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Redesigning and Cost Optimization of Multipurpose Led Light

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Abstract: *Plastic processing is the pillar of economy in most of the advanced economies. The plastic industry in India is significantly contributing to the economic development and growth of indispensable sectors. It assist plastic processors to boost capacities for rendering services in domestic market and markets overseas. In the industrialization era, the conventional fabrication techniques and machine designs are being analyzed and ameliorated to expedite production in accordance to production cost. This study intended designing of a plastic moulding die of a multi-purpose LED light aiming its comparison with available contemporary light in terms of cost and material. The proffered product design was examined under various process parameters on SolidWorks. Further, the cost sheet was prepared contrasting direct and indirect capital incurred in fabrication process. This analyses allowed fabrication of proposed die at an optimized cost and concluded the production of light with a steady design at a low production capital.*
Key Words: *Plastics, LED light, Optimization, Moulding die, SolidWorks*

I. Introduction

Electronic lights have always been a genesis of aesthetic, embellishments and importantly day-to-day illumination. The success in modernization of electronics field has led these electronic lights now affordable to mankind. With similar intentions, the paper becomes resourceful and hence proposed a multipurpose light for which a die has been designed for the manufacturing of its body using plastic as its molding material The redesigned light and an existing light are juxtaposed in terms of design, material and cost. As a consequence, the redesigned light is likely to give an enhanced productivity rate at an optimized cost resulting in an expectant of rise in demand in the present modish market.

I. Matin et al. [1] presented a parametric mold design system requiring a minimum set of injection molding parameters and reducing the development cost and time. Nagahanumaiah et al. [2] conferred the methodology developed for each stage particularly for injection molding and pressure die casting enabling reduction in lead-time and cost. W. Hu et al. [3] describes the fabrication of a cavity layout design system for multiple cavity injection moulds. Z. Rutkauskas et al. [4] deals with the application of intelligent system for injection mold design. A new square sectioned cooling channel system for injection molds was extended by A. B. M. Saifullah et al. [5] via simulation and experimentation with a comparative analysis. Wong C. T. et al. [6] delineated the design of plastic injection mould for producing a plastic product with the aid of CAD, CAM and Pro-Manufacturing from Pro-E. Kamaruddin et al. [7] and Ozcelik et al. [8] investigated for amelioration of mechanical properties made from polypropylene by utilizing Taguchi optimization technique. Siddiquee et al. [9] and Doong et al. [10] studied for the feasibility of recycled HDPE considering tensile, compressive and flexural strength as the process performances and melt temperature, holding pressure, injection and holding time as the molding parameters. I. I. Rubin et al. [11] studied that higher value for injection pressure lowers the chance dimensional inaccuracy by reducing the chances of shrinkage and increases the density. Also the effect of gates on the cavity filling pattern and residual stress of the injection molded part were investigated by Xie et al. [12], Shen et al. [13] and Zhai et al. [14] showed simulation methods for gate location analysis in which the ideal location and size of gates was calculated for injection molding. N. Singh et al. [15] presented the cycle time reduction concept and successfully applied on to the injection moulding machine for DVD manufacturing. A. Akbarzadeh et al. [16] correlated the concept of ANOVA post studying the relationship between input and output of process parameters. In order to minimize defects and to improve the productivity Gang XU et al. [17] and B. Ozcelik et al. [18] presented ANN-based quality prediction system for a plastic injection moulding process. M. C. Song et al. [19] discussed that an injection mold in which ultra-thin wall plastic parts can be molded is designed and manufactured. T. Boronat et al. [20] investigated the effects of reprocessing on the processability of two ABS-grade thermoplastic polymers by capillary rheology. S. H. Changet al. [21] exercised on the failure of a die used in plastic injection molding made from AISI H13 steel and was intended for the production of plastic cups. G. Wang et al. [22] discussed the high injection speeds in micro-molding and thereby introduced expansion injection molding. Michigan et al. [23] studied that plastics are made from different organic materials depending on the purpose they are designed in different compositions.

