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Design and Material Selection of Screw Feeder of Injection Molding Machine

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Abstract*: *The efficiency of the 'Injection molding Machine' lies in the proper designing of screw feeder mechanism. The screw feeding mechanism needs to be setup differently for different materials, molds etc. The proper design includes the work from selecting the appropriate materials, designing for the optimum design, analysis of the designed parts at different flow rates, speed and temperatures. There are various parameters that govern the efficiency of the 'Injection molding Machine'. These parameters include 'Filling Pressure', 'Mold Surface Temperature', 'Raw Material Melting Temperature', 'Filling Time' etc.

Keywords: Injection Mounding Machine, Screw Feeder Optimization, Materials Selection, Filling time

I. INTRODUCTION

Injection Molding Machine are known for their adaptability in manufacturing sector. It can be used for mass production and obtaining highly precise manufactured parts.

Injection molding is a method of manufacturing a plastic product from powdered thermoplastics by supplying the material through hopper to a heated chamber in order to make it easy to mold and force the material into the mold by the using the screw. In this whole process pressure should be persistent till the material is hardened and is ready to be detached from the mold. This is the most common and preferred way of producing a plastic products with any complexity and size.

The injection molding process

The stages of injection molding process are as follows

1. Polymer is feed through hopper to barrel
2. It is heated to a sufficient temperature to make it flow
3. The molten plastic which got melted will be injected under high pressure into the mold

This process combined is known as Injection. After injection pressure is applied to both plates i.e. fixed and moving plates of the injection molding machine in order to hold the mold tool together afterwards the product is set to cool which helps it in the solidification process.

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After the product gets its shape the two plates will proceed away from each other in order to detach the mold tool which is known as mold opening and finally the molded product is ejected or removed from the mold. And the process will get repeated.The molding cycle gets started with the recantation of the ejector plate, followed by shutting of the mold. The polymer resin is melted and injected into the mold by the injection unit. Hydraulically operated plunger is used to push the plastic through a heated region. The melt gets converged at a nozzle and is injected into the mold.

The melt is imposed into the mold in two stages:

1. The mold cavities are filled with molten resin. As the material is imposed forward, it gets passed over a spreader (torpedo), within the barrel resulting in mixing. This stage is determined by the rate injection velocity, pressure and time. Injection velocity is defined as the rate at which the plunger gets move forward.

2. Hold stage is started when no more material can be forced into the mold and where melt can still leak back through the gate. Forces are applied against the material in the cavity until the gate freezes to avoid leaking of the melt. In some machines, pack and hold are combined into a single holding stage.

Parts to be injection molded must be very attentively designed to make the molding process smoother; the material used, the desired shape and attributes of the part, the material of the mold, and the properties of the molding machine must all be taken into consideration.Each stage is controlled by a specific pressure and time span. Once the mold is filled and the gate gets cooled, the injection molding machine switches to the cooling stage. The cooling time decides the amount of cooling. After the cycle gets completed and before the next cycle can be run, the machine must be checked and get clearance as per directions in the manual.[7]

Problem statement

The injection molding machine consists of the hopper, screw, the barrel and the injection nozzle of which the main focus is on the screw feeder of the injection molding machine the aim is to design, optimization and analysis of screw feeder to improve the quality of produces parts and obtain higher production rate. The project focus on increasing the fatigue life of screw feeder and to perform FEA analysis Here our main objectives are to increasing the mass flow rate of the granular plastic resin, thus increasing the machine capcity from 7 shots per min to 11 shots per min, to decrease the weakness in the screw feeder which increases the fatigue life of the screw feeder.

To reduce the torsional failure of the screw with proper application of coupling. And improving heat convection through barrel. A step of process of designing of any physical object. for the machine is important task for the good optimizations and result. In the context of design, the main goal of material selection is to minimize cost while meeting product performance goals, it allows to design durability and performance of the product.

