

GLOSS AND MOLDED GLOSS STABILITY

The key factor to the ABS gloss is rubber particle size and it is found that the logarithm of gloss decreases linearly with particle size. Gloss is affected by many factors, especially during molding and the parameters that increase the gloss are high mold surface temperature, fast injection speed, and high injection pressure [25]. Under long residence time and high melt temperature, the gloss of ABS is decreased by rubber particle agglomeration [26].

CHEMICAL RESISTANCE

The strong polarity of acrylonitrile results in the excellent chemical resistance properties of ABS and it can retain its mechanical properties at high acrylonitrile levels in extremely aggressive environments, including polar solvents. ABS can be used as a barrier for oxygen and carbon dioxide at very high acrylonitrile levels. The key component of ABS chemical resistance is the combination of resistance to solvent penetration and higher crack surface energy after solvent exposure [27].

FLAMMABILITY

Flammability is a critical measure in ABS applications where exposure to possible ignition sources is a concern. Adding halogen containing additives during compounding the improved flame resistance in ABS can be achieved. Non-halogen containing flame retardants can also be used that are less detrimental to the atmospheric ozone [28].

2.2 POLYMERIZATION PROCESS

ABS polymers are two-phase polymer systems containing rubbery polybutadiene particles dispersed in a glassy SAN matrix. Grafted polybutadiene rubber particles and SAN copolymer matrix are two major intermediates in ABS manufacturing.

MECHANISM OF GRAFTING

Polybutadiene radicals can be formed through the following reactions.

i. Addition to internal double bonds in polybutadiene [29]

$$R^{*} + \wedge\wedge\wedge\wedge\wedge\wedge\wedge CH_2\text{-}CH{=}CH\text{-}CH_2\wedge\wedge\wedge\wedge\wedge\wedge\wedge \longrightarrow \wedge\wedge\wedge\wedge\wedge\wedge\wedge CH_2\text{-}CH(R)\text{-}CH\text{-}CH_2\wedge\wedge\wedge\wedge\wedge \quad (1)$$

ii. Hydrogen abstraction [30]

$$R^{*} + \wedge\wedge\wedge\wedge\wedge CH_2\text{-}CH\text{-}CH\text{-}CH_2\wedge\wedge\wedge\wedge\wedge\wedge \longrightarrow RH + \wedge\wedge\wedge\wedge\wedge\wedge\wedge\,{}^{*}CH_2\text{-}CH\text{-}CH\text{-}CH_2\wedge\wedge\wedge\wedge\wedge \quad (2)$$

iii. Addition to vinyl double bonds in polybutadiene [31]

$$R^{*} + \wedge\wedge\wedge\wedge\wedge\ CH(CH{=}CH_2)\text{-}CH_2\wedge\wedge\wedge\wedge\wedge\wedge \longrightarrow \wedge\wedge\wedge\wedge\wedge\ CH({}^{*}CH\text{-}CH_2\text{-}R)\text{-}CH_2\wedge\wedge\wedge\wedge\wedge\wedge \quad (3)$$

The most widely used processes in the ABS industry are emulsion polymerization processes as shown in figure 2.1. The advantages of emulsion processes are easy control of heat transfer, rubber cross linking, rubber particle size, and graft morphology [33].

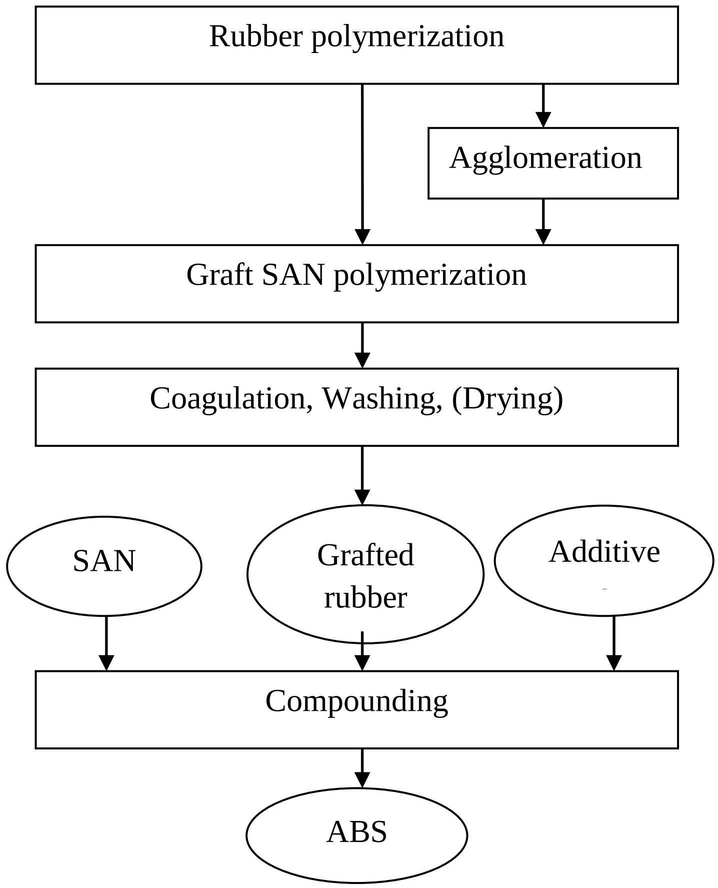


Figure 2.1 Emulsion ABS polymerization process [32].

The properties of the final ABS products are determined by the structures formed during the manufacturing processes. Key structural factors influencing final ABS properties include (1) the composition, particle size, and crosslink density of the rubber particles, (2) the morphology, graft level, and composition of grafted polymers, and (3) the composition and molecular weight distribution of the matrix SAN copolymers [34].

ABS composition can be estimated by using number of techniques and to measure the amount of AN in polymer, elemental analysis of C, H, and N can be used assuming the only source of nitrogen is acrylonitrile [35].

The amount of polybutadiene rubber, styrene, and acrylonitrile can be determined by using Fourier transform infrared (FTIR) and FT-Raman spectroscopy [36]. The most convenient methods available for measuring the particle size of ABS produced with emulsion processes are the instruments based on quasi-elastic light scattering and these methods are very fast with an analysis time in the order of a few minutes [37]. Capillary hydrodynamic fractionation chromatography (CHDF) and centrifugal fractionation instruments would give particle size distribution with longer analysis time [38].

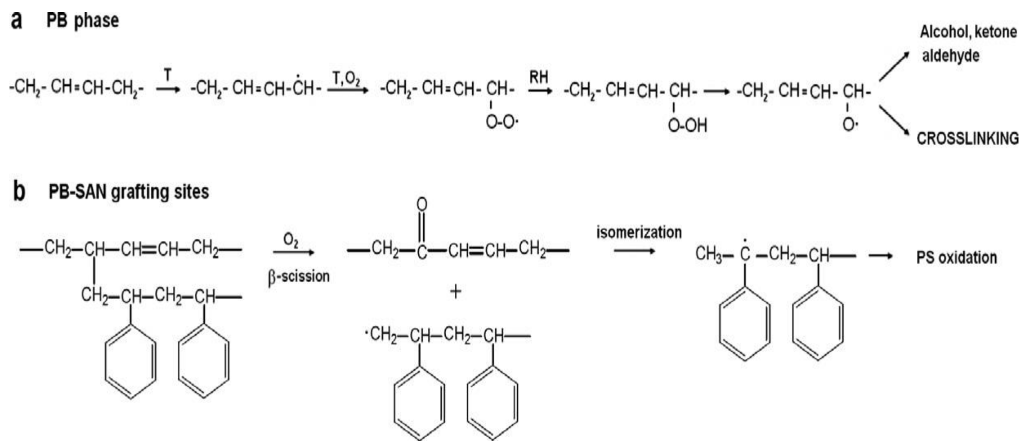
Measuring swelling index of a polymer in a solvent and calculating the crosslink density through the Flory-Rehner swelling equation is the most common method of obtaining the crosslink density of rubber in ABS [39].

2.3 POSTPROCESSING METHOD

The major fabrication process for ABS products is injection molding. ABS should be predried before molding to prevent surface defects. Drying of ABS can be carried out for 2 hours at about 85ºC or 4 hours at about 75ºC [40]. Melting and molding surface temperatures are 220-260 ºC and 50-70 ºC, respectively. The hydraulic injection pressure ranging from 40 – 140 MPa is commonly used for molding ABS. The weight of the entire molded shot should not exceed 75% of the rated machine capacity to avoid poor quality parts [41]. ABS materials are available as compounds for injection molding, blow molding, extrusion and calendaring, as sheet from thermoforming or cold forming, and in expandable grades for foam molding.

ABS is used to injection mold interior panels and trim, grills, wheel covers and mirror housings [42]. Mold materials with the different thermal properties affect the mechanical properties of the plastic parts in injection molding [43].

It is important to understand the degradation mechanisms to which recycled ABS is subjected during its life cycle and it is shown in figure 2.2. Since ABS consists of PB and SAN phases, the degradation mechanism of this polymer deals with the degradation paths of those components [44]. In particular, the PB phase is selectively attacked during the initial stages of degradation [45].



(4)

(5)

Figure 2.2 Degradation mechanism of ABS [45].

Five consecutive cycles of injection molding using ABS material was performed. During this study failure strength slightly increased, the strain to failure showed a very slight tendency to decrease after five processing cycles. Infrared and dynamic mechanical analyses demonstrate that the changes of these properties were due to the degradation of polybutadiene component [46]. From the industrial point of view of recycling and eventual reuse, the lost of characteristics and the addition of new ones can be solved upgrading recycled materials. Recycled ABS was blended with PC in order to increase impact strength and increase the flame retardant property [47].

2.4 APPLICATIONS, ADVANTAGES AND DISADVANTAGES OF ABS

- The largest volume applications for ABS resin on a worldwide basis are in the appliance, automotive, electrical/electronics, and pipe markets.
- ABS competes in these markets with modified polyphenylene oxide, polycarbonate, polyvinyl chloride, polystyrene, and polypropylene [48]. Extrusion grades have been developed to meet the specific requirements for this application and others.
- One particular application of ABS in appliance market is refrigerator liners and other applications include injection molded housings for small kitchen appliances, tools and vacuum cleaners.
- In the automotive market, ABS resins have been used in applications both with the interior and exterior of the automobile [28].

- Interior applications include instrumental panels, ducts, consoles, door parts, and other small interior parts.
- Exterior parts include mirror housings, front radiator grilles, and headlight housings or some models.
- Parts that are exposed to direct sunlight require stringent weatherability requirements. In addition, in the automotive market, ABS plating grades are used in applications such as decorative trim and grilles.
- Plating grades require excellent plate adhesion, low temperature ductility, and high temperature resistance.