Need To Redesign Multipurpose Led Light

Product design is a vast topic and section in any production industry. It forms the integral part which emphasizes the designing of the product to optimize its cost and productivity rate, which governs the markets and are a part of every house. These multipurpose lights are easily available in the market at a high cost as they are partially made of thermoplastics and costly metallic material. The revision in the product design defines the aesthetic look of the product along with the usage of strong and flexible plastic material at a reasonable cost. The design makeover also helps to attain maximum efficiency owing to the new technical and geometrical features.

Design Of Multipurpose Led Light And Its Mould Die

The multipurpose light is divided into three parts namely, component body, cover ring and lock. This section discusses the same along with their respective mould dies.

1. Component Body

The Fig. 1 shows the orthographic projection of main component of the multipurpose light along with its mould die. The holder part of main component has a diameter of 20 mm while the outer diameter of the cap is 62 mm with inner diameter as 18 mm. The height of the main component is 42 mm. The width of the die is 80 mm and the distance between the two guide pins is 60 mm. the cross section of the guide pins are 13 mm x ϕ 6 mm and 97 mm x ϕ 7.99 mm.

2. Cover Ring

The Fig. 2 displays the orthographic projection of the cover ring with its mould die. This is the front part of the light which envelopes the main component. The outer and inner diameters of the ring are 66 mm and 50 mm respectively while the distance between the pins of ϕ 2 mm is 20 mm. The width of the die is 80 mm with distance between the guide pins (ϕ 6 and ϕ 8 mm) as 60 mm and the ingate radius as 2.50 mm.

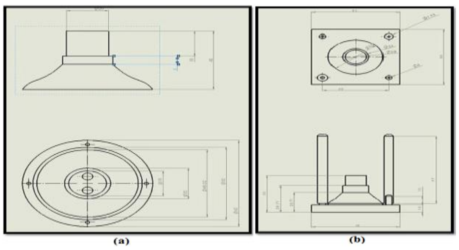


Fig. 1 Orthographic Projection of (a) Component Body and (b) Mould Die

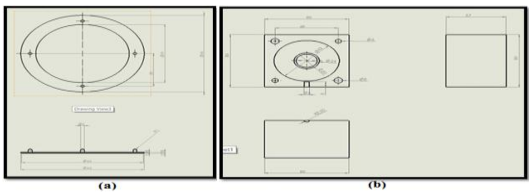


Fig. 2 Orthographic Projection of (a) Cover Ring and (b) Mould Die

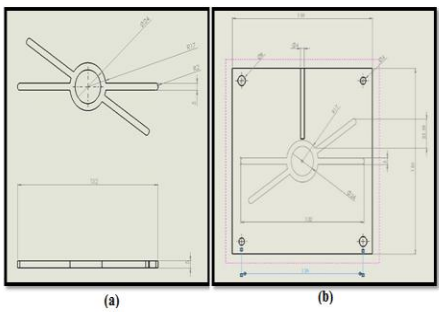


Fig. 3 Orthographic Projection of (a) Lock and (b) Mould Die

3. Lock

The Fig. 3 shows the third component i.e. lock of the multipurpose light along with its mold die. This part holds the light in position at the place of application. The inner and outer diameters are 24 mm and 34 mm respectively while the width of the holding portion of the lock is of 5 mm length with a curvature of 2 mm. The width of the die is 150 mm and the distance between the guide pins is 130 mm. And the diameter of the guide pins are 8 mm and 6 mm while the ingate size is 4 mm.

Selection Of Product Materials

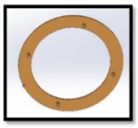
A number of thermoplastics were extensively studied along with their properties and were further surveyed in the market in terms of cost and easy availability. These thermoplastics included styrene acrylonitrile, peek, acetal, ethylene vinyl acetate, high density polyethylene, low density polyethylene, nylon, polybutylene terephthalate, polyetherimide, polycarbonate, polypropylene, polystyrene, polyvinyl chloride, etc. Among all the available thermoplastics, acrylonitrile butadiene styrene (ABS), low density polyethylene (LPDE) and polypropylene (PP) were selected as the material for the body of multipurpose led light.

Design Analysis Of Redesigned Light

The following section discusses the design analysis of various parts of the product through the software.

