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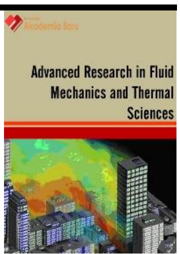

Numerical Analysis and Fabrication of Battery Holder for Two Wheelers

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ABSTRACT

The high-performance plastics usage is increasing in the automobile field because of its advantages over other metals and alloys. Corrosion resistance, light weight, low cost, flexibility in design are the major advantages of plastics above the conventional metallic materials. In this paper a metal version component converted into plastic version in order to increase efficiency, reduce the overall cost of a two-wheeler and to improve the production rate of component. Different types of material such as PP + 15% TALC, PP + 30% GF, PP + 30% TALC, Nylon 6 + 15% GF, Nylon 66 UF, Nylon 6 UF, Nylon 66 + 30% GF, ASA LI941 and ASA LI913 tested for 10,000km road test, vibration test and fitment test. An injection moulding used to produce the component and 'Mouldx3D' software was used for mould flow analysis and other simulation. The different parts of injection moulding tool made up of C45, P20 and D2 materials. Among different materials, ASA LI913 was selected since it has better weather resistance than others and the impact strength matched to metal version component. Finally, it was found that the cost of the component made of Plastic considerably less than same component made of metal.

Keywords:
Plastic materials; Injection moulding; Conversion of metal to plastic; ASA Material

1. Introduction

Nowadays the automobile sector is using the high-performance plastics considerably in many of their systems and this trend is expected to continue further. Main reasons for choosing the plastics over other materials are light weight and hence reduction in fuel consumption, ease of manufacturing, cost effectiveness. Studies have shown that 5-7% of reduction in fuel consumption can be obtained by reducing 10% of vehicle weight [1-3]. Production and marketing of fuel-efficient cars is the need and demand of futuristic vehicles and this can be achieved by converting metal components to plastic material since plastic offers better corrosion resistance, flexibility in design

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and integrating components, allow longer life to vehicle, reusable and give more comfort and safety [4]. Due to their advantages over aluminium and other materials, plastics has been using in more than 1000 different car parts and studies show that 50% of car interior now being made up of plastics. The plastic is the second most common class of automotive material after ferrous metals and alloys. The vehicle uses roughly about 150 kg of plastics and plastic composites versus 1163 kg of iron and steel. Currently plastics is moving around 10-15 % of total weight of the car [5-7]. 66% of the total plastics used in automotive industry are covered by only 3 types of plastics, i.e., PP (32%), PU (17%) and PVC (16%). PP has been very successfully applied to the forming of fibres; this makes PP the single largest polymer in use. Its high strength-to-weight ratio makes it very useful in industries and also insoluble in room temperature, however on heating above its melting point can be dissolved in aromatic and chlorinated hydrocarbons. On the other hand, Nylons are widely used in automotive industry for the fabrication of components like peripherals, throttle body housing, and cylinder head covers, air intake manifolds, cooling systems, and engine parts due to the fact it reduces the production cost by 30% as well as 50% weight of the component compared to metals respectively [8]. PP is one of the most widely used common plastics due to its good corrosion resistance, easy processing as well as low cost. There has been a rapid growth in the demand of high-performance PP because of the commercial significance. However, the relatively low mechanical performance of pure PP limits its application in the fields of engineering such as automobiles. Glass fibre (GF) reinforcement is the most efficient and economical way to improve the mechanical performance of PP and further satisfy the needs in different applications [9,10]. This was proved by the experimental investigation carried out by the Merter *et al.,* [11] in which the hybrid yarns were developed using polypropylene and glass fibres through air jet and direct twist preparation techniques, in which the reinforced PP exhibited tremendous improvement of the mechanical properties. Even though the PP has excellent corrosion resistance and easy to manufacture the wear resistance of the PP is bad, in order to improve the wear resistance Palanikumar *et al.,* [12] added calcium carbonate ($CaCO_3$) with PP, from his study 10% $CaCO_3$ addition has improved about 70% better wear resistance than the neat PP, tests are conducted with varying load, sliding speed.

The development of polymer and its composite found a way to replace the metal and its alloy parts and Nomura *et al.,* [13] made an attempt to carry out the systematic review on automobile bumpers and its materials, in which he replaced the metal bumper using PP composite such as Multi walled carbon nanotubes (MWCNT), Single walled carbon nanotubes (SWNT), carbon black, glass fibre, carbon fibre, nano-clay, etc., to achieve the sufficient mechanical properties. The study showed that the reinforcement of 1.5 wt.% of MWCNT enhanced the mechanical properties significantly, where the tensile strength, flexural strength, flexural modulus, and Young's modulus was found to be enhanced by 42.8, 33.7, 17.4, and 16%, respectively compared to pure PP, however the optimum filler concentration was still a concern in his study [13]. PP not only used for its excellent corrosion resistance and easy to manufacture but also an insulation in the sandwiched material used for refrigerated vehicle walls box panel with the potentials of weight reduction, low thermal conductivity, reduction in engine power, CO_2 gas emissions, fuel consumption and cost saving. Uwa *et al.,* [14] introduced, in their study, the composite of PPMAPPNC (Polypropylene (PP) /Maleic-Anhydride-grafted-Polypropylene (MAPP)/ Nano clay). Test results revealed that tensile strength and stiffness improved with low clay contents. Thermal conductivity analysis showed that composites with high proportion of clay have high resistance to heat. PP98MAPP4NC3 composite was optimal, and could be used as a better replacement to the conventional sheets in Refrigerated Vehicles [14]. Liu *et al.,* [15] compared the metal and plastic bi-directional tidal turbine rotor models by experimentally evaluate the performance, in which result showed a substantial decrease in maximum power performance for the plastic rotors – about 40% decrease at a tip speed ratio of around 3.0

compared with the metal rotors. The main reason for the reduction in power performance of the plastic rotors was found to be the change in angle of zero lift because of the bending of the blade section due to flexibility and poor rigidity of the polyamide (Nylon). This poor rigidity and flexibility might be due to the semi-crystalline structure of the nylon. Liu *et al.,* [15] shows, in their study, "Nylon Unfilled (Nylon without blend)" material is not suitable for several applications and the results would have been better if author Liu *et al.,* [15] used reinforced glass fibre with nylon.