ADVANTAGES OF ABS PLASTIC

Excellent impact resistance. It can have good appearance for cosmetic parts. Strength is moderate. Good resistance to acids and bases [49].

- Flame Retardant
- Heat Resistance, High
- Impact Resistance, Good
- Impact Resistance, High
- Processability, Good
- RoHS Compliant
- General Purpose
- Flow, Good
- Flow, High

DISADVANTAGES OF ABS PLASTIC

It is sensitive to thick sections in your part which may cause voids, bubbles or sink. Attacked by hydrocarbons and organic solvents. Heat resistance is low [49].

1. Limited weathering resistance
2. Moderate heat, moisture and chemical resistance
3. Relatively high cost
4. Flammable with high smoke generation

2.5 INJECTON MOLDING

Injection molding consists of high pressure injection of the raw material into a mould which shapes the polymer into the desired shape [50]. At the present time, only injection molding is economical for mass production due to its high productivity [51]. Basically all kind of polymers, known sometimes as resins, can be used. This includes all thermoplastics, and some elastomers and thermosets. The injection molding process at micro scale is very complex and there are many factors which influence the process such as: injection speed, injection pressure, melt temperature, mold temperature, and others [52].

Injection molding parameters can be grouped into three main categories [53]:

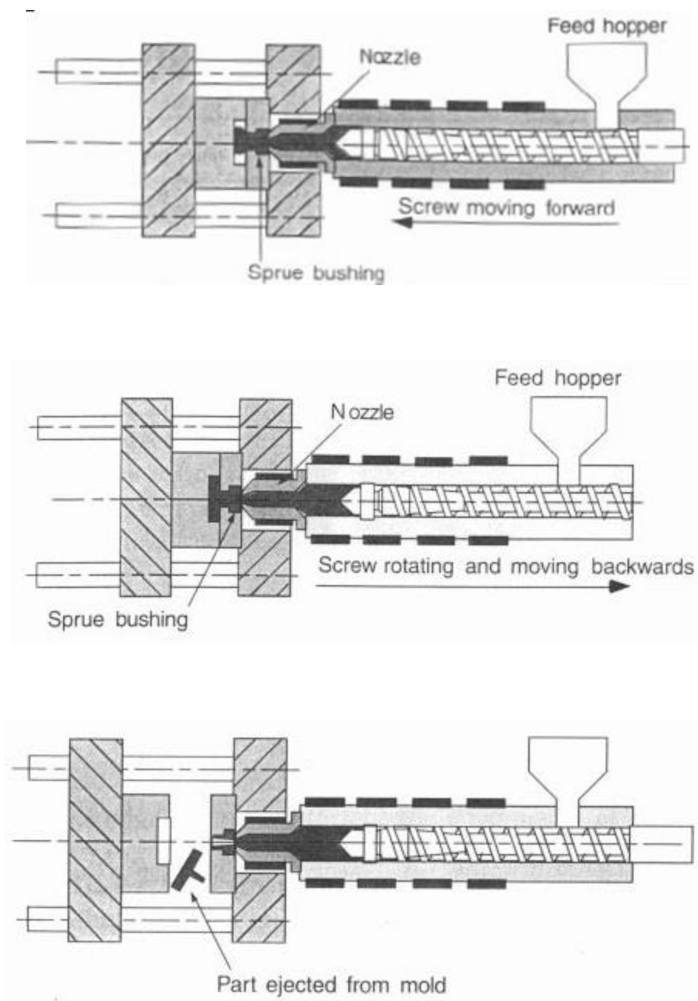
1. The parameters related to the injection unit of the PIMMs.
2. The parameters related to the clamping unit of the PIMMs.
3. The parameters related to the other functional units of the PIMMs.

The powder injection molding (PIM) process is a combination of powder metallurgy and plastic injection molding technologies. The process has developed from the injection molding approach used for forming plastics, but the technology for PIM is more complicated than that of plastic injection molding, which arises from the need to remove the binder and to density and strengthen the part. The PIM process uses ceramic or metal powders [54].

The process is commonly termed metal injection molding (MIM) or ceramic injection molding, depending on whether metal or ceramic powder is used. The PIM technology is still shrouded in secrecy and guarded by patents, although its usage is increasing. The process is commonly used for the mass production of near-net shape parts. Today, PIM finds diverse applications in small, intricate high-volume and high-value parts. Some of its applications are in the gun and armament parts, office machinery, computer peripherals, medical and dental instruments, orthodontic devices, food and beverage components [55], [56]. Although most injection molding processes are covered by the conventional process description above, there are several important molding variations including, but not limited to [57]:

- Die casting
- Metal injection molding
- Thin-wall injection molding
- Injection molding of liquid silicone rubber

The injection molding process is a cyclic process. Four significant stages of the process are filling, packing, cooling and ejection. The first stage is the ‘‘filling stage’’ in which the mould cavity is filled with hot polymer melt at injection temperature as shown in figure 2.3(a). After the cavity is filled, in the ‘‘packing stage’’, additional polymer melt is packed into the cavity at a higher pressure to compensate the expected shrinkage as the polymer solidifies as shown in figure 2.3(b). Next, the mould is cooled until the part is sufficiently rigid to be ejected, and this stage is the ‘‘cooling stage’’. The last one is the ‘‘ejection stage’’ in which the mould is opened and the part is ejected as shown in figure 2.3(c), after which the mould is closed again to begin the next cycle [58].



(a)

(b)

(c)

Figure 2.3 Cycle of injection molding [59].

(a)Stage.1 Injection of the plastic melt into the mold (b) Stage.2 Holding and screw recovery (c) Stage.3 Ejection of the part(s)

2.6 INJECTION MOLDING MACHINE

An injection molding machine is a machine which produces components by injection molding and it is shown in figure 2.4. IMMs in general consist of two functional units that are arranged separately: the injection unit and the clamping unit [60].

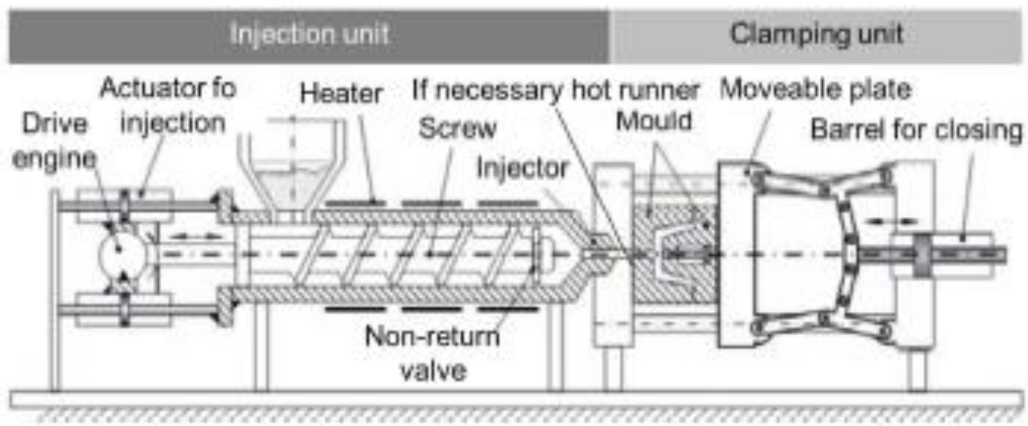


Figure 2.4 Schematic view of an IMM [60].

The clamping unit holds the injection mold. It is capable of closing, clamping, and opening the mold. Its main components are the fixed and moving plates, the tie bars, and the mechanism for opening, closing and clamping [61].

The total clamp force needed is determined by the projected area of the part being moulded. This projected area is multiplied by a clamp force of from 1.8 to 7.2 tons for each square centimeter of the projected areas. As a rule of thumb, 4 or 5 tons/in^2 can be used for most products. If the plastic material is very stiff, it will require more injection pressure to fill the mould, and thus more clamp tonnage to hold the mould closed [62]. The required force can also be determined by the material used and the size of the part; larger parts require higher clamping force. Injection molding machines have many components and are available in different configurations, including a horizontal configuration and a vertical configuration.

However, regardless of their design, all injection molding machines utilize a power source, injection unit, mold assembly, and clamping unit to perform the four stages of the process cycle and the equipment is shown in figure 2.5.

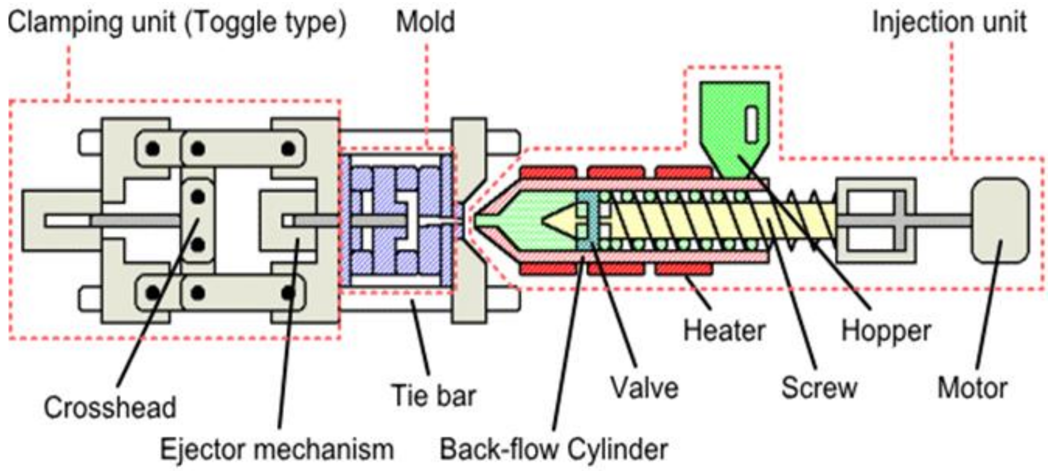


Figure 2.5 Injection molding equipment [63].

The injection unit is responsible for both heating and injecting the material into the mold. The first part of this unit is the hopper, a large container into which the raw plastic is poured. The hopper has an open bottom, which allows the material to feed into the barrel. The barrel contains the mechanism for heating and injecting the material into the mold. The material enters the grooves of the screw from the hopper and is advanced towards the mold as the screw rotates. While it is advanced, the material is melted by pressure, friction, and additional heaters that surround the reciprocating screw.

The molten plastic is then injected very quickly into the mold through the nozzle at the end of the barrel by the buildup of pressure and the forward action of the screw. This increasing pressure allows the material to be packed and forcibly held in the mold. Once the material has solidified inside the mold, the screw can retract and fill with more material for the next shot [64].