This part can be successfully filled with an injection pressure of 39.8 MPa (5770.74 psi). The injection pressure required to fill is less than 66% of the maximum injection pressure limit specified for this analysis, which means pressure is under the specified limit. Since the Maximum Temperature at End of Fill has remained within 10°C of the starting melt temperature, there is little to no risk of plastics material degradation.

Table 1: Model Information of Multipurpose LED Light

Model Reference			
Material Name	Polypropylene(PP)	Polypropylene (PP)	Polypropylene (PP)
Type	Shell	Solid	Solid
Volume	10.94 (cm^3)	1.41 (cm3)	7.12 (cm3)
Weight	10.02 (G)	1.29 (G)	6.52 (G)
Size	62.00 (mm) x 42.00 (mm) x 62.00 (mm)	66.00 (mm) x 3.78 (mm) x 65.99 (mm)	132.00 (mm) x 5.00 (mm) x 68.54 (mm)

The minimum flow front temperature is less than the starting melt temperature by more than 10°C. Such significant cooling effects could cause filling and packing problems, increase injection pressure requirements, cause poor weld line integrity and appearance and have a negative effect on the overall properties of the molded part. The flow front melt temperature is within the acceptable range of +/- 10°C from your starting melt temperature. This helps promote good mold filling and packing, minimizes injection pressure requirements, helps achieve good weld line integrity and appearance and gives you the best chance to manufacture a part with optimum properties. The predicted cooling time is determined when 90% of the part temperature is less than the material ejection temperature.

1. Component Body

a. Fill Time Analysis

The initial time of fluid take .004795 second to enter into die. The portion which is near about the gate full fill fast and take much time which portion far from gate of die (mould).

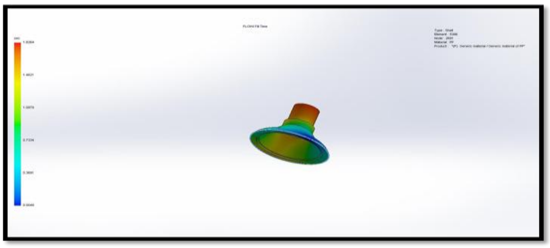


Fig. 4 Fill Time Analysis

The maximum time to take fill cavity of die is 1.8264 seconds. Fill time depends on pressure of fluid flow in die. On increasing pressure of fluid, the fill time is decrease. So here blue colour indicates the starting time of filling and the red shows the complete time to reach the fluid upto end of component.

b. Pressure Analysis

The minimum pressure of fluid is zero in the die cavity. The maximum pressure of fluid is 9.46 MPa. The maximum pressure observe in intial portion of cavity where fluid enter into the die. The minimum pressure observe on end of cavity. At the starting time there is a requirement of high pressure to fill the cavity completely but as the cavity fills there is decrease in pressure. The value of pressure is high on curvature of the component where the red colour is shown and pressure is low where the blue colour is shown and in the middle or inner yellow portion the pressure is low and almost constant.

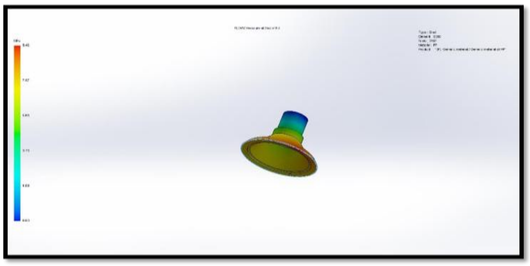


Fig. 5 Pressure at End of Fill Analysis

c. Temperature Analysis

The minimum temperature of fluid is 207.34^0C and maximum temperature of fluid is 230.15^0C.the temperature of fluid is decrease towards the end of cavity. So here blue colour indicates the end of main component where the temperature is low and dark red colour is that portion where the temperature is high.