Dubin and Homsi from BASF Corporation [16] successfully converted 3-Blade Metal Fan into 5-Blade Plastic Fan since Plastics offer many advantages over stamped sheet metal or die cast materials. For their conversion they used Nylon 6 reinforced composite (15/25% GF) due to its unique blend of properties. The study showed the following results such as: 1) the five-blade plastic fan efficiency was about 5.3% higher than that of the three-blade metal fan. 2) The plastic design exhibited less deflection, lower stress levels, and more uniformly distributed stress gradient and thus results in less vibration and noise. This translated into a fan with better structural integrity and reliability. 3) The five-blade plastic design results in lower overall blade deflection, as well as deflection pattern that was more symmetrical, which translated into less wear on the axle bearings and motor, with consequently longer life. 4) the overall system cost was also reduced then metal version due to the fact that plastic is less in price than metal as well as plastic fan takes up less space in the axial direction result in lower stock height. On the other hand, author Güllü *et al.,* [17] found that glass fibre reinforced with polyamide exhibited improvements in both tensile strength and impact resistance. SriMurugan *et al.,* [18] tried to improve the wear resistance of the spur gear by using Nylon 6 with GF reinforcement as material in the ration of 80%PA/20%GF and 70%PA/30%GF. The author not only noticed better improvement in the wear resistance but also mechanical properties improved such as tensile strength, toughness etc., but author failed to compare the Nylon reinforced Glass fibre material result with the existing spur gear material.

ASA is the development of ABS. Instead of butadiene rubber ASA comprise the acrylate rubber by absence of double bond, which gives ten times the weathering resistance and resistance to UV radiation than ABS. ASA is significantly more resistance to environment stress cracking than ABS, especially to alcohol and cleaning agents. It retains gloss, colour and thus makes it excellent use for automobile aesthetic application [19]. Even though the ASA is the advance material and substitute for ABS, one of the biggest worries about ASA is its impact strength. So, Zhang *et al.,* [20] decided to try the Chlorinated Polyethylene (CPE) with ASA to improve its Impact Strength. CPE act as impact modifier and the result of adding this with ASA showed good sign such that the impact strength increased by 80% with the addition of 15% CPE in ASA. From this it can be infer that ASA has good aesthetic property, UV resistance and can be used for glossy requirement but due to impact strength it may not suitable for some application [20]. Styrene acrylonitrile is a copolymer plastic consisting of styrene and acrylonitrile (SAN). It is widely used in place of polystyrene owing to its greater thermal resistance. The chains of the polymer show alternating repeat units of styrene and acrylonitrile, and it is a copolymer. The relative composition is typically between 70 and 80% by weight styrene and 20 to 30% acrylonitrile. Larger acrylonitrile content improves mechanical properties and chemical resistance, but also adds a yellow tint to the normally transparent plastic [21].

For a cam bush of high voltage transformer, author Jamsheed *et al.,* [22] designed and analysed the injection molding tool. In his paper he briefly described about the material that can be used for the manufacturing of the tool (mould) for the injection molding such as Hardened steel, Pre-hardened steel, Aluminium and Beryllium-copper alloy. Steel moulds are high cost to construct, but their longer lifespan results in higher production of parts which equalize the higher initial cost. Pre-hardened steel moulds are used for lower volume requirement because of its less wear resistance; hardness ranges from 38-45 HRC. Hardened steel moulds have high wear resistance and lifespan due to the fact it will be hardened after machining, hardness ranges between 50-60 HRC. Aluminium moulds can cost less. Beryllium copper can be used in the mould where the area requires fast heat removal or areas that see the most shear heat [22]. AISI P20 is a common mould steel with good fatigue abrasion and impact strength, which is a molybdenum and chromium-containing low carbon steel along with high hardenability. Generally, this steel is used for mould base, ejector plates; P20 can also use for larger core and cavity blocks which do not need heat treatment such as proto-mould for just few thousand plastic components. The P20 steel can be heat treated to turn it into high hardenability and use it to manufacture core and cavity which expected to produce several million of plastic components [23]. Nylon 6 (PA6 or Polyamides 6) and Nylon 66 (PA66 or Polyamides 66) plastic composites are widely used in Automobile industries. However, water absorption is one of the severe problems during utilization of these PA6 and PA66. Chaichanawong *et al.,* [24] attempted to investigate the effect of water absorption on the Glass fibre reinforced polyamide composites and the results showed that water absorption strongly influences on its mechanical properties. However, with increasing the weight percent of the glass fibre in the glass fibre/polyamide composites the moisture absorption contents decreased. AISI H13 is heavily alloyed versatile steel with excellent high temperature, wear resistance and excellent toughness. It is a molybdenum, vanadium and chromium containing hot working tool steel with excellent hardenability which is commonly used for high speed machining of cavity and core plates [25]. Sometimes mould can also be made using Aluminium material since it shows few advantages such as less weight, higher heat transfer and low production cost compared to steel materials. However barely 5000–50,000 plastic components could be produced through such aluminium moulds. The author optimized change in mechanical properties of ABS (Acrylonitrile-Butadiene-Styrene) and the results were melt temperature and injection pressure affected the mechanical properties more for steel mould material than aluminium mould material [26]. He [27] reviewed about main failure modes of plastic mould and the reason behind the failure. The author also added that selection of mould material and heat treatment process for the mould were greatly influencing in the mould in terms of failure.

2. Problem Definition

During the Design of automobile, achieving the complexity of part design in Sheet Metal, Casting or other Machining process is complex and it involves more cost for R&D as well as in Mass Production.

At the same time automobile manufacturer tries many solutions to reduce fuel consumption of vehicle, overall cost of vehicles and to improve the productivity of the part.

3. Objective

The purpose of the present research is to convert a Metal version component which was used in the previous two-wheeler model into plastic component to increase the efficiency and performance of the two-wheeler by reducing the weight of the component. On the other manufacturing a component in sheet metal includes many processes and thus take more time, therefore by making the component in plastic through injection moulding, it increases the production rate. The cost of per plastic component is less than metal component since plastic raw material is cheaper than metal also manufacturing of plastic component is easier than metal version.

4. Material Selection

The materials for moulding components are selected based on the customer requirements in the industrial applications. Customer expectations of the fabricated component are, 2000 hours of UV resistance, retainment of glossy finish, less water absorptance and cost effective.

According to the customer requirement, eight different materials were chosen. Table 1 shows the comparison of properties of different materials. Among eight materials Nylon 66 also known as PA66 has higher Part Cost than others because the raw material cost is higher for Nylon 66 material and it can also be observed that tensile strength of Nylon 6 + 15% GF as well as Nylon 66 + 30% GF are higher than any other materials, it is due to the fact that both Nylon 6 + 15% GF and Nylon 66 + 30% GF contain GF content. The Glass Fibre increase the mechanical properties of the material and this was proven by Merter *et al.,* [11]. The above statement can also be proven by comparing the tensile strength of PP + 30% Talc and PP + 30% GF material shown in Table 1; the tensile strength of PP + 30% Talc and PP + 30% GF are 16 MPa and 76 MPa respectively. The Talc content is used to reduce the part cost since it does not alter any properties of the material. It is important to notice the water absorption of different material since the battery holder is going to use for holding the battery and it should be free from moisture content. From Table 1, it can also be observed that nylon material has very high-water absorption than other materials.