The clamping unit main function is to open and close the mold along with ejecting the parts. The two most common types of mold clamps are the direct hydraulic and the toggle clamps. Toggle clamps are actuated by hydraulic cylinders. These clamps utilize mechanical linkages to generate higher forces than a direct connection from a hydraulic cylinder of the same size.

After amplification by the toggle mechanism, the clamping cylinder, attached to the tail platen, extends, pushing the moving platen to lock the mold halves together as shown in figure 2.6 [65].

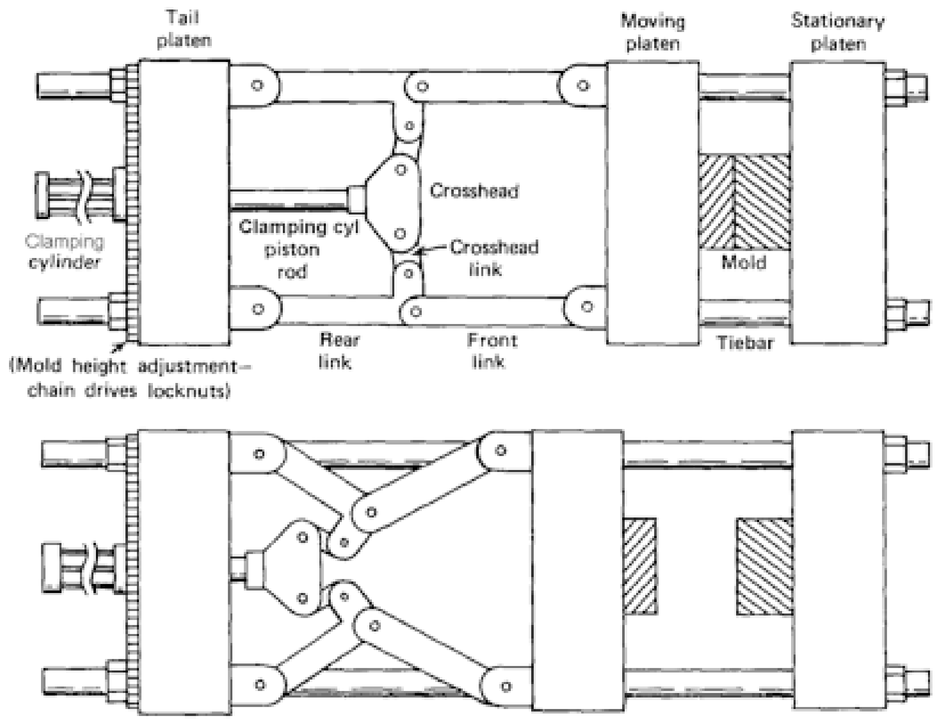


Figure 2.6 Five point toggle clamp [65].

A mold is a hollow metal block into which molten plastic is injected to from a certain fixed shape. It is a cavity to which the molten material is allowed to fill for the production of desired shaped parts. Mould comprises of two parts namely core and cavity. It can also be called as die [66].

Molten plastic flows into a mold through a sprue and fills cavities by way of runners and gates. Then, the mold is opened after cooling process and the ejector rod of the injection molding machine pushes the ejector plate of the mold to further eject moldings [63].

The schematic representation of mould parts is are shown in figure 2.7.

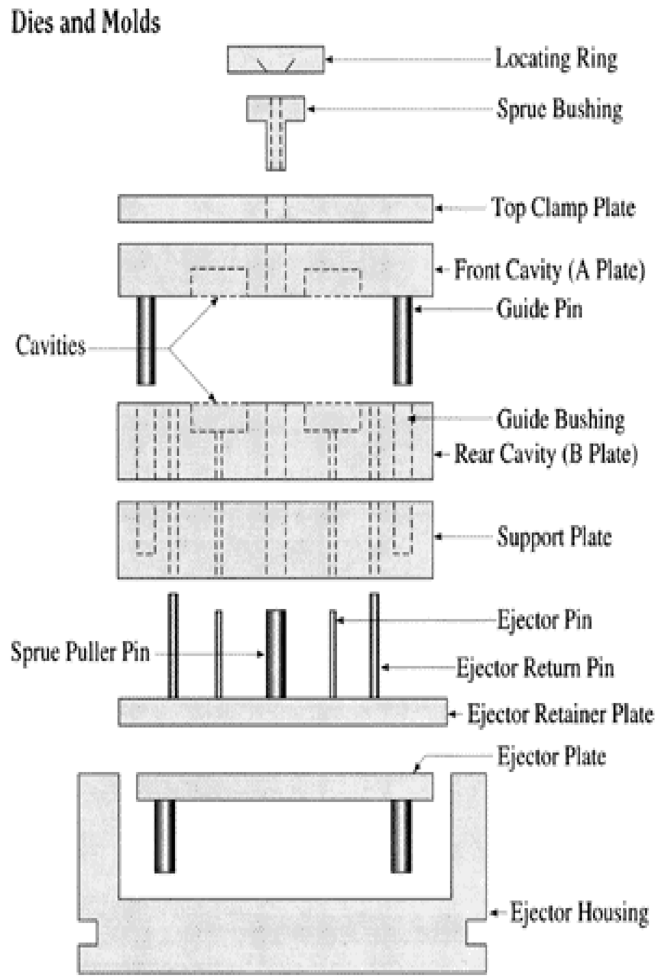


Figure 2.7 moulds [66]

Plastic resin enters the mould through a sprue or gate in the injection mould; the sprue bushing is to seal tightly against the nozzle of the injection barrel of the moulding machine and to allow molten plastic to flow from the barrel into the mould, also known as the cavity. The sprue bushing directs the molten plastic to the cavity images through channels that are machined into the faces of the A and B plates. These channels allow plastic to run along them, so they are referred to as runners [62].

Sprue bushings connect the nozzle of the injection molding machine to the runner system of the mold as shown in figure 2.8. Ideally, the sprue should be as short as possible to minimize material usage and cycle time [67].

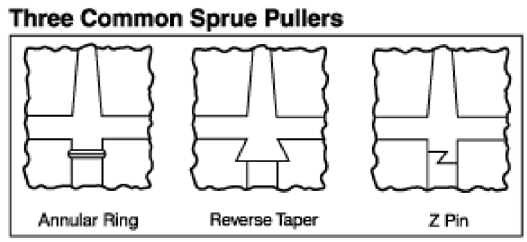


Figure 2.8 Three common sprue pullers [67]

There are two factors to consider when designing runner systems for directing material to the cavity. The first consideration is to design the runner channel system so that it gets material to the cavity in the shortest, most direct route and avoids lot of bends, twists, and turns in getting material to the gate. Another factor to consider is that the runner system is balanced [68]. Two basic types of runners are used in injection molding, the cold runner and hot runner. Cold runner systems are used on either two or three plate molds as shown in figure 2.9. Two-plate molds have one parting line along which the mold is split into two halves. Three-plate molds have two parting lines. When a part is ejected, the mold splits into three sections. Hot runner molds are two-plate molds [69].

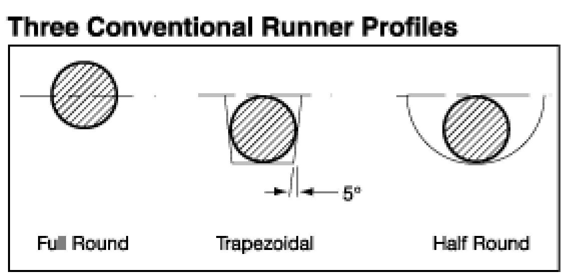


Figure 2.9 Cold runner cross sectional geometries [67]

Hot runner systems are divided into two parts: the manifold and the drops. The manifold has channels that carry the plastic on a single plane, parallel to the parting line - to a point above the cavity. The drops are placed perpendicular to the manifold - and carry the plastic from the manifold to the part [69].

The schematic representation of hot runner systems is shown in figure 2.10.

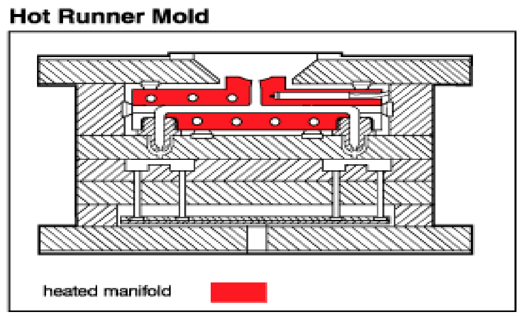


Figure 2.10 Hot runner mold [67]

The gate is the major passageway for material to flow from the injection molding machine barrel to the mold cavity. The gate directs the flow of molten material from the runner channel system into the mold cavity. The location of the gate on the molded part plays a major role in how the part will perform, as well as the quality, properties, performance of the part [68]. The common gate types used in injection molding are sprue gate, pin gate, edge gate, ring rate, diaphragm gate, fan gate, film gate, tab gate and it is shown in figure 2.11.

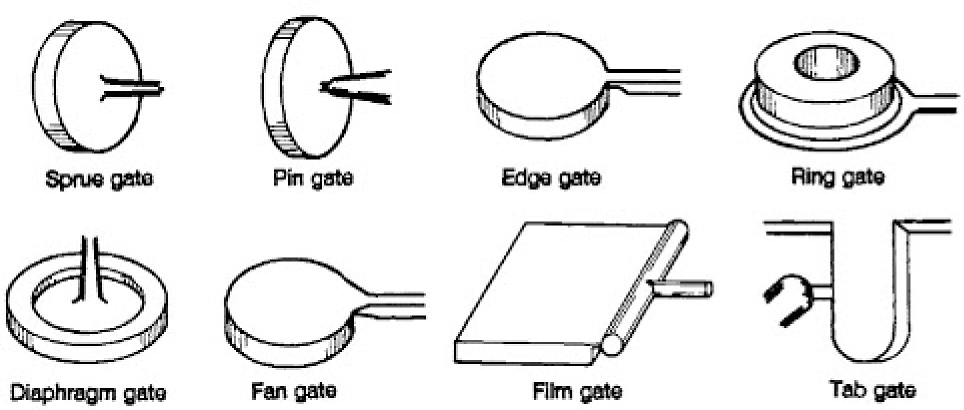


Figure 2.11 Types of gates in injection molding [70]

Sprue gate

Sprue gates are used in large parts made in a single cavity tool. Typically, the gate is located at the center of the part to allow for even flow through the part [68].

A big advantage of sprue gate designs is the simplicity in designing this type of gate versus tunnel and pinpoint gates. End use applications where sprue gates are used are in business machine applications.