II. LITERATURE SURVEY

The repeatability precision of weight for injection molded products is a major technical parameter to measure the quality and precision of injection molded products and evaluate the performance of injection molding machine. The influence of melt temperature, packing pressure, mold temperature and packing time on the weight of microinjection molding products was studied by Taguchi orthogonal experiment. The influence of peak cavity pressure on the weight of products also got analyzed. The experimental results portrays that the packing pressure is the most major process parameter influencing both the weight of the tensile and the impact specimens.[6]

.Reaction injection molding includes aspects of polymerization reactor analysis as well as melt injection molding. Processing can be broken down into several unit operations: metering and machine performance, impingement mixing, mold filling, curing and mold design. Commercial RIM machines have been used successfully for non-filler systems. The results are generally satisfactory. Reactants are usually allowed to circulate through the mix head, or even through impingement nozzles, such that uniform temperature control and appropriate agitation of reactants can be obtained. Most heads can switch from the recycle to injection mode under high pressure operation, to minimize the lead/lag problem. The mixing chamber is self-cleaned at the end of each shot by a hydraulically driven piston which pushes out all the residue mixture from the mix head after mold filling. Flow rate/flow area can be adjusted externally by the nozzle size adjuster. Flow rate also can be controlled by the pressure setting. Two or four streams impingement mixing is the common mixing technology used in the present RIM machines. Static or impingement type after-mixers have been used extensively to improve the mixing. Mold filling seems not to be a problem for conventional RIM operation if mold design is appropriate. The typical pressure inside the mold cavity during filling is less than 350 KPa. With the help of slight foaming during curing, RIM polyurethanes usually have excellent, depression-free surfaces. A number of qualitative descriptions of automotive type RIM have appeared, and some basic studies of the process are being carried out. However, as yet there does not appear to be a complete understanding of how the process influences the structure and properties of the polymer formed. The majority of RIM parts have been made in the 140–300 MPa flexural modulus range for fascia applications, where appearance, weight-reduction, and impact resistance are the most important criteria. A representative formulation used to produce automotive fascia by reaction injection molding consists of a polyether/polyester polyol with molecular weight in the range of 1000–3000, a short chain extender like ethylene glycol, 1,4-butane diol or a diamine and a modified derivative of 1,4-diphenylmethane diisocyanate, MDI. The need for further weight reduction to meet government mileage requirements, and for improved corrosion and impact resistance, makes the extension of RIM materials to other external automotive body components increasingly attractive. For these applications, there will be several new requirements: flexural moduli in the 700–4000 MPa range to provide dimensional stability, but still with the desirable impact strength; a low thermal coefficient of linear expansion to allow satisfactory mating with sheet metal surfaces. An increased thermal stability would also be required for parts that would be painted and baked on the car, or for applications such as hoods with higher in-use thermal exposure.[1]

III. METHODOLOGY

A. General Arrangement Layout

The layout of injection moulding machine was drawn which gave us the overview of the parts and its location in the machine or the system.

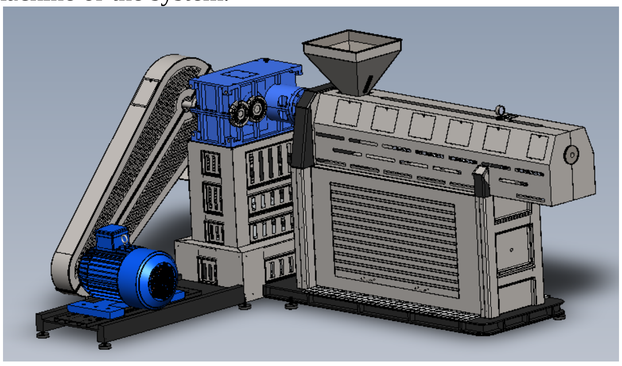

Fig 1:GA layout of Injection Molding Machine

B. Material Selection by Ashby Standard

It is very crucial process involved in any project. As density and strength were important factors so, for this project we selected density vs strength property chart by Ashby.By using Granta software and importing geometry data to it, we were able to find the candidate material.