Table 2 shows the aesthetic properties of different materials in which because of glass fibbers the surface finish was poor and glossy finish cannot be obtained. Except ASA all other materials exhibited poor surface finish as well as poor UV resistance. In ASA surface appearance is good due to the presence of acrylate rubber, which gives ten times the weathering resistance and resistance to UV radiation. ASA is the suitable material for a product developer when the product needs to have glossy finish.

Table 1
Comparison of properties of different materials used for battery holder

Sl. No	Material	Part Cost	Material Cost Per (Kg)	Physical Weight (G)	Properties				
					Young's Modulus In (Gpa)	Tensile Strength In (Mpa)	Density (G/Cc)	Hardness In (HRC)	Water Absorption (%)
1	PP + 15% TALC	133	115	512	1.45	18	0.98	76	0.03
2	PP + 30% GF	140.95	125	590	5.1	76	1.46	85	0.01
3	PP + 30% TALC	129.11	110	595	0.5	15	1.14	76	0.04
4	Nylon 6 + 15% GF	263.33	280	670	6.06	115	1.23	119	7
5	Nylon 66 UF	318.59	385	640	3.0	80	1.14	110	7
6	Nylon 6 UF	271.22	290	640	2.9	82.7	1.59	115	7
7	Nylon 66 + 30% GF	306.75	335	765	8.9	140	1.36	112	7.5
8	ASA LI941	135	220	512	-	47	1.7	105	0.04

Table 2
Aesthetic Properties of materials

Sl. No	Materials	Aesthetic properties
1	PP + 15% TALC	Poor finishing and less than 300 hours UV Resistance.
2	PP + 30% GF	Poor finishing due to GF and less than 300 hours UV Resistance.
3	PP + 30% TALC	Poor finishing and less than 300 hours of UV Resistance.
4	Nylon 6 + 15% GF	Poor finishing due to GF and UV resistance of 1000 hours
5	Nylon 66 UF	Average Aesthetic and material also too costly compare with other material
6	Nylon 6 UF	Average aesthetic and UV Resistance of 1000 hours
7	Nylon 66 + 30% GF	Poor Aesthetic as well as material too costly compare with other material
8	ASA LI941	Excellent Aesthetic, 3000 hours good UV Resistance and better choice for exterior parts.

From eight different materials eight different components were made through injection moulding using prototype mould. The eight components were allowed for testing such as vibration test, durability test and finally checking the fitment of a part in bike. The vibration test is a simulation test whereas durability test is experimental test. The vibration test was done using software in which simulation ran for two types of frequency for four hours such as uniform frequency and other one was by varying frequency range. The durability test is allowing the rider to ride the bike for 10,000 Km and finally checking the component if any damage occurred. Among these eight materials, the component made up of PP + 15% Talc, PP + 30% GF, PP + 30% Talc material were rejected because of poor impact resistance, UV resistance and surface finish. However, nylon 66 UF and Nylon 66 + 30% GF has better impact resistance, it has lesser UV Resistance and more water absorption along with higher cost compared to other materials. Finally, among Nylon 6 UF and ASA LI941, ASA LI941 was selected since Nylon 6 UF does not pass the aesthetic test as well as UV exposure Test. ASA LI941 was way better than Nylon 6 UF in terms of aesthetic property and has good UV resistance, however ASA LI941 had lesser impact resistance compared to Nylon 6 UF. Table 3 shows the comparison of properties between Nylon 6 UF and ASA LI941.

Table 3
Comparison of properties between ASA LI941 and Nylon 6

Sl. No	Material	Test Method	Unit	ASA LI941	NYLON 6
1	Material Cost	-	Rs	240	220
2	Part Cost	-	Rs	135	125
Properties					
3	Density	ASTM D792	g/cm^3	1.07	1.13
4	Mould Shrinkage	ASTM D955	%	0.5	1.2
5	Tensile Strength @ Break	ASTMD638	MPa	47	65-75
6	Tensile Elongation @ Break	ASTM D638	%	25	10
7	Flexural Modulus	ASTM D790	MPa	2300	2500
8	Flexural Strength	ASTM D790	MPa	75.5	110
9	Izod Impact Strength 3.2 Notch at 23°c	ISO 180	kg/cm	14	22
10	Rockwell Hardness	ASTM D256	R Scale	105	112
11	HDT	ASTM D648	-	97	150
12	Fire Resistance	-	-	Poor	Average
13	UV Resistance	-	hours	3000	300
14	Wear Resistance	-	-	Average	Good
15	Salt Resistance	-	-	Excellent	Excellent
16	Fresh Water Resistance	-	-	Excellent	Excellent

Table 4 shows the weatherability comparison between ASA LI941 and Nylon 6 UF. The samples were exposed with UV rays for different hours as mentioned in Table 4. Nylon 6 has 1000 hours of UV resistance and ASA LI941 has 3000 hours of UV resistance which mean UV rays can be expose on Nylon 6 material for maximum of 1000 hours after which the component colour will change but ASA LI941 can withstand 3000 hours of UV rays without change in colour. From Table 4, it can also notice that for the same hours of UV exposure Nylon 6 showed greater value of colour change than ASA LI941. ASA LI941 fulfilled all the requirements of customer but it was lack in impact resistance, so ASA LI913 was introduced which is the development of ASA LI941 in terms of Izod Impact resistance.

Table 4
Weatherability Test comparison between Nylon 6 and ASA LI941 material

Test Description	Test Method	Hours of Exposure	Colour Change (De Value)*	
			NYLON 6	ASA LI941
Uv Exposure	SAE J 2527	300	0.20	-
Accelerated Xenon		500	0.34	-
Arc Exposure Test		1000	1.10	0.5
		2000	-	2.0
		3000	-	3.0

**Targeted value ≤3*

Table 5 shows the Comparison of properties between ASA LI913 and ASA LI941.