Tab gate

Tab gates usually extend from the runner into the part and can have the same thickness as the part. These types of gates are found in consumer applications such as storage drawers and in small enclosure for electronics.

Ring gate

These are used primarily around cylindrical cores. In this case the material flows around a core pin and flows down to fill the pin evenly. A major advantage that ring gate have is that these gates can prevent the formation of trapped air, which can cause weld or knit lines [68].

INJECTION MOLDING COMPOUNDS [71]

Injection molding method is used to produce various products using various materials. The base polymer used in the injection molding and its applications are shown in table 2.2

Table 2.2 Materials used in injection molding

BASE POLYMER	***PRINCIPAL APPLICATIONS***
Acrylonitrile-butadiene-styrene	Furniture, cabinets, containers, trim
Aeetal	Clock gears, miniature engineered parts
Acrylic	Automobile light lenses, plastic glazing
Cellulose	Esters trim, moldings, screwdrivers
Polycarbonat	Auto bumpers, traffic lights, lenses
Polyeste	Appliance parts, pump and electrical housings
Polyethylene	Housewure, food storage, dunnage
Fluoroplastics	Corrosion/solvent-resistant parts
Polyimide	Aerospace items, electrical insulators B C

Table 2.2 continuation….	
BASE POLYMER	***PRINCIPAL APPLICATIONS***
Ionomer	Bumper rub strips, golf ball covers
Nylon	Auto parts, bearing retainers, appliances
Polyphenylene oxide and alloys	Auto instrument panels
Polypropylene	Battery cases, auto parts, containers
Polystyrene	Toys, advertising displays, picture frames
Polysulfone	Camera cases, aircraft parts, connectors
Polyvinylchloride	Soft steering wheels, Irim items
Alkyd	Switches, motor housings, pot/pan handles
Allyl	Electrical connectors, circuit boards
Epoxy	Electrical insulators, electronic cases
Polyester	Automotive structural parts
Polyimide	Aircraft components, aerospace parts
Melamine	Dinnerware, microwave cookware
Phenolic	Distributor caps, plastic ash trays
Urethane	Automotive body panels, bumpers
Vinyl ester	Composite car/truck springs, wheels

Metal powders used in injection molding are prepared by different methods: carbonyl synthesis, gas atomization or water atomization under high pressure. The more suitable powders are those with spherical shape or one approaching it. Gas atomized powders are purer compared water atomized powders. For example, powders of stainless steel grade 316L prepared by gas atomizing contain 0.006 mass% carbon and 0.021 mass% oxygen, and by water atomization they are correspondingly 0.021 and 0.22 mass% [72].

Various products can be produced using injection molding and some of the products are listed in the table 2.3.

Table 2.3 Products produced from injection molding

Power-tool housing	Telephone handsets
Electrical Switches	DVDs
Automotive dash boards	Battery Casings
Drug Inhalation Units	Disposable razors
Wheelie bins	Television Cabinets
Automotive bumpers	Washing-up bowls

2.6 QUALITY CONTROL AND SAFETY MODELLING

Parts made in injection moulding process can have their own unique set of possible defects due to the complex technology involved. In order to produce quality and consistent finished products, they are examined and checked using a thorough quality control process before any product is dispatched and defects are shown in figure 2.4 and safety modeling are shown in figure 2.5.

Table 2.4 Quality control

DEFECTS	**APPEARANCE**
Gas marks (burning)	Gas or burn marks are small, dark or black spots on the part surface. Air trapped in pockets may compress, heat up and cause burn marks. Strategically locating air vents of the proper depth within the mold is the best way to avoid burn marks. Adjustments injection speed and screw speed can also be altered to reduce or eliminate marks.
Shot shorts	A short shot is the incomplete filling of a mould cavity which results in the production of an incomplete part. Changing the plastic injection moulding parameters can correct this.
Weld lines	Weld Lines are created when two or more melt flow fronts meet possibly causing a visible line. It can also create a weakened area in the finished moulded part. Adjusting moulding parameters such as injection pressure, temperature and speed can help avoid this problem.

Table 2.4 continuation……	
Flash	Moulding flash occurs when a thin layer of material is forced out of the mold cavity at the parting line or ejector pins location. The machine clamp force must be greater than the pressure in the cavity, to sufficiently hold the mould plates shut and the mould must be properly built and maintained to avoid this problem.
Sink marks	Sink marks are caused by localised shrinkage of the material at thick sections without sufficient compensation when the part is cooling. Parts designed with a consistent wall thickness are less prone to this issue. Adjusting moulding parameters such as injection pressure and time can often minimise the effect of the sink mark.
Flow marks	Flow marks may result if molten plastic does not properly flow as it fills the cavity. Changing moulding parameters or adjusting the mould by changing the gate location or size can usually eliminate this problem.
Splay	Bubbles may flow along the part surface during the plastic injection moulding process. The trapped air can cause incomplete filling and packing, and will often cause a surface blemish in the final part. Correct mold design and processing parameters can prevent splay [73].

Table 2.5 Safety requirements

MEASURES	APPLICATIONS
Movable guard	The movable guard prevents access to the clamping and ejector mechanisms as well as other moving parts of the machine and mold. Do not start a machine or leave a machine operating unless this guard is in place. This guard may be fixed on some machine designs, requiring a tool to remove it.
Movable rear guard	The movable rear guard should be equipped with at least two interlocks that stop clamp motion when the guard is open. This guard should only be opened for setup and maintenance activities. Use the front operator’s gate for operator access to the mold space.
Safety interlock valve	The hydraulic safety interlock valve prevents the clamp from closing when the operator’s gate is open.

Table 2.5 continuation….	
Operators gate	The operator's gate allows the operator access to the mold and should be equipped with interlocks (such as electrical, hydraulic, and mechanical) that allow the machine to operate only when the gate is closed. Do not attempt to overrides any of the interlocks or to reach over, under, around, or through the operator's gate (or other guards) while the machine is operating.
Personal protection equipment	Personal protective equipment (PPE), such as a face shield, gloves, and other appropriate equipment should be worn while performing maintenance or servicing activities when a hazard may be present.
Control panel	The control panel on the front of the Injection Molding machine features a red Emergency Stop Button that prevents all machine motion when pressed.
Purge guard	The purge guard covers the nozzle of the Injection Molding machine and helps prevent crushing injuries or burns from the splatter of molten plastic material. The purge guard should be interlocked. Opening an interlocked purge guard interrupts injection unit operation, prevents purging and motion of the injection unit.
Electrical cabinet	The electrical cabinet guards the machine's electrical system and protects unauthorized people from electrical hazards.
Hopper	When in place, the hopper guards the feed throat opening, which connects the hopper to the injection unit, and does not allow workers' hands or limbs to enter the area where the screw is turning. When the hopper is removed, workers should follow the manufacturer's recommended procedures to avoid exposure to potential hazards. Wear appropriate personal protective equipment (PPE) and do not place your hand into the feed throat area. In addition, to avoid the possibility of being sprayed by molten material, do not look down the feed throat directly. Safety signs should be posted to alert workers of potential hazards.

Table 2.5 continuation….	
Hoses and fittings	Hoses and fittings can fail and spray hot oil or other substances at high pressure onto workers if punctured, frayed, or damaged. In addition, oil sprays can cause injuries and fire hazards. Inspect hoses and fittings for wear and damage as recommended by the manufacturer and replace as needed [65]. Injection moulding is used to create many things such as wire spools, packaging, bottle caps, automotive dashboards, Game boys, pocket combs, some musical instruments (and parts of them), one-piece chairs and small tables, storage containers, mechanical parts (including gears), and most other plastic products available today. Injection moulding is the most common modern method of manufacturing parts; it is ideal for producing high volumes of the same object [74].

3. METHODOLOGY

Generally, motor cover is used in table top grinder which has various applications in day to day life to grind stuffs to prepare food like dosa, idli, etc. and motor cover was produced using injection molding machine (WINDSOR) of model: SP.130 with the ABS plastic material of grade (1M14GM). Injection molding machine used was shown in figure 3.1

Figure 3.1 Injection molding machine

The barrel was shown if figure 3.2 which has four zones, namely zone 1, zone 2, zone 3, zone 4, and a nozzle through which mold comes out after melting. Each zone will have different temperatures and it is controlled my thermocouple sensor. These zones consists of long tube inside through which mold flows and it is covered my heater.

Figure 3.2 Barrel of injection molding machine

The methods used to analysis are CFD and THERMAL in ANSYS 14.5, after analysis and simulation it was fabricated using injection molding machine and then the fabricated product was subjected under testing using furnace to determine the exploitation temperature.

3.1 MODELLING AND SIMULATION

Initially, the flow pipe of the injection molding machine and the motor cover body of the table top grinder is designed using PRO E (CREO 1.0) software as shown in figure 3.3.

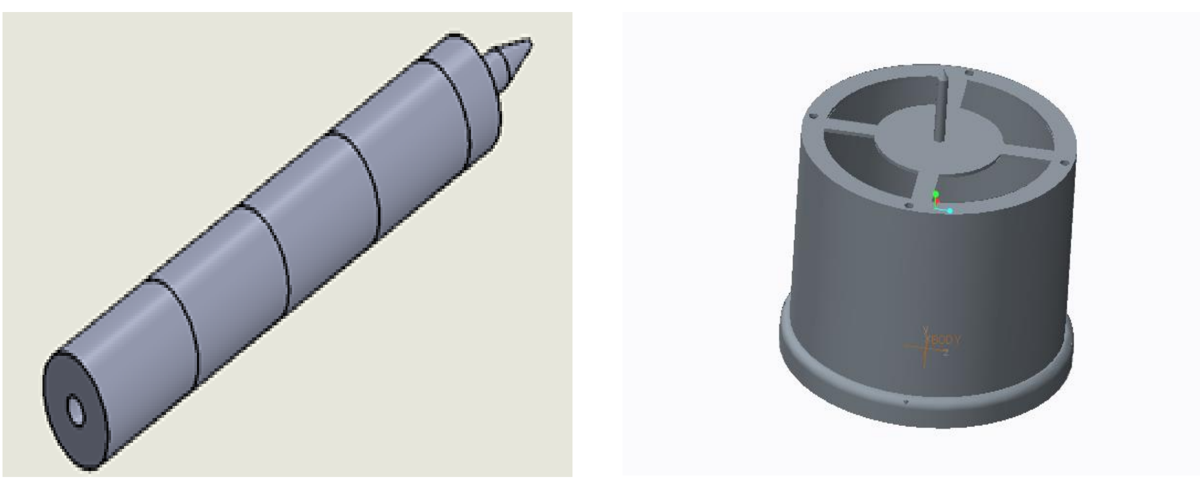


Figure 3.3 Isometric view of flow pipe and body of the motor cover

PRO E software is generally used by mechanical engineers to design and it is integrated 3D CAM/CAD/CAE solution created by Parametric Technology Corporation. This software provides solid modeling, assembly modeling, drafting, finite element analysis and tooling functionality for mechanical engineers.