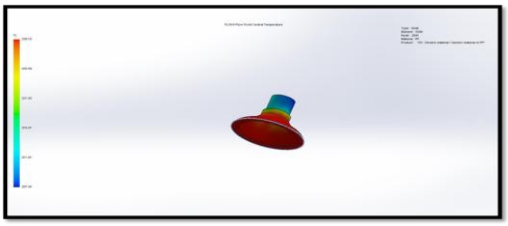


Fig. 6 Flow Front Central Temprature Analysis

d. Shear Rate Analysis

The values for the shear rate at the end of fill has a minimum value of 9.056763 and a maximum value of 1928.118042. But for this component the value of the shear rate is nearly constant throughout the filling. And here the blue colour indicates a constant value of shear rate at the end of fill of the main component.

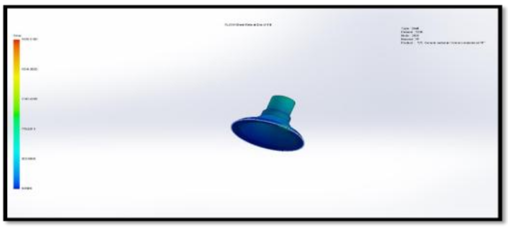


Fig. 7 Shear Rate at End of Fill Analysis

2. Cover Ring

a. Fill Time Analysis

In the Fig. 8, the blue colour is the starting stage of filling and the red colour is the end of fill. So to fill the mould cavity of the ring there is a flow of fluid from one side of ring and then the fluid keeps on filling upto the next other side of ring. And here the time to fill the cavity of ring is 0.457403 sec.

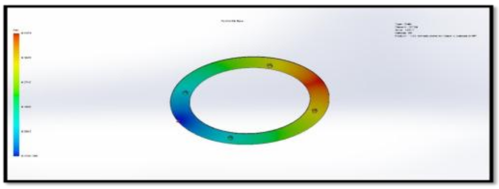


Fig. 8 Fill Time Analysis

b. Pressure Analysis

The minimum pressure of fluid is 0.10 in the die cavity. The maximum pressure of fluid is 34.42 MPa. The maximum pressure observe in initial portion of cavity where fluid enter into the die. The minimum pressure observe on end of cavity. At the starting time there is a requirement of high pressure to fill the cavity completely but as the cavity fills there is decrease in pressure. The value of pressure is high on curvature of the component where the red colour is shown and pressure is low where the blue colour is shown and in the middle or inner yellow portion the pressure is low and almost constant.

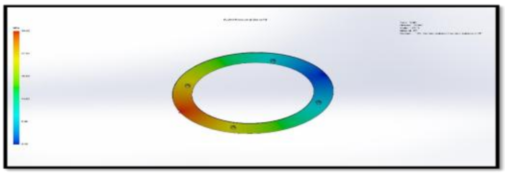


Fig. 9 Pressure at End of Fill Analysis

c. Temperature Analysis

There is a minimum value of the temperature at the end of fill that is 123.166901 and a maximum temperature of 225.429398°C. In the above diagram the blue region is that where the temperature is low and the red region is that where the temperature is high.

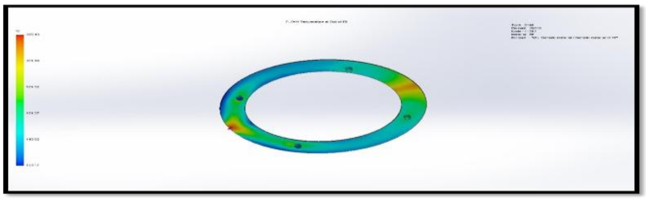


Fig. 10 Temperature at End of Fill Analysis

The minimum temperature of fluid is 210.66^{0}C and maximum temperature of fluid is 229.91^{0}C.the temperature of fluid is decrease towards the end of cavity. So here blue colour indicates the end of the ring where the temperature is low and dark red colour is that portion where the temperature is high and there is intermediate temperature where the green colour is shown.

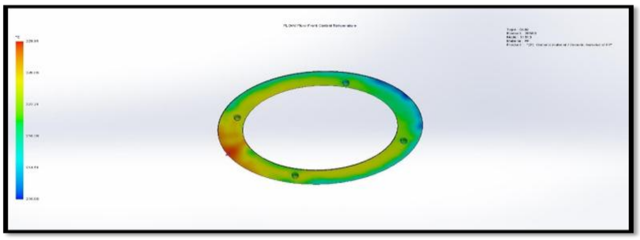


Fig. 11 Flow Front Central Temperature Analysis

d. Shear Rate Analysis

The values for the shear rate at the end of fill has a minimum value of 0.348693 and a maximum value of 5436.907227. But for this component the value of the shear rate is nearly constant throughout the filling. And here the blue colour indicates a constant value of shear rate at the end of fill of the ring.