Table 5
Comparison of properties between ASA LI913 and ASA LI941

Properties	Method	Units	ASA LI941	ASA LI913
Physical				
Specific Gravity, 23˚C	ASTM D792	-	1.08	1.07
Mold Shrinkage, 23˚C, 3.2 mm, 23 ˚C	ASTM D955	%	0.4~0.7	0.4~0.7
Melt Flow Rate, 220˚C, 10 Kg	ASTM D1238	g/10min	6	5
Mechanical				
Tensile Strength at Yield, 23˚C, 50 mm/min, 3.2 mm	ASTM D638	MPa	47	42
Tensile Elongation at Break, 23˚C, 50 mm/min, 3.2 mm	ASTM D638	%, (Min)	15	35
Tensile Modulus, 23˚C, 50 mm/min, 3.2 mm	ASTM D638	MPa	2100	1800
Flexural Strength, 23˚C, 15 mm/min, 3.2 mm	ASTM D790	MPa	76	64
Flexural Modulus, 23˚C, 15 mm/min, 3.2 mm	ASTM D790	MPa	2300	1900
Izod Impact Strength, Notched, 3.2 mm, 23˚C	ASTM D256	J/m	170	435
Izod Impact Strength, Notched, 3.2 mm, -30˚C	ASTM D256	J/m	60	60
Izod Impact Strength, Notched, 6.4 mm, 23˚C	ASTM D256	J/m	140	340
Izod Impact Strength, Notched, 6.4 mm, -30˚C	ASTM D256	J/m	40	60
Rockwell Hardness	ASTM D785	R–Scale	104	92
Thermal				
HDT, Edgewise, 1.82 Mpa, 6.4 mm, Unannealed	ASTM D648	˚C	94	86
VICAT, 50N, 50˚C/h	ASTM D1525	˚C	102	94
RTI Electrical	UL 746B	˚C	50	50
RTI Mechanical with Impact	UL 746B	˚C	50	50
RTI Mechanical without Impact	UL 746B	˚C	50	50

5. Design of Mould

Mould design involves the task of suitable selection of mould material. The design of mould depends upon the final part material. When it needs to mould steel, one has to consider for good machining properties, better polish ability, and good properties of etching and spark erosion also comfortable heat treatment, Minimum inclusion level, and consistently high quality.

5.1 Runner

In the present work, hot runner system (HRS) is used for the battery holder mould as it offers advantages over cold runner system (CRS). Elimination of runner waste, reduced cycle time and uniform melt flow are major advantages of HRS. However, it has higher maintenance and tooling cost.

5.2 Gate Point

The Gate point used was MTG because the gate is too bulky to be automatically sheared by the machine. In MTG there are several types such as Edge Gate, Hot tip Gate, Direct or Sprue Gate are available in which for the battery holder mould Sprue Gate has been chosen because the mould is a single cavity mould of large part that require symmetrical filling, easy to design and involves less maintenance cost.

5.3 Gate Location

Gate should be placed in such a way to get uniform flow and make sure to allow for easy manual or automatic degating. Figure 1 shows the Top and Bottom view of the Battery Box. In the bottom view of Battery Box gate point is seen as shown in Figure 2. The Gate point located at the bottom surface and that too the centre of the plane that was because to avoid voids and sink. Placing the gate at the heaviest cross section is advisable for better part packing.

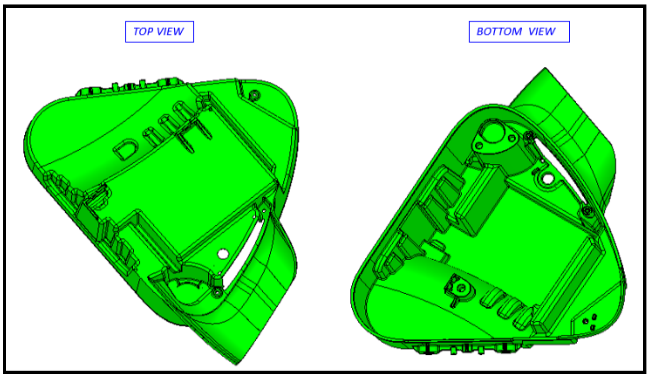


Fig. 1. Top View and Bottom View of Battery Holder

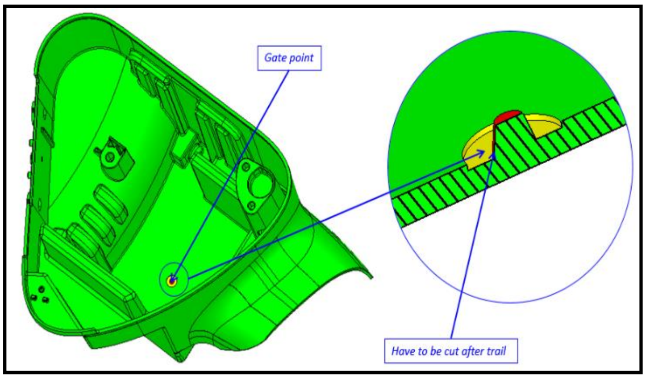


Fig. 2. Gate Point of Battery Holder

5.4 Shrinkage Allowance

The shrinkage of plastic is the volume contraction of polymers during the cooling step of the processing of polymers. This contraction is partly due to the difference of density of polymers from the melt state and the cooled, rigid state. Most of the plastic moulded part shrinkage occurs in the mould while cooling. A small amount of shrinkage occurs after ejection as the part continues to cool and after that the part may continue to shrink very slightly until the temperature and moisture content stabilize. In higher shrink materials such as acetal and nylon, the post-mould shrinkage can be significant. It is difficult to process the nylon material due to the shrink percentage is high and post-mould shrinkage is necessary for the Nylon material. This is also a reason why among 8 materials ASA was chosen instead of nylon material. Table 6 shows the shrinkage percentage for different materials [28].

Table 6
Shrinkage percentage for Different Materials

Material	Shrinkage (%)
ABS	0.6
Acetal	1.8
Acrylic	0.6
Nylon 6	1.2
Nylon 6 (30%GF)	0.4
Nylon 66	1.5
Nylon 66(33%GF)	0.5
PBT	2.0
PP (co-polymer)	2.0
PP (30%Talc)	1.0
PP (30%GF)	0.5
PVC	1.5

5.5 Cooling System

The design of cooling system is very important in a Mould design since the cooling time takes up 70% to 80% of injection molding cycle time, a well-designed cooling system can shorten the molding time and improve the productivity. Poor design of cooling system will extend molding time and increase production cost [29].

The cooling system should be efficient, easy to manufacture and to avoid deformation of part it should be uniform. Some factors that matters to the cooling effect~~ive~~ are mould steel and cooling line layout. The higher the thermal conductivity of the injection mould steel, the better heat transfer and the shorter cooling time needs. The closer the mould cavity goes to the cooling pipes, the greater the diameter of cooling pipes which results in better cooling effect and shorter cooling time [30]. Figure 3 shows the cooling system proposed for the battery box.