Geometry can be said as building blocks of Engineering design process and there is also ability to generate geometry of other integrated design disciplines such as industrial and standard pipe works.

After creating the geometric model of flow pipe and the body of the motor cover using PRO E, this designed geometric model is imported into ANSYS software to carry out CFD (computational fluid dynamics) and THERMAL simulation.

ANSYS is a general-purpose finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static/ dynamic, structural analysis (both linear and nonlinear), heat transfer, and fluid problems, as well as acoustic and electromagnetic problems [75].

CFD is the branch of fluid dynamics providing a cost effective means of stimulating real flows by the numerical solution of the governing equation [76]. A THERMAL analysis calculates the temperature distribution and thermal quantities in a system or component [77]. Here with the use of CFD each zonal flow pattern inside the flow pipe can be analyzed. THERMAL ANALYSIS is used to check if the temperature is distributed through entire mold to obtain good quality product.

3.2 ANSYS ANALYSIS OF FLOW PIPE

There are different zones in the injection molding machine flow pipe, namely inlet, outlet, zone 1, zone 2, zone 3, zone 4, and a nozzle through which mold comes out after melting as shown in figure 3.4. Each zone will have different temperatures and it is controlled by thermocouple sensor.

The material of flow pipe is EN24 stainless steel and the ABS solid pebbles flows inside the flow pipe, with the temperature provided in the flow pipe the ABS material melts and flows in fluid form.

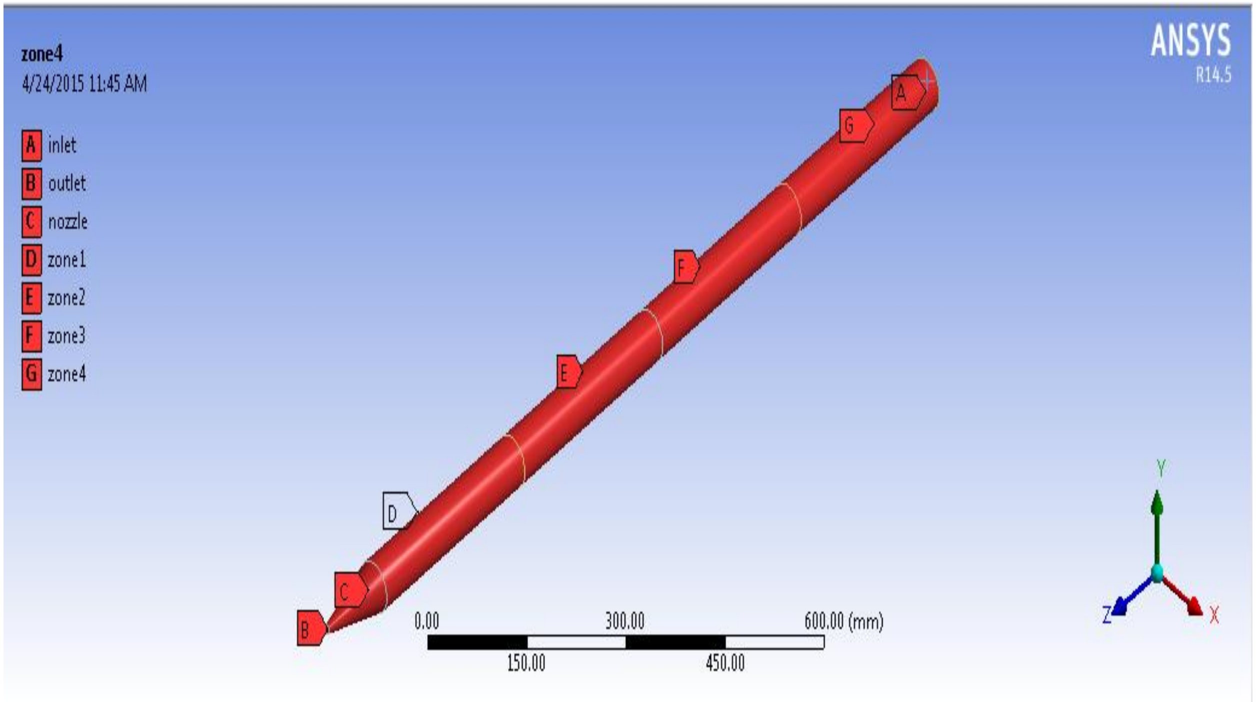


Figure 3.4 Different zones of the flow pipe

Firstly, the existing parameters like temperature, pressure are collected from the industry which was considered as CASE 1 parameters to analysis the exact process happening inside the flow pipe and the results obtained. For this analysis, CFD is used to determine the flow pattern and the THERMAL to determine the area of heat distribution in the product so that the defect occurring area in the product can be identified.

After this analysis with existing temperature and pressure, another two sets of parameters are taken to experiment to reduce the defect occurring in the product. These two sets of parameters were considered as CASE 2 and CASE 3 respectively.

The existing parameters that are used in the industry were considered as CASE 1 parameters and these parameters were used in CFD and THERMAL. Table 3.1 is the existing parameter using in the industry and it was analyzed using CFD to determine the flow pattern.

CASE 1

Table 3.1 Boundary conditions for case 1 CFD analysis

SECTIONS	Temperature in °C
NOZZLE	100
ZONE 1	150
ZONE 2	140
ZONE 3	120
ZONE 4	80
Injection pressure : 80 bar	

CFD ANALYSIS OF CASE 1

TOTAL TEMPERATURE CONTOURS

From the figure 3.5it is seen that the minimum temperature is 97°C (370K) and the maximum temperature is 135°C (408K), which is given as the input for the THERMAL analysis. This figure describes the flow pattern with the temperature ranges in all zones.

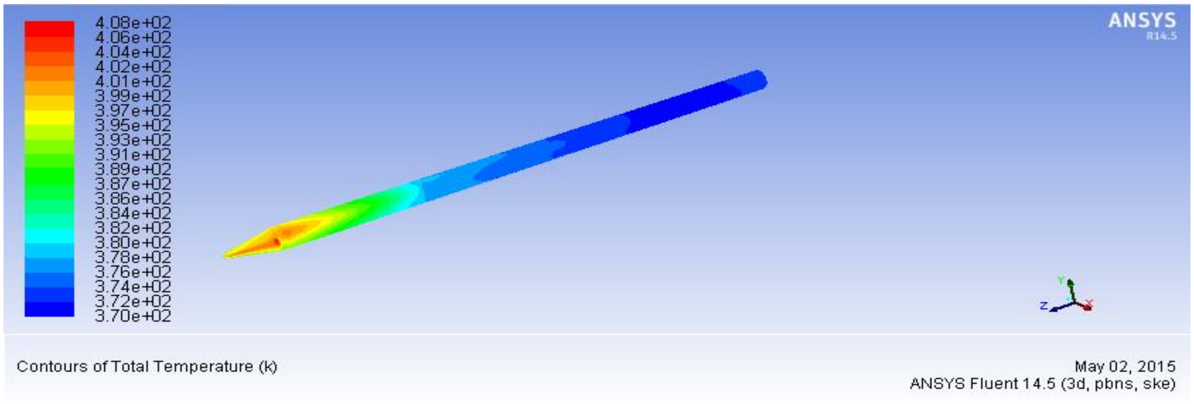


Figure 3.5 Total temperature contours

TOTAL TEMPERATURE VARIATION

The figure 3.6 indicates a temperature variation in this analysis at various named sections. In this figure a temperature indicates in Y- Axis and position of the particular section indicates in X- Axis.

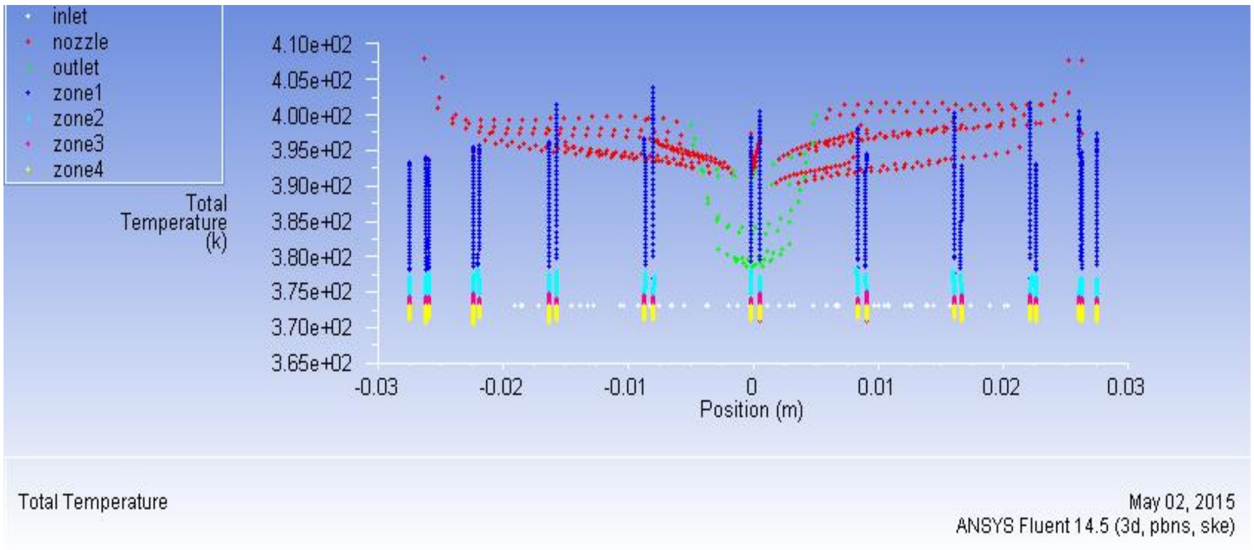


Figure 3.6 Temperature variation in all zones (in K)

For an example, color red indicates the temperature values occur in the Nozzle Section. Hence a nozzle section has a maximum temperature of 135.85°C (409K) and Minimum temperature of 118.85°C (392K). Same condition for Zone 4 the maximum and minimum temperature is 96.85°C (370K) and 99.85°C (373K) respectively indicates in color yellow.