Table 1- Candidate material and their properties

Material Name	Properties		
	Yield Strength	***Tensile Strength***	***Density (g/cc)***
Low Carbon steel 8620	460	455	7.20
Carbon Steel 4140	700	1014	4.42
Carbon Steel 135	851	1100	8.40
Stainless Steel 304	480	510	2.73
Stainless Steel 316	276	310	2.70
Tool Steel H13	425	485	2.80
D-2 Tool Steel	700	1029	4.68

It is very necessary to identify the function of the element or part for which the material is to be selected. In this case we aim to improve the torsional strength of the part.

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There are three methods for quantitative material selection, they are as follows;

1. Cost per Unit Property Method
2. Weighted Properties Method
3. Digital Logic Method

The properties of the materials are scaled based on the weight factor of the physical property which is also known as the weight factor of the property. The scaled property chart is given below,

Table 2:-Candidate Material and Scaled Properties

Material Name	Scaled Properties		
	Yield Strength	*Tensile Strength*	*Density (g/cc)*
Low Carbon steel 8620	54.05	41.36	85.71
Carbon Steel 4140	82.256	92.18	52.60
Carbon Steel 135	100	100	100
Stainless Steel 304	56.404	46.36	32.5
Stainless Steel 316	32.432	28.18	32.142
Tool Steel H13	49.941	44.090	33.33
D-2 Tool Steel	82.256	93.5454	55.714

Then, Performance index is calculated for each material. This performance index is then multiplied with the relative cost of that material to get the final material values or say total performance index.

The material with the maximum total performance index is selected as the material for the particular part.

Table 3:-Candidate material and its Relative Cost, Performance Index and Total Performance Index

Material	Relative Cost	Performance Index	Total Performance Index
Low carbon steel 8620	2.9	59.319	172.027
Carbon steel 4140	6.5	76.512	497.333
Carbon steel 135	6.1	100	610
Stainless steel 304	2.1	44.25	92.930
Stainless steel 316	2.7	30.564	82.525
Tool steel H13	2.5	41.967	104.91
D-2 Tool steel	8	78.112	624.901

Through the table plotted above it is clear that the highest calculated performance index is showed by the material D-2 Tool steel and hence this material is finalized for the screw feeder part of the injection moulding machine.

C. Calculations and Designing

There are various calculations involved before we actually start making the part. For designing any part these calculations are very important. With the help of calculations we are able to find the dimensions of the part. Other parameters like flow rate, various temperatures, pressure is found out with help of it

Table 4:-Case Studies of parameters

Description	*Case 1*	*Case 2*	*Case 3*	*unit*
INPUT				
Barrel Diameter	0.078	0.09	0.065	m
Screw lead	0.078	0.09	0.065	m
Screw speed	210	190	150	rpm
Number of flights	28	35	21	
Flight width	0.005	0.003	0.004	m
Channel width	0.025	0.025	0.021	m
Depth of the feed zone	0.007	0.005	0.004	m
Conveying efficiency	0.25	0.25	0.25	
Bulk density of polymer	1000	1000	1000	kg/m2
Length of metering zone	0.201	0.16	0.014	m
Flight clearance	0.0001	0.00013	0.00005	m
pressure diff. across metering zone	300	300	300	bar
Melt viscosity	1406	1406	1406	Pa.s
Density of the melt	1000	1000	1000	kg/m3
Therml conductivity of the melt	0.174	0.174	0.174	W/(m.k)
Heat of fusion of the polymer	125.5	125.5	125.5	KJ/kg
Specific heat of the solid polymer	2.2	2.2	2.2	KJ/(Kg.k)
Viscosity in the melt film	1406	1406	1406	pa.s
Barrel temperature	140	140	140	˚c
Meting point of the polymer	75	75	75	˚c
Temperature of the solid polymer	40	40	40	˚c
Density of the solid polymer	1000	1000	1000	kg/m3
Depth of the feed	0.007	0.007	0.007	m
Empirical Factor	0.286	0.286	0.286	
Melt viscosity in screw channel	1406	1406	1406	pa.s
Shear rate in channel	122.5221135	179.0707813	127.6272016	s-1
channel depth at the outlet	0.003	0.003	0.003	m
Reciprocal of power exponent	0.5	0.5	0.5	
ratio of channel depths	1	1	1	
factor	15562.97288	18814.71676	15883.89268	
length of the screw zone	1.68	1.24	1.1	m
Specific heat of melt	2	2	2	KJ/(Kg.k)
The flight diameter	0.0778	0.08974	0.0649	m
vicosity in flight clearance	1400	1400	1400	pa.s
length of the melt zone	0.201	0.201	0.201	
Diameter	0.15	0.15	0.15	m
Torque	17810	14500	11200	Nm
Accelertion due to Gravity	9.81	9.81	9.81	m2/sec