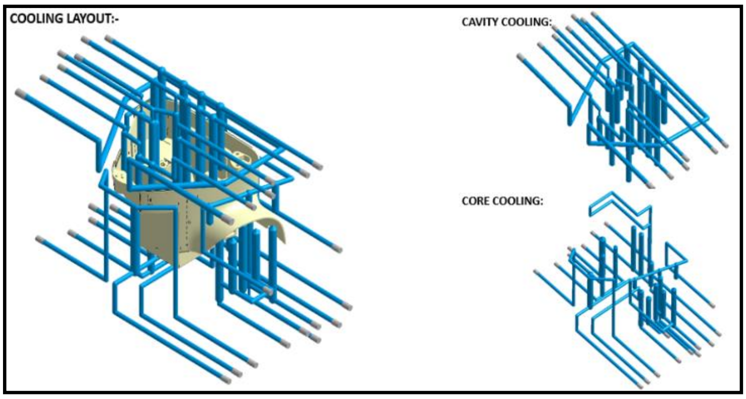
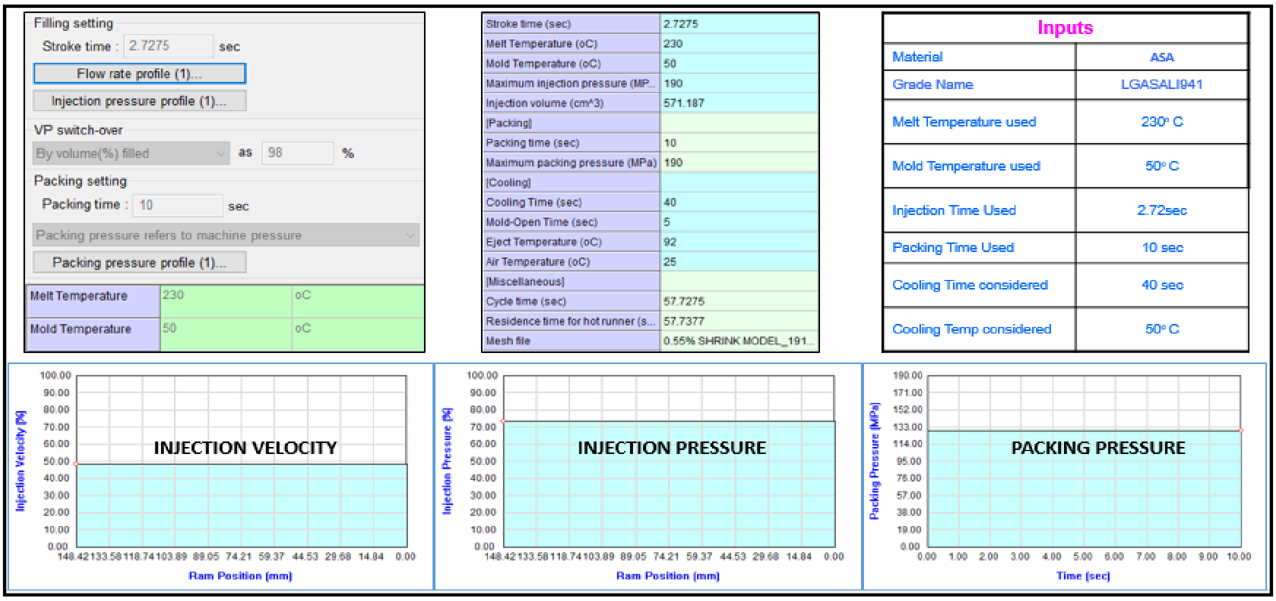


Fig. 3. Cooling System of Battery Holder

6. Simulation of Battery Holder

Analysis was carried out for the part “BATTERY HOLDER” to study and calculate the flow pattern, fill time and packing time. Determination of the clamp force and injection pressure is required for the mould which helps to select the exact injection moulding machine and approximate cycle time. Polymer selected for analysis was ASALI913. Cooling holes diameter is 12 mm and Gate diameter is 4 mm. The software used for the simulation of battery Holder was “Moldex3D”.

Figure 4 shows the Setting dialog box, the input data and initial conditions required for the simulation of Battery Holder. For the simulation it was required to give material details. It was taken that injection velocity and injection pressure were 50% and 75% of its maximum value respectively while packing pressure was 130 MPa. Other parameters such as mould temperature, melt temperature, stroke time, cooling time, mould open time, cycle time can be seen in Figure 4.


Filling setting
Stroke time : 2.7275 sec

VP switch-over
By volume(%) filled as 98 %
Packing setting
Packing time : 10 sec
Packing pressure refers to machine pressure

Melt Temperature	230	oC
Mold Temperature	50	oC

Stroke time (sec)	2.7275
Melt Temperature (oC)	230
Mold Temperature (oC)	50
Maximum injection pressure (MP...	190
Injection volume (cm^3)	571.187
[Packing]	
Packing time (sec)	10
Maximum packing pressure (MPa)	190
[Cooling]	
Cooling Time (sec)	40
Mold-Open Time (sec)	5
Eject Temperature (oC)	92
Air Temperature (oC)	25
[Miscellaneous]	
Cycle time (sec)	57.7275
Residence time for hot runner (s...	57.7377
Mesh file	0.55% SHRINK MODEL_191...

Inputs	
Material	ASA
Grade Name	LGASALI941
Melt Temperature used	230° C
Mold Temperature used	50° C
Injection Time Used	2.72sec
Packing Time Used	10 sec
Cooling Time considered	40 sec
Cooling Temp considered	50° C

Fig. 4. Input data for simulation of Battery Holder

Figure 5 shows the Melt Front Advancement (MFA). It is a process of filling the part with molten plastic step by step with increasing percentage of 20-25%. From the MFA, the filling/packing pattern of the melt can be examined. Incomplete filling/short shot, over-pack flash, weld line, and air trap problems can be detected and avoided by modifying Process or processing variables. Figure 5(d) shows the Melt Front of 95% in which the end of filling area was marked clearly, and the area needed more concentration since possibilities of weld line was more. These weld line formation can be easily rectified by increasing the injection pressure and temperature of molten plastic. Figure 5(e) shows the part filled 100% and the MFA at different time was shown in different colour. The red colour regions were filled faster than blue colour regions. From the scale it can be seen clearly the filling time for each colour.