TOTAL PRESSURE CONTOURS

Pressure also plays important role in injection molding process to obtain good quality product. Since pressure is directly proportional to temperature, the pressure value will affect the temperature which in turn will cause damage to the product. Thus, it is necessary to optimize the pressure value to obtain good quality product.

In case 1, the injection pressure was given as 80 bar and in the nozzle maximum pressure drop can be seen as 91 bar as shown in figure 3.7.

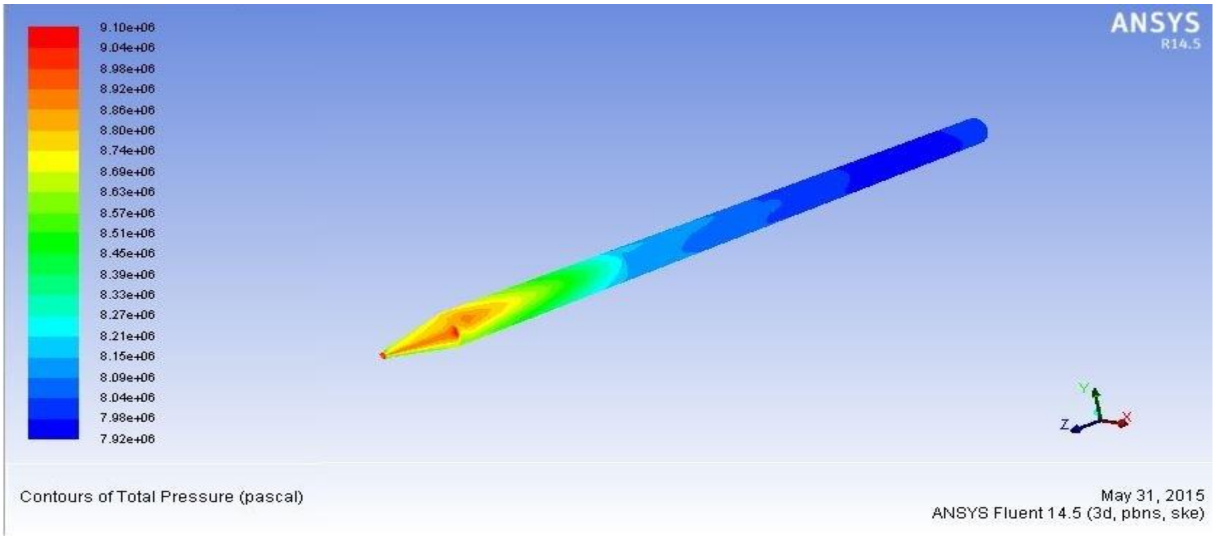


Figure 3.7 Total pressure contours

THERMAL ANALYSIS OF CASE 1

After CFD is performed for the boundary conditions of CASE 1, with the result of CFD analysis, it is subjected to THERMAL analysis to determine the heat distribution across the product.

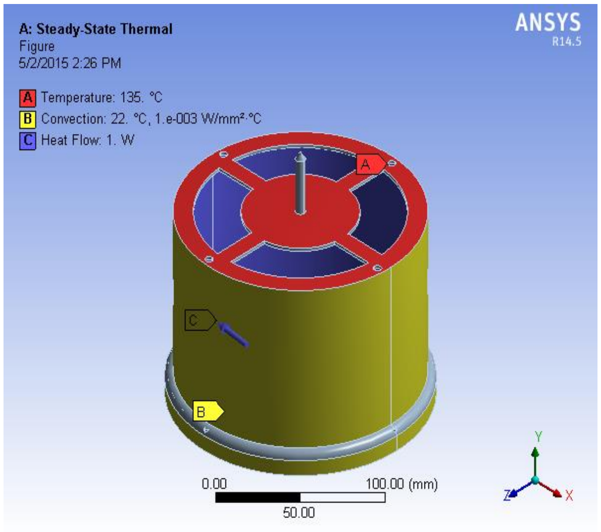
BOUNDARY CONDITIONS FOR CASE 1

The maximum temperature is 135°C (408K) as shown in figure 3.8 which is the maximum temperature that is obtained in the CFD analysis as shown in figure 3.5.

TEMPERATURE DISTRIBUTION

The figure 3.9 shows the heat distribution across the product with maximum temperature distribution value in red color and minimum temperature distribution value in blue color as 138.54°C (411.69K) and 14.303°C (287.453K) respectively. The portion in blue color indicates the shot short defect which means incomplete filling of the mold to get complete good quality of the product.

With the result of case l analysis, two sets of experiments were carried out with assumed parameters as CASE 2 and CASE 3 to eliminate the defect occurred in CASE 1and to obtain good quality product.



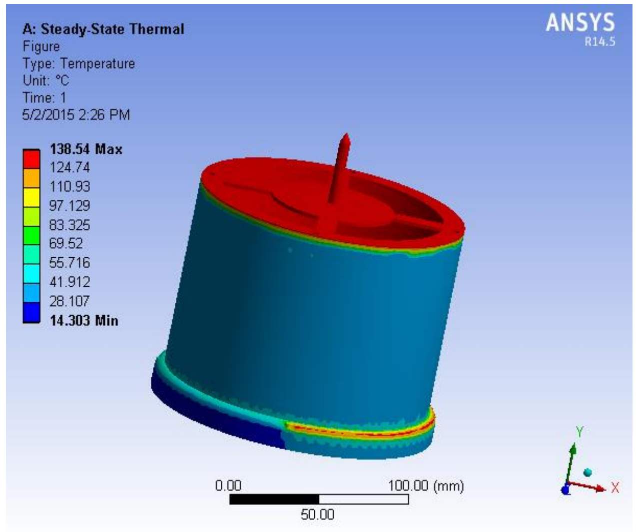


Figure 3.8 Boundary conditions ***Figure 3.9 Heat distribution***

First set of assumed parameters were taken as CASE 2 parameters, which was analyzed using CFD and THERMAL.

CASE 2

Table 3.2 is the assumed parameters used in CFD analysis to determine flow pattern.

Table 3.2 Boundary conditions for case 2 CFD analysis

SECTIONS	Temperature in °C
NOZZLE	100
ZONE 1	160
ZONE 2	150
ZONE 3	130
ZONE 4	110
Injection pressure: 90 bar	

CFD ANALYSIS OF CASE 2

TOTAL TEMPERATURE CONTOURS

From the figure 3.10 it is seen that the minimum temperature is 100°C (373K) and the maximum temperature is 151°C (424K), which is given as the input for the THERMAL analysis. This figure describes the flow pattern with the temperature ranges in all zones.

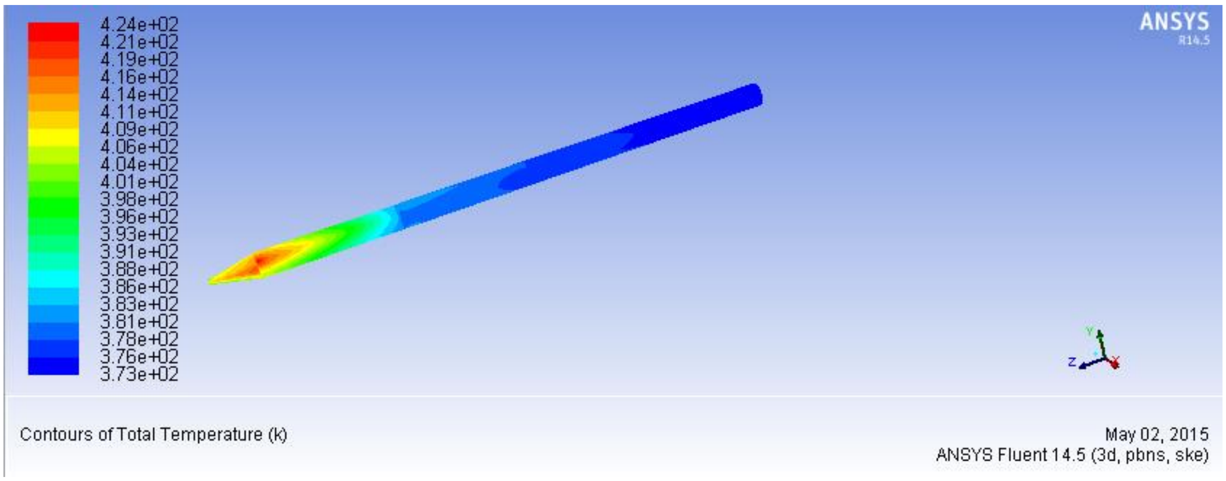


Figure 3.10 Total temperature contours

TOTAL TEMPERATURE VARIATON

The figure 3.11 indicates a temperature variation in this analysis at various named sections. In this figure a temperature indicates in Y- Axis and position of the particular section indicates in X- Axis.

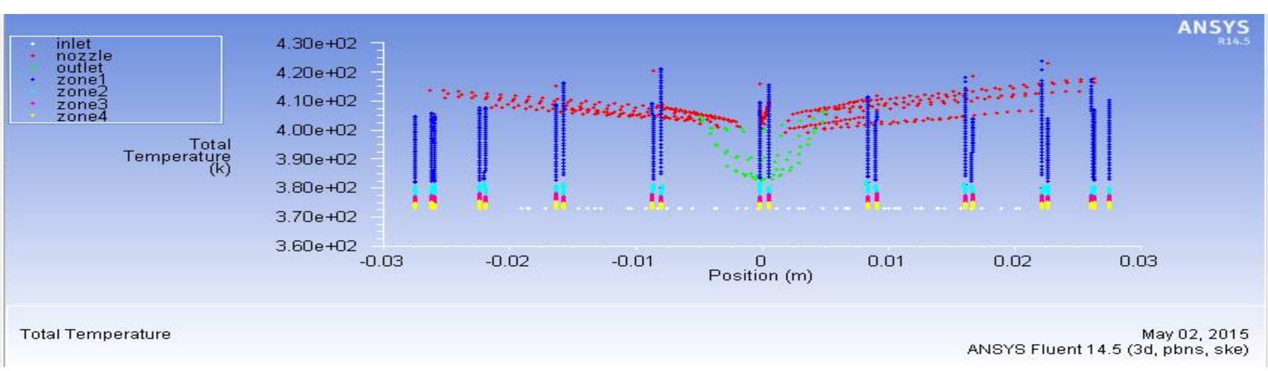


Figure 3.11 Total temperature variation

For an example, color red indicates the temperature values occur in the Nozzle Section. Hence a nozzle section has a maximum temperature of 149.85°C (423K) and Minimum temperature of 126.85°C (400K). Same condition for Zone -4 the maximum and minimum temperature is 102.85°C (376K) and 98.85°C (372K) respectively indicates in color yellow.