Description	*Case 1*	*Case 2*	*Case 3*	*unit*
Desity of the screw metal	7850	7850	7850	kJ/m3
Elastic modulus of screw	2.1E+11	1.9E+11	2E+11	Pa
Allowable shear stress	1.00E+08	1.00E+08	1.00E+08	MPa
non-uniform pressure diff. around screw circumference	3000000	3000000	3000000	Pa
OUTPUT				
Helix angle	0.308169071	0.308169071	0.308169071	rad
Conveying rate in feed zone	290.2793748	277.6477489	85.50684199	kg/hr
Volume flow rate of pressure flow	0.00005437266	0.00000602243	0.00004463714	m3/s
mass flow rate	195.7415736	21.68076552	160.6937044	kg/h
Drag flow	0.000168989	3.04868E-05	1.76146E-05	m3/s
mass flow rate	608.3601545	109.7525219	63.41256822	kg/h
ratio of pressure flow to drag flow	0.321752784	0.197542299	2.534098664	
Melt conveying rate	0.000403928	8.52182E-05	9.80738E-05	
Average shear rate	122.5221135	179.0707813	127.6272016	
Velocity of the barrel surface	0.857654794	0.895353906	0.510508806	m/sec
Velocity of the solid bed	0.460760912	0.440710713	0.161577555	m/sec
Relative velocity	0.44131352	0.493840553	0.359895591	m/sec
Velocity component	0.26013911	0.271573796	0.154844709	m/sec
Thickness of melt film	0.000103673	0.000101482	0.000123132	m
Average film tempterature	107.5	107.5	107.5	˚c
Temperature of melt film	238.6442617	271.7208617	194.7183525	˚c
Melt pressure	403.9740008	389.24000	390.24000	bar
Thermal diffusivity	0.000000087	0.000000087	0.000000087	m2/s
The parameter β	0.100574713	0.153783525	0.01795977	
Heat transfer btw melt and barrel	788.518983	890.2427621	543.8056235	W/(m2.k)
Correction factor for screw power	1.007177812	1.003402758	1.002914867	
Power dissipated in screw channel	61.2130844	63.93375179	27.30085278	KW
Power dissipated in flight clearance	9.505041688	5.972463247	4.049574567	KW
power required to raise pressure of melt	1.63117978	0.180673046	1.339114203	KW
Screw power	72.34930587	70.08688809	32.68954155	KW
Max Shear Stress	26875728.94	21880857.36	16901076.03	Pa
Max Feed depth	2.66E-02	2.98E-02	3.35E-02	m
Lateral deflection of screw	0.000259659	0.000286992	0.000272642	m
Critical Pressure for buckling	2581.683629	2335.808998	2458.746313	bar
Critical Screw Speed for vibraions	14513.81012	13805.38715	14164.02836	RPM
Horizontal force	756000	756000	756000	N

With help of 3D CAD software such Solid works the Screw feeder was designed on the basis of basic dimensions to be analysed for further investigation.