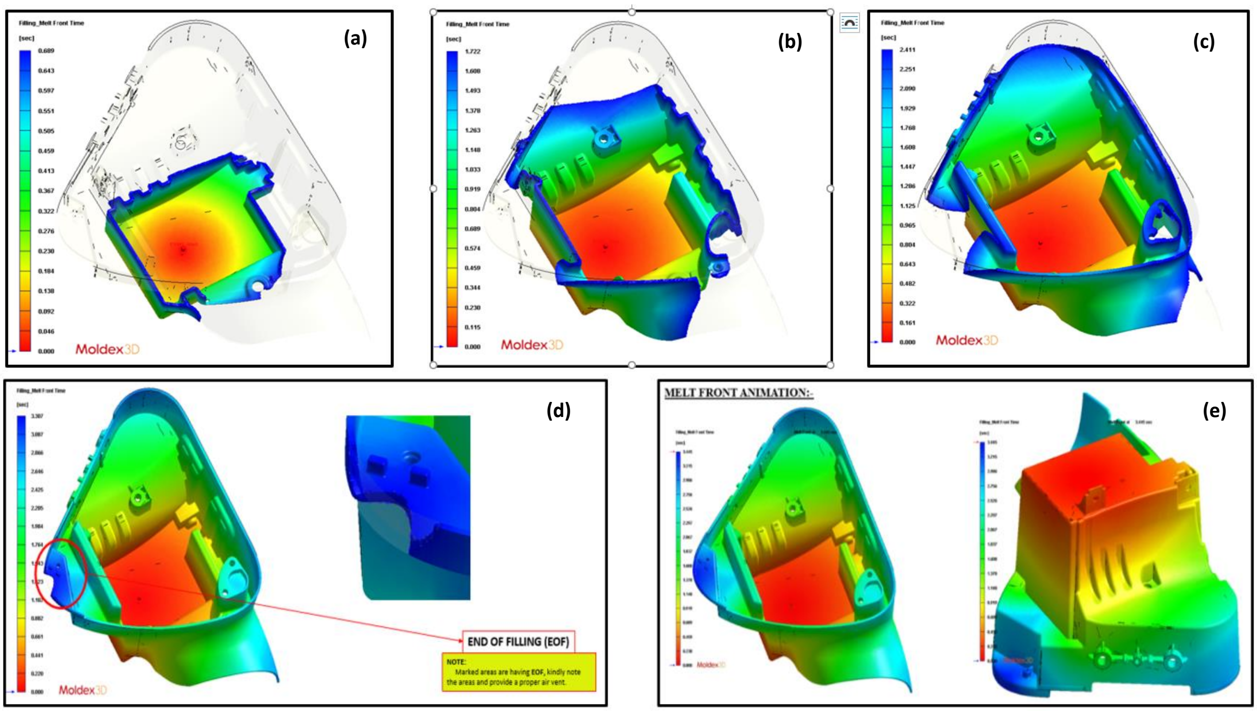


Fig. 5. (a) Melt Front 20% (b) Melt Front 50% (c) Melt Front 70% (d) Flow pressure (e) Melt Front Temperature

From Figure 6, it can be noticed the regions of Air trap which is in blue colour. The Air trap causes the Burn mark in the part which affect the part's aesthetic condition. These can be avoided and rectified by providing proper 'Air Vent' near the air trap areas. From Figure 7, it can be noticed that after 480 Ton force the clamping force decreasing gradually and it nearly took 4.5 sec to reach the highest point of clamping force. From the graph it was finalized that 450-tonnage machine required to operate the mould. Figure 8 shows the Flow pressure of molten plastic into the mould. It can be seen that near the gate point the flow pressure is high and at the End of Filling area it is less in pressure. Since the part was complex in shapes and contained many small areas and holes the cooling pipes cannot reach those areas and during the cooling process those areas remain unchanged in terms of temperature, this can be noticed from Figure 9. The green colour area contains higher temperature than the blue area that was because the distance between cooling pipes and the region were little far and conduction of heat takes higher time than blue region.