TOTAL PRESSURE CONTOURS

In case 2, the injection pressure was given as 90 bar and in the nozzle maximum pressure drop can be seen as 97.4 bar as shown in figure 3.12.

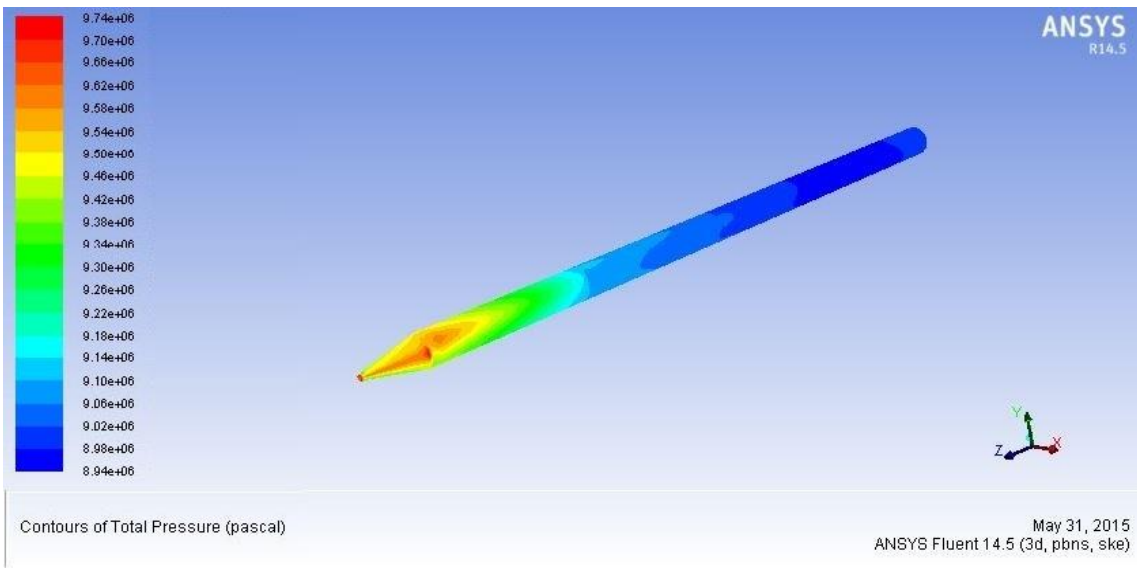


Figure 3.12 Total pressure contours

THERMAL ANALYSIS OF CASE 2

After CFD is performed for the boundary conditions of CASE 2, with the result of CFD analysis, it is subjected to THERMAL analysis to determine the heat distribution across the product.

BOUNDARY CONDITIONS FOR CASE 2

The maximum temperature is 151°C (424.15K) as shown in Figure 3.13 which is the maximum temperature that is obtained in the CFD analysis as shown in Figure 3.10.

TEMPERATURE DISTRIBUTION

The Figure 3.12 shows the heat distribution across the product with maximum temperature distribution value in red color and minimum temperature distribution value in blue color as 155.04°C (428.19K) and 15.135°C (288.285K) respectively. The portion in blue color indicates the shot short defect and it was seen that the defect percentage is minimum when compared to CASE 1.

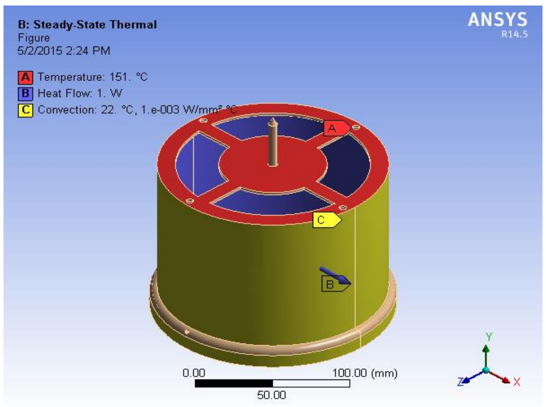


Figure 3.13 Boundary conditions

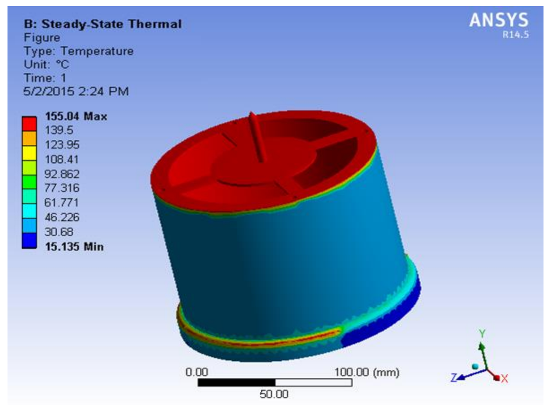


Figure 3.14 Heat distribution

Second set of assumed parameters were taken as CASE 3 parameters

CASE 3

Table 3.3 is the assumed parameters used in CFD analysis to determine flow pattern.

Table 3.3 Boundary conditions for case 3 CFD analysis

SECTIONS	Temperature in °C
NOZZLE	100
ZONE 1	180
ZONE 2	160
ZONE 3	150
ZONE 4	140
Injection pressure: 100 bar	

CFD ANALYSIS OF CASE 3

TOTAL TEMPERATURE CONTOURS

From the figure 3.15 it is seen that the minimum temperature is 100°C (373K) and the maximum temperature is 168°C (441K), which is given as the input for the THERMAL analysis. This figure describes the flow pattern with the temperature ranges in all zones.

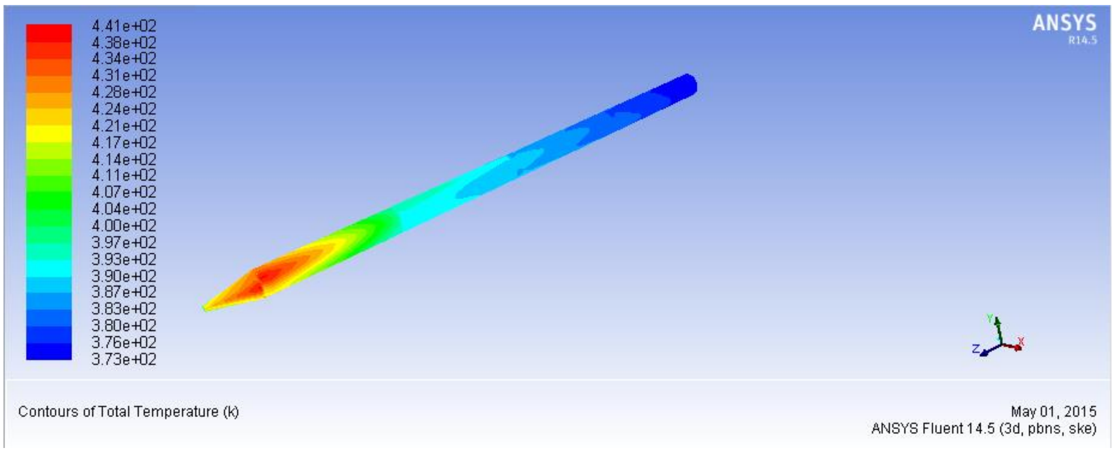


Figure 3.15 Total temperature contours

TOTAL TEMPERATURE VARIATION

The figure 3.16 indicates a temperature variation in this analysis at various named sections. In this figure a temperature indicates in Y- Axis and position of the particular section indicates in X- Axis.

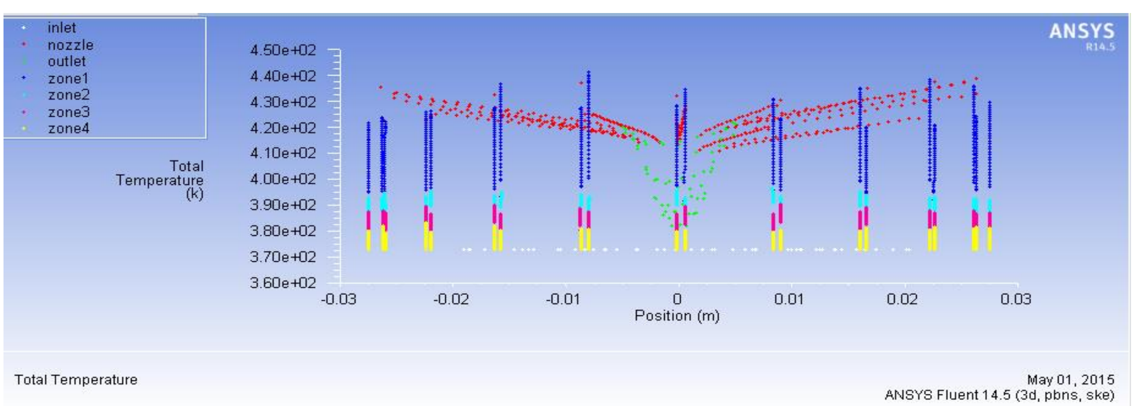


Figure 3.16 Total temperature variations

For an example, color red indicates the temperature values occur in the Nozzle Section. Hence a nozzle section has a maximum temperature of 167.85°C (441K) and Minimum temperature of 138.85°C (412K). Same condition for Zone 4 the maximum and minimum temperature is 109.85°C (383K) and 99.85°C (373K) respectively indicates in color yellow.

TOTAL PRESSURE CONTOURS

In case 2, the injection pressure was given as 100 bar and in the nozzle maximum pressure drop can be seen as 103 bar as shown in figure 3.17.