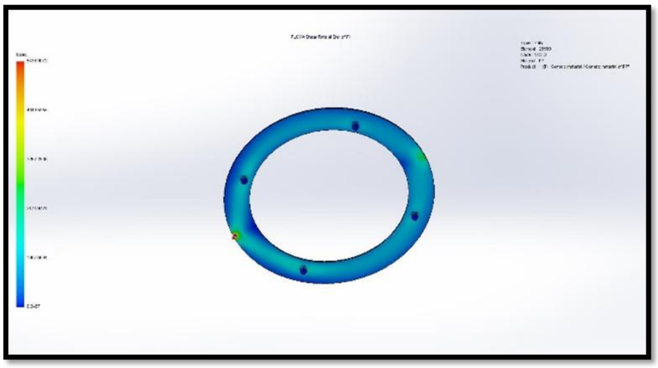


Fig. 12 Shear Rate at End of Fill

3. Lock

a. Fill Time Analysis

In the Fig. 13, the blue colour is the starting stage of filling and the red colour is the end of fill. So to fill the mould cavity of the lock there is a flow of fluid from center side of lock and then the fluid keeps on filling upto the next other sides of the lock. And here the time to fill the cavity of lock is 2.528519 sec.

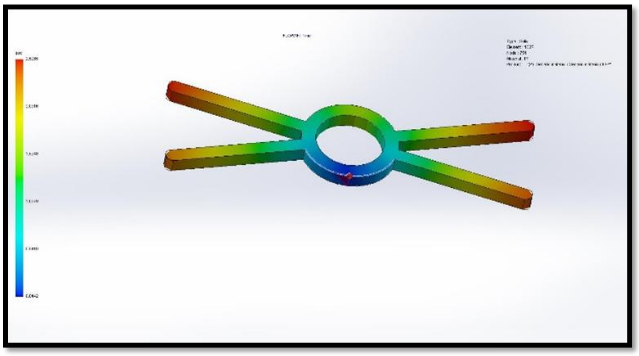


Fig. 13 Fill Time Analysis

b. Pressure Analysis

The minimum pressure of fluid is 0.10 in the die cavity. The maximum pressure of fluid is 3.62 MPa. The maximum pressure observe in intial portion of cavity where fluid enter into the die. The minimum pressure observe on end of cavity. At the starting time there is a requirement of high pressure to fill the cavity completely but as the cavity fills there is decrease in pressure. The value of pressure is high on curvature of the component where the red colour is shown and pressure is low where the blue colour is shown and in the middle or inner yellow portion the pressure is low and almost constant.

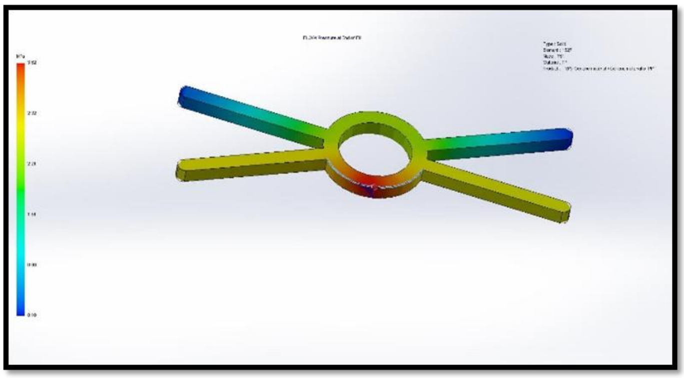


Fig. 14 Pressure at End of Fill Analysis

c. Temperature Analysis

There is a minimum value of the temperature at the end of fill that is 112.376297°C and a maximum temperature of 209.773193°C. In the above diagram the blue region is that where the temperature is low and the red region is that where the temperature is high.