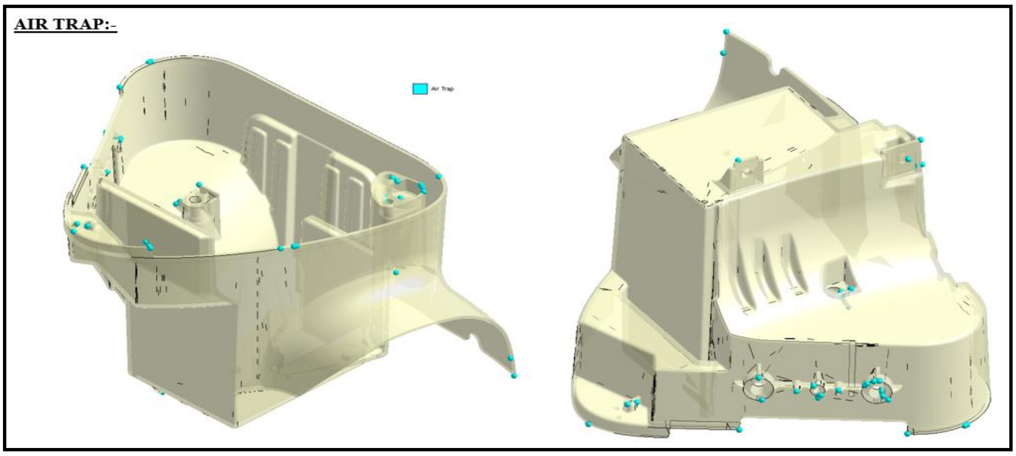


Fig. 6. Air Trap

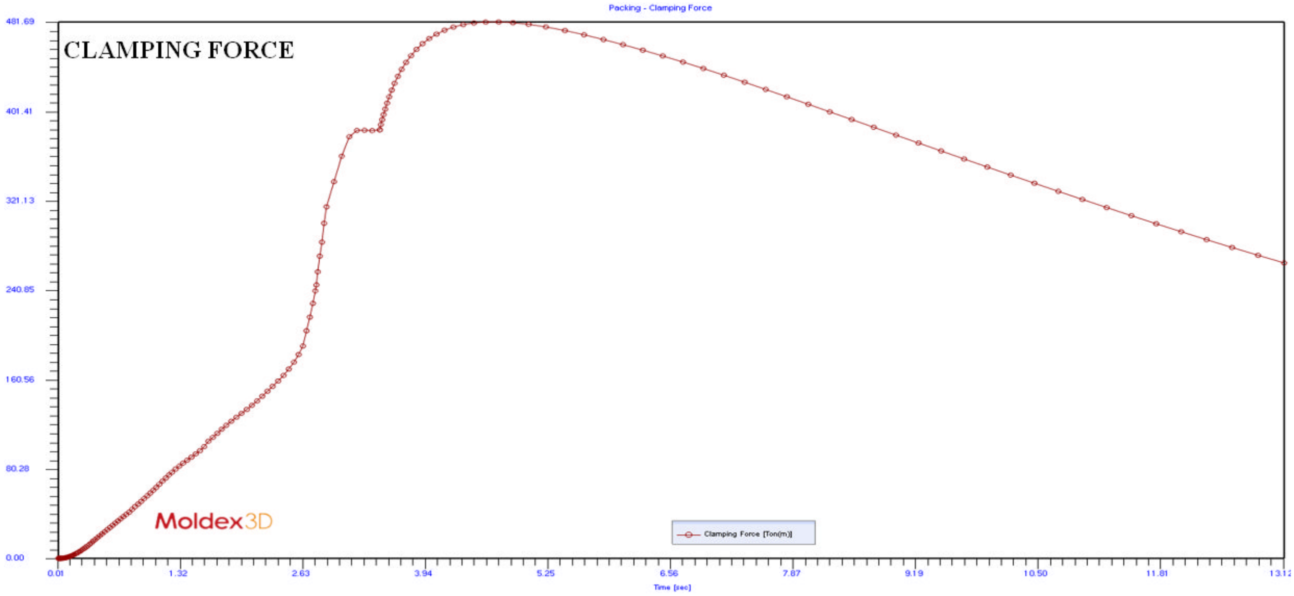


Fig. 7. Clamping force of Battery Holder

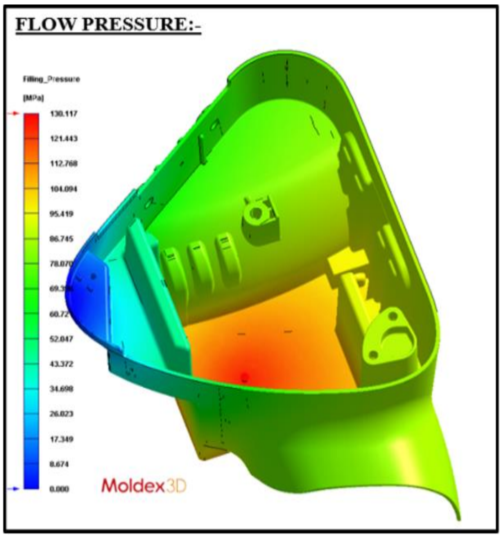


Fig. 8. Flow Pressure

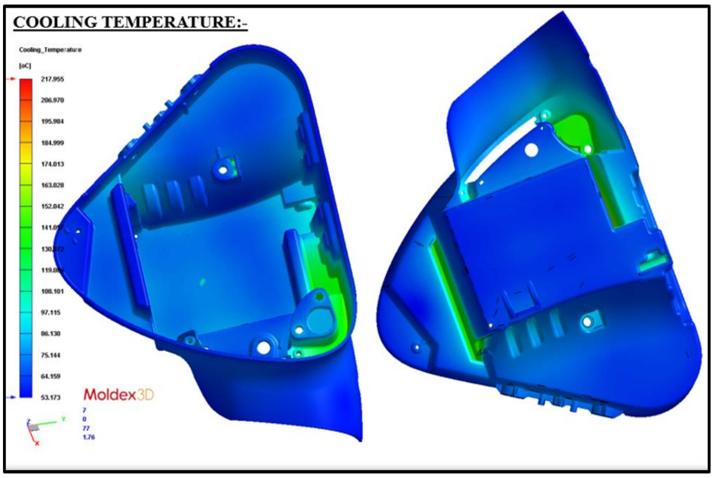


Fig. 9. Cooling Temperature

Figure 10 shows the cooling efficiency of the Battery holder. It can be noticed that there are so many cooling pipes provided to reach the maximum cooling efficiency and are in different colour which indicates the temperature conveyed and dissipated from the mould. The red colour was high in temperature since it was placed near the Gate point where the temperature always higher than any other regions. Figure 11 shows the cooling time of the Battery Holder. The Component after injection of molten plastic will be allowed to cool and solidify until it reaches the Ejection Temperature (ET). Once the component reached the ejection temperature it will be ejected from the mould. The battery holder nearly takes 50sec to reach the ET. Small area marked in the red circle has not reached the ET, so special care needs to be taken since that is the point where another component will be assembled with a screw. Warping is usually caused by non-uniform cooling of the mould material. Different cooling rates in different regions of the mould causes the plastic to cool differently and thus create internal stresses. These stresses, when released, lead to warping. Warping can cause the part to fold, twist, bend and blow, so cooling should be given to the mould uniformly. Sometimes warping can’t be avoided due to complex design of part, so 2 mm or less than distortion of part will be allowed. Figure 12 shows Total warpage of Battery holder and it can be observed that there are only 2 regions which are in red colour which has warpage of nearly 2 mm and other regions have not distorted much. Sometimes the warpage can be controlled by giving the proper wall thickness.