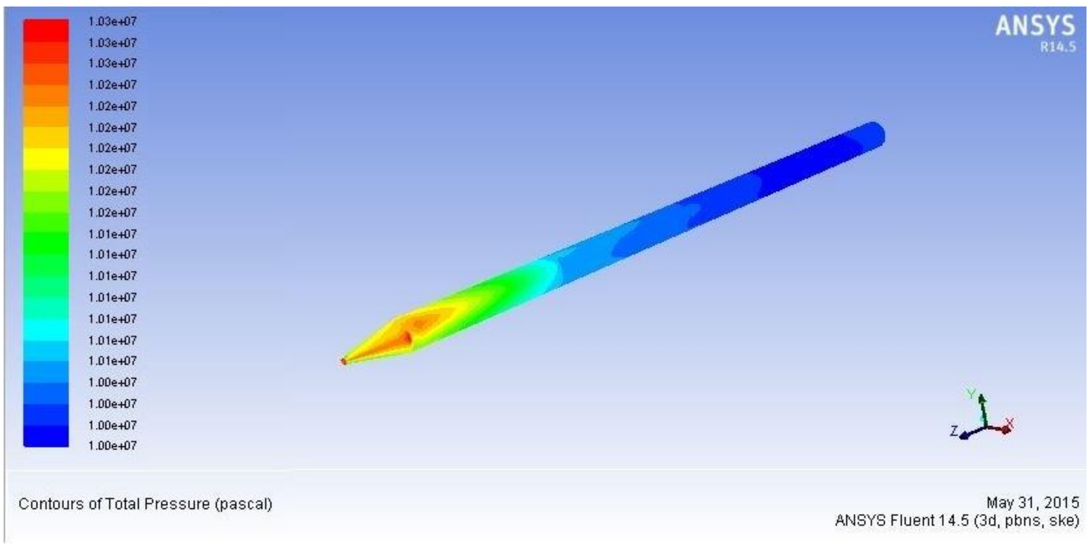


Figure 3.17 Total pressure contours

THERMAL ANALYSIS OF CASE 3

After CFD is performed for the boundary conditions of CASE 3, with the result of CFD analysis, it is subjected into THERMAL analysis to determine the heat distribution across the product.

BOUNDARY CONDITIONS FOR CASE 3

The maximum temperature is 168°C (441.15K) as shown in figure 3.18 which is the maximum temperature that is obtained in the CFD analysis as shown in figure 3.15.

TEMPERATURE DISTRIBUTION

The figure 3.19 shows the heat distribution across the product with maximum temperature distribution value in red color and minimum temperature distribution value in blue color as 172.58°C (445.73K) and 17.988°C (291.138K) respectively. In this CASE good quality of product is obtained without shot short defect in ABS plastic product.

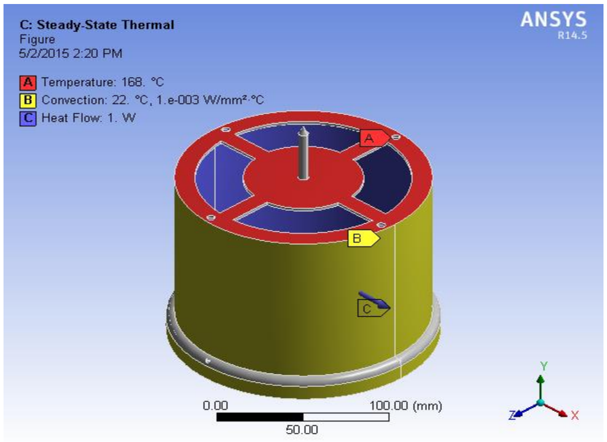


Figure 3.18 Boundary conditions

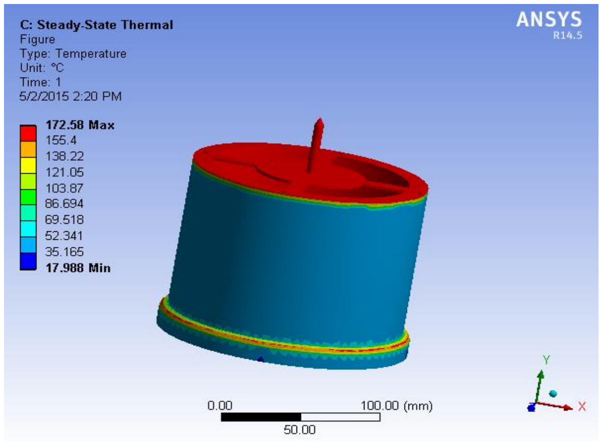


Figure 3.19 Heat distribution

4. INJECTION MOLDING OF MOTOR COVER

4.1 FABRICATION

After the analysis of CASE 1, CASE 2 and CASE 3 using CFD and THERMAL in ANSYS, it is then subjected into fabrication to prove the results obtained.

FABRICATED MOTOR COVER USING CASE 1 PARAMETERS

The boundary conditions that were taken as CASE 1 for nozzle, zone 1, zone 2, zone 3, zone 4, were 100°C, 150°C, 140°C, 120°C, 80°C respectively and the injection pressure was 80 bar. Figure 4.1 shows the motor cover fabricated with the parameters used in CASE 1. Since the heat distribution is not good at the end, the shot short defect can be seen at the mouth of the motor cover made up of ABS plastic using injection molding. This is the product obtained from the existing parameters used in industry after analyzing in ANSYS (CFD and THERMAL).

Figure 4.1 Fabricated motor cover using case 1 parameters

FABRICATED MOTOR COVER USING CASE 2 PARAMETERS

The boundary conditions that were taken as CASE 2 for nozzle, zone 1, zone 2, zone 3, zone 4, were 100°C, 160°C, 150°C, 130°C, 110°C respectively and the injection pressure was 90 bar. Figure 4.2 shows the motor cover fabricated with the parameters used in CASE 2. In this case also heat is not distributed completely throughout the mold and at the mouth end of the motor cover the shot short defect can be seen clearly.

Figure 4.2 Fabricated motor cover using case 2 parameters

FABRICATED MOTOR COVER USING CASE 3 PARAMETERS

The boundary conditions that were taken as CASE 3 for nozzle, zone 1, zone 2, zone 3, zone 4, were 100°C, 180°C, 160°C, 150°C, 140°C respectively and the injection pressure was 100 bar. Figure 4.3 shows the motor cover fabricated with the parameters used in CASE 3. In this heat is distributed completely throughout the mold can be seen which resulted in the production of good quality ABS plastic motor cover of table top grinder.

Figure 4.3 Fabricated motor cover using case 3 parameters

4.2 SUMMARY OF OBTAINED RESULTS

As mentioned in the introduction, the objective of this project is to optimize the parameters like temperature and pressure of injection molding machine to produce defect free, good quality ABS plastic table top grinder motor cover. As per the experiments carried out above, it was clear that the CASE 3 parameters were suitable to obtain good quality product.

Initially, parameters that is existing in the industry was used to analyze to know the exact process happening in the flow pipe which resulted with shot short defect with the maximum and minimum heat distribution of 138.54°C and 143.03°C respectively. With this result as reference, CASE 2 and CASE 3 were performed with different parameters. In CASE 2, the result was obtained with shot short defect which is minimum compared to CASE 1 with the maximum and minimum heat distribution of 155.04°C and 15.135°C respectively.

Finally, CASE 3 was performed which resulted with no shot short defect (good quality ABS plastic motor cover) with the maximum and minimum heat distribution of 172.58°C and 17.988°C respectively.

To prove these analyses further, fabrication was carried out with all the three cases of parameters. In fabrication it was very clear that CASE 3 parameters resulted in the production of good quality product and the recommended parameters were shown in table 5.1 below.

Table 4.1 Recommended parameters

	Temperature in °C
NOZZLE	100
ZONE1	180
ZONE2	160
ZONE 3	150
ZONE4	140

4.3 SAMPLING AND TESTING

Tests are carried out to determine the exploitation temperature of the product (ABS plastic table top grinder motor cover). Exploitation temperature is the working temperature of the product and furnace is used to test the exploitation temperature. Furnace is an instrument used to find the melting point, exploitation temperature, etc. of a material by placing it on the furnace and increasing the temperature. This test is carried out to check the quality of the produced motor cover of table top grinder to determine the temperature at which the product can withstand to the maximum.

To test the product, initially the product is made into several work pieces with as shown in Figure 4.4.

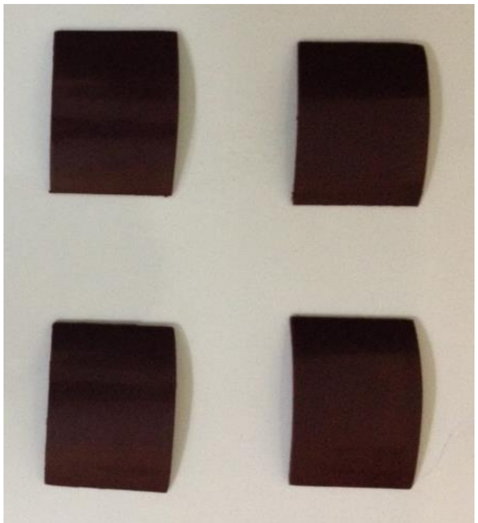


Figure 4.4 Work pieces of ABS motor cover

These work pieces are placed in tilting furnace to determine the working temperature as shown in Figure 4.5. On increasing the temperature of the furnace the desired quality of the product can be obtained.

Figure 4.5 Furnace

Work pieces of motor cover before the testing was shown in Figure 4.6 and the work pieces of motor cover after the testing was shown in Figure 4.7.

Figure 4.6 Part of motor cover before testing

Figure 4.7 Part of motor cover after testing

Testing was carried out with four test pieces from the motor cover produced using injection molding process. From these testing it was concluded that the ABS plastic motor cover work pieces reaches the temperature range 145°C - 150°C during the exploitation. And motor cover can withstand the maximum temperature of 150°C.

5 CONCLUSIONS

The main aim of this project to find the solution to eliminate the shot short defect (incomplete filling of the mold) that occurs in the motor cover of the table top grinder produced in the injection molding machine using ABS material was achieved by optimizing the parameters used in the injection molding process. The ABS material used for the motor cover production is grade IM14GM.

1. The equipment used for the production of motor cover of table top grinder was injection molding machine (WINDSOR) of model: SP.130.
2. The material used for the motor cover production was ABS plastic material of grade (1M14GM).
3. ANSYS analysis was performed to determine the optimized parameters for the production of good quality ABS plastic motor cover. From the ANSYS analysis, experiments, modeling, performed using three different sets of parameters it was concluded that CASE 3 parameters were suitable to obtain defect free and good quality ABS plastic motor cover using injection molding.

   The injection molding machine has different zones of which the optimization was carried out. The optimized temperatures (CASE 3) of nozzle, zone 1, zone 2, zone 3, zone 4, with which the good quality motor cover was produced is 100°C, 180°C, 160°C, 150°C, 140°C, respectively and the injection pressure was optimized as 100 bar. Whereas in CASE 1 and CASE 2 parameters, the product was experiencing the shot short defect since there was no proper heat distribution throughout the mold. From the THERMAL analysis and fabrication of product, it was proven that CASE 3 parameters were suitable for the injection molding of ABS plastic motor cover of table top grinder with the maximum and minimum heat distribution of 172.58°C and 17.988°C respectively.
4. Using these parameters (CASE 3), the motor cover was fabricated using injection molding machine to prove the good quality production of motor cover.
5. This produced good quality motor cover was then subjected to temperature testing to determine the working temperature. The working temperature was determined as 145°C - 150°C and the motor cover can withstand the maximum temperature of 150°C.

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