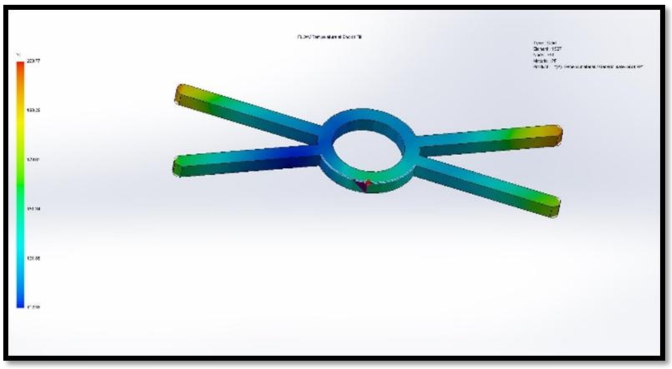


Fig. 15 Temperature at End of Fill Analysis

The minimum temperature of fluid is 202.567001°C and maximum temperature of fluid is 228.319199°C. The temperature of fluid is decrease towards the end of cavity. So here blue colour indicates the end of the lock where the temperature is low and yellow is that portion where the temperature is high and there is intermediate temperature where the green colour is shown.

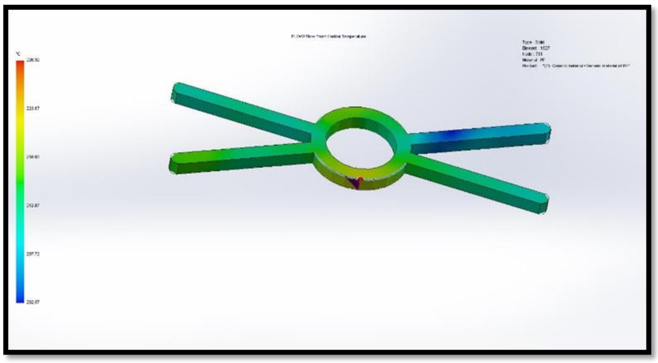


Fig. 16 Flow Front Central Temperature Analysis

d. Shear Rate

The values for the shear rate at the end of fill has a minimum value of 0.014002 and a maximum value of168.422104.

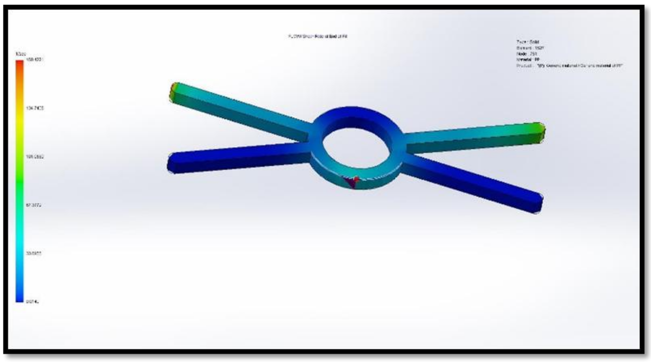


Fig. 17 Shear Rate at End of Fill Analysis

But for this component the value of the shear rate is nearly constant throughout the filling. And here the blue colour indicates a constant value of shear rate at the end of fill of the lock.