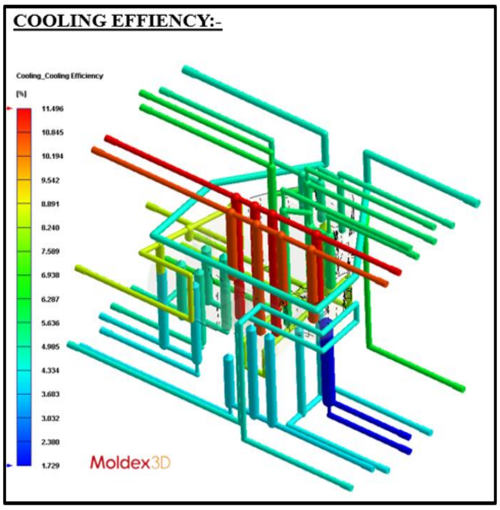


Fig. 10. Cooling Efficiency

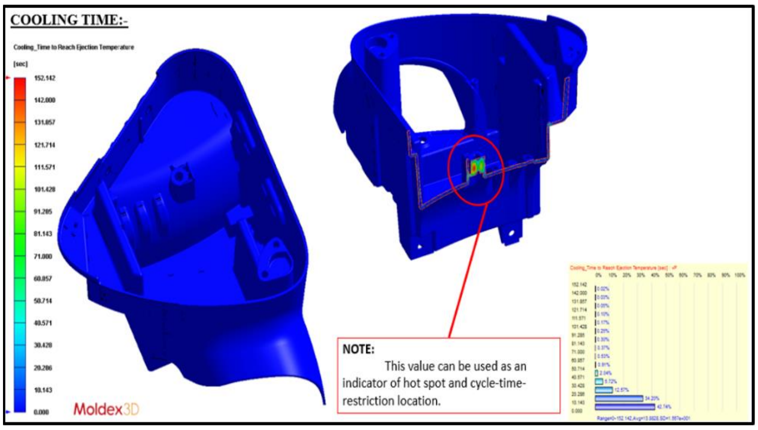


Fig. 11. Cooling time required for Battery Holder

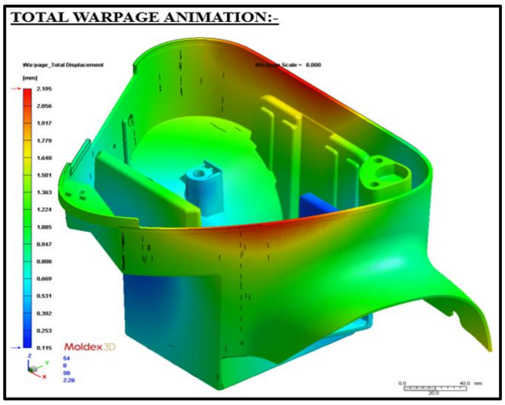


Fig. 12. Total Warpage of Battery Holder

7. Manufacturing of Mould

Usually, the manufacturing of mould involves two processes. They are (i) Computer numerically controlled (CNC) machining and (ii) Electrical discharge machining). In the first phase, the mould was manufactured using CNC, where nearly desired shape and size was achieved. In CNC, corners, curves, exact shape and size of mould can't be achieved properly. These things are taken care by EDM machining process. The Battery Holder mould contains the following parts namely – mould base, core, cavity, pillars, bush, wear plate, wedge, cam, ejector plate, ejector pin, sleeves, core pin, springs. Table 7 shows the different mould parts made up of different materials.

Table 7
Mould Parts and its Materials

Mould Part	Material
Mould base & Ejector Plate	C45
Core & Cavity	P20
Pillars & Bush	EN353
Wear plate, Wedge & Cam	EN24 & EN31
Ejector Pin, Sleeves, Core Pin & Springs	D2

8. Moulding the Battery Holder in Injection Moulding Machine

The machine used for the production of Battery Holder was "MILACRON 450". The mould manufactured for the production of battery box components has 10 Lakhs shot capacity. The material used for the production of battery holder was ASALI941. During the production of Battery holder, there were few problems arrived such as “catch up on the cavity side, shot fills, warpage”. The catch up on the cavity side means usually after injection of molten plastic into the die cooling will be done then part will be ejected from the mould from core side, if the part remains on the cavity side instead of core side ejection can’t be perform and this condition is called “catch up on cavity side”. This has created difficulties in the ejection of part, in order to rectify this and make the part remain on the core side, 8 ejection pins were made under-cut 15° and thus let the molten plastic to settle few on the ejection pins under-cut area and made the part remain on the core side. Figure 13 shows the ejection pin under cut, in the image it can be seen that ejection pin end appears like ‘V’ notch. On the other hand, the shot fill was formed at the End of Filling (EOF) area. This occurred due to the decreased pressure and temperature of molten plastic before reaching the EOF area. This shot fill was rectified by increasing the pressure flow such as injection pressure as well as increasing the temperature of molten plastic. There was one more problem called ‘Warpage’ encountered during the moulding of part. This was rectified by manufacturing a fixture called “COOLING FIXTURE”. The warpage usually formed during cooling, due to nonuniform wall thickness or Cooling. In such case once a part is ejected from the mould, it is allowed to put the cooling fixture.

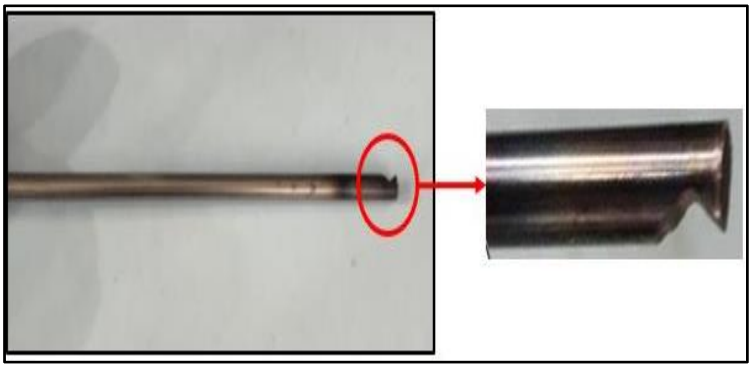


Fig. 13. Under cut in Ejector Rod

9. Results and Discussion

From the simulations, the following result parameters were obtained as in Table 8.

Table 8
Result from the simulations

Parameters	Values
First fill time	2-3 sec
Cycle time	75 sec
Injection pressure	82 bars
Injection temperature	200-240 °C
Mould temperature	40-60 °C
Maximum clamping force	450 tons
Holding pressure	60 bars
Holding time	4 sec
Cooling time	30 sec
Shot weight	0.455 Kg
Shot size in machine	183 mm
Distance between the bar	830 * 830 mm
Mould thickness	600 mm

9.1 Cost Estimation of Battery Holder

9.1.1 Material cost

Material = ASA LI913
Raw material cost per Kg = Rs.211
Net weight = 0.450 Kg
Runner weight = 0.001 Kg
Wastage 1Kg per day = 0.0009 Kg
Gross Weight = Net weight + Runner Weight + Wastage 1Kg per day = 0.452 Kg
Raw Material Cost per Component = (Gross weight * Raw material cost per Kg) – Scrap Recovery = 95.351-0.080 = Rs.95.27
Raw material cost = Rs.95.27

9.1.2 Processing cost

Manufacturing Method = Injection Moulding process
No. of Cavity = 1
Machine Tonnage Required = 450 Ton
Machining Hour Rate (MHR) = Rs.336
Cycle Time in sec = 75sec
Therefore No. of Shots per Hour @90% Efficiency = 46.29
Processing Cost = MHR ÷ No. of Shots per Hour @90% Efficiency = 7.26
Processing Cost = Rs.7.26

9.1.3 Cost of per component

Raw material cost + Processing Cost = 95.27 + 7.26 = 102.53
Cost of a Battery Holder is Rs.102.53

9.2 Cost of Metal Version Component

Cost of per Metal version Battery Holder is Rs.163.26. It is thus evident that by using Plastic version Battery Holder nearly Rs.61 per unit can be saved. To manufacture a single unit of Metal version Battery Holder it took nearly 1.30 hour, it was because the metal version battery holder can’t be made as a single component rather 7 different components were made and assembled. Then followed by painting process. By using plastic version, battery holder production rate can be increased, cost of vehicle can be reduced and since plastic is less in weight compared to metal version, fuel efficiency can be increased.

10. Conclusion

In this work a metallic battery holder of two-wheeler vehicle was converted into Plastic version Battery holder through injection moulding process. The material used to produce plastic battery holder was ASA LI913 since it has better impact resistance and UV resistance than other materials.

Due to the plastic battery holder the cost of two-wheeler decreases, the fuel efficiency increases because of reduced gross vehicle weight. An increased production rate is achieved by injection moulding of plastic battery holder. The production rate can be increased by using multi cavity mould and the cost of component can be reduced by using better alternative material.

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