Material Properties Of Various Elements Of Multipurpose Led Light

Table 2 Summary of Process Parameters of Elements of Multipurpose LED Light

Fill Settings				Flow Settings			
Part Name	**Component Body**	**Cover Ring**	**Lock**	**Part Name**	**Component Body**	**Cover Ring**	**Lock**
Filling Time	1.83 sec	0.44 sec	2.57 sec	**X-dir. Clamping Force**	1.1800 Tonne	0.2121 Tonne	0.0958 Tonne
Main Material Melt Temperature	230 °C	230 °C	230 °C	**Y-dir. Clamping Force**	1.8000 Tonne	2.3060 Tonne	0.2500 Tonne
Mold Wall Temperature	50 °C	50 °C	50 °C	**Z-dir. Clamping Force**	1.1800 Tonne	0.2101 Tonne	0.2022 Tonne
Injection Pressure Limit	100 MPa	50 MPa	100 MPa	**Requiring injection pressure**	9.4600 MPa	34.4241 MPa	3.6249 MPa
Max. Inject (Machine) Flow Rate	194 cc/s	194 cc/s	194 cc/s	**Max. central temperature**	230.1800 °C	225.5794 °C	209.9232 °C
Flow/Pack Switch Point in Filled Volume	100 %	100 %	100 %	**Max. average temperature**	205.6700 °C	226.4522 °C	214.4917 °C
Pressure Holding Time	3.95 sec	1.76 sec	5.02 sec	**Max. bulk temperature**	229.2300 °C	0.1853 MPa	0.0729 MPa
Total Time in Pack Stage	18.34 sec	4.39 sec	25.74 sec	**Max. shear stress**	0.1500 MPa	5436.9070 1/sec	168.4221 1/sec
Auto Filling Time (1: Exist, 0: Not)	1	1	1	**Max. shear rate**	1928.1200 1/sec	158.17 sec	27.18 sec
Auto Packing Time (1: Exist, 0: Not)	1	1	1	**Averaged perfect cooling time**	15.2500 sec	9.30 sec	46.27 sec
Venting Analysis (1: Exist, 0: Not)	0	0	0	**CPU Time**	33.12 sec		
Cavity Initial Air Pressure	0.1 MPa	0.1 MPa	0.1 MPa	**Cycle Time:**	44.05 sec		
Cavity Initial Air Temperature	25 °C	25 °C	25 °C				

Fabricated Elements Of Mould Die Of Multipurpose Led Light

Fig. 18 shows the individual parts of the mould die of the multipurpose LED light after the fabrication process.

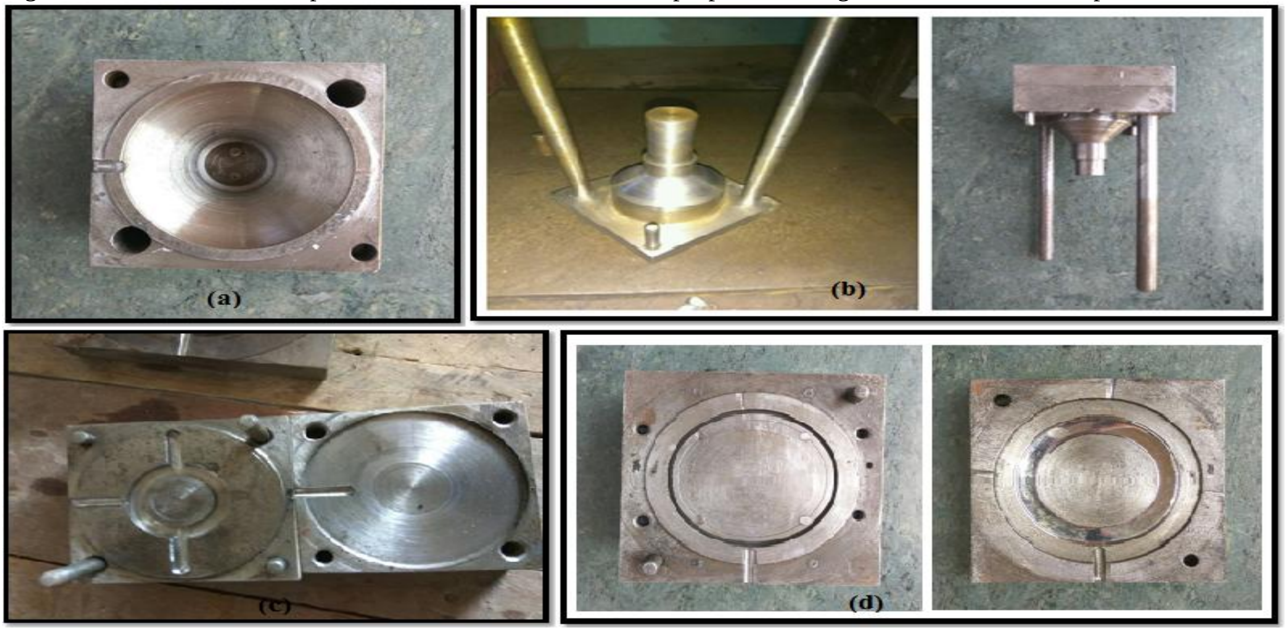


Fig. 18 (a) Cavity Plate (b) Core Plate (c) Relief on Parting Surface (d) Baffle Circular Cooling Channel

II. Summary Of Result Of Design Analysis

Table 3 Result Analysis

S. No.	Process Parameters	Component Body (Part 1)		Cover Ring (Part 2)		Lock (Part 3)	
		Minimum	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
1.	**Fill Time**	0.004795	1.826412	0.000082	0.457403	0.044152	2.528519
2.	**Pressure at End of Fill**	0.000000	9.460874	0.100000	34.424091	0.100000	3.624877
3.	**Flow Front Central Temperature**	207.344406	230.150894	210.660706	229.908005	202.567001	228.319199
4.	**Shear Rate at End of Fill**	9.056763	1928.118042	0.348693	5436.907227	0.014002	168.422104
5.	**Max. Inlet Pressure**	0.000000	9.461000	0.000000	34.874001	0.000000	3.689000
6.	**Inlet Flow Rate**	0.000000	5.981000	0.000000	3.373000	0.000000	3.143000
7.	**X-dir. Clamping Force**	0.000000	1.511000	0.000000	0.226000	0.000000	0.113000
8.	**Y-dir. Clamping Force**	0.000000	2.197000	0.000000	2.458000	0.000000	0.294000
9.	**Z-dir. Clamping Force**	0.000000	1.510000	0.000000	0.224000	0.000000	0.239000

COST OF MOULD DIE

The table below which shows the cost sheet for the fabrication of mould die for the designed product which is the multipurpose light. The Fig. 19 shows the assembled view of the mould die for the redesigned multipurpose LED light.

Table 4 Mould Die Cost

S. No.	Items	Amount
1.	Material Use- EN31	680
2.	Making Charges for Front Ring	1500
3.	Making Charges for Main Body	3000
4.	Making Charges for Lock	1500
5.	Making Charges for Inner Front Plate	1700
6.	Making Charges for Inside Circuit Holding Plate	1800
	Total	**10180**

Fig. 19 Assembled Mould Die

Cost Comparison And Analysis Of Available And Redesigned Product

The existing product in the market has different cost as compared to the product. And that difference in the cost is due to the variation in the material used for the fabrication of the product. The market product has a cost of 5 rupees for main component, 3 rupees for front plate or ring with coating, 1 rupees for spring and in last 6 rupees for circuit. Thus in total, the cost of a single unit of product is about 15 rupees. But in this project the cost of production of a single unit of multipurpose light was reduced. As mentioned above in the

Table the cost of fabrication of a single unit of product is about 10.35 rupees. Hence, the total production cost reduction of a single unit of product is approximately 4.65 rupees.

Table 5 Comparison between Available and Redesigned Product

Part Name	Available Product	Redesigned Product
Main Component Body (Part 1)		
Front Plate or Cover Ring (Part 2)		
Assembled Part		

Table 6 Cost Sheet of Light Product

S. No.	Particulars	Cost Per Unit
	Direct Cost:	
1.	Material Use ABS for Front Ring	2.5
2.	Material Use PP for Main Body	0.75
3.	Material Use PP for Lock Part	0.3
4.	Material Use LDPE for Inner Front Plate	0.5
5.	Material Use PP for Circuit Holding Plate	0.1
6	Circuit Cost	4
7.	Labour Cost	1.1
	Total Direct Cost (A)	**9.25**
	Indirect Cost:	
8.	Variable Overhead	0.1
9.	Fixed Overhead	1
	Total Indirect Cost (B)	**1.1**
	Total Cost (A+B)	**10.35**

III. Conclusion

Redesigning of fabricating-molding die for multipurpose light proves nothing less than advancement in indispensable manufacturing and electronics sectors. Out of all available thermoplastics, the molding material for the body of proposed light rendering desired qualities for the intended application is polypropylene making current use of mild steel replaceable in existing light in the market. Cost analyses regarding fabricating-molding die and the proposed molding material manifests that the inspired production could now be done at optimized economic cost.

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