D.Analysis

There are various types of analysis carried out on a part. For the Screw feeder we used Finite Element analysis. It reduces the cost of actual prototyping and testing. Number of tests are carried out with help of soft wares to optimize the product and develop it faster.

The software we used for the analysis of the screw feeder is solid works. The parameter applied was torsional force. The result was obtained in the form of stress, strain, displacement and factor of safety.

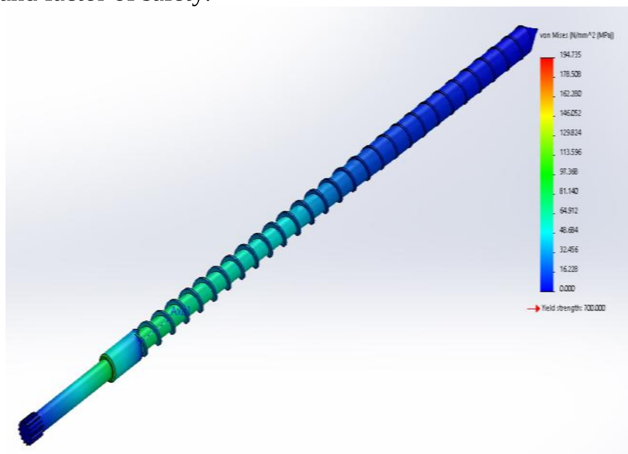

Fig 2: Analysis of the screw feeder for the von misses stress.

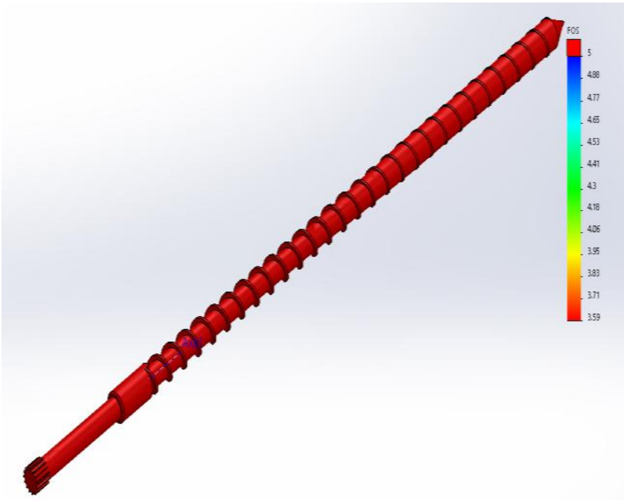

Fig 3: Analysis of the screw feeder for the factor of safety

IV. RESULTS

The material D2 tool steel and carbon steel 135 showed good results through the software. Both the materials showed high torsional strength. However the displacement were same for both the materials.

Table 5:-Candidate Material and its FOS and Yield Strength

Material	**FOS**	**Yield strength**
Low carbon steel 8620	2.4	460MPa
Carbon steel 135	4.4	850MPa
Carbon Steel 4140	3.6	700MPa

D2 Tool Steel	3.6	700MPa

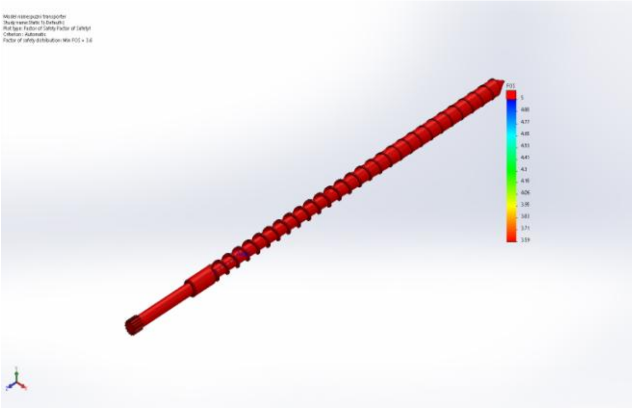

Fig 4:-Analysis of Screw Feeder for D2 Steel(FOS=3.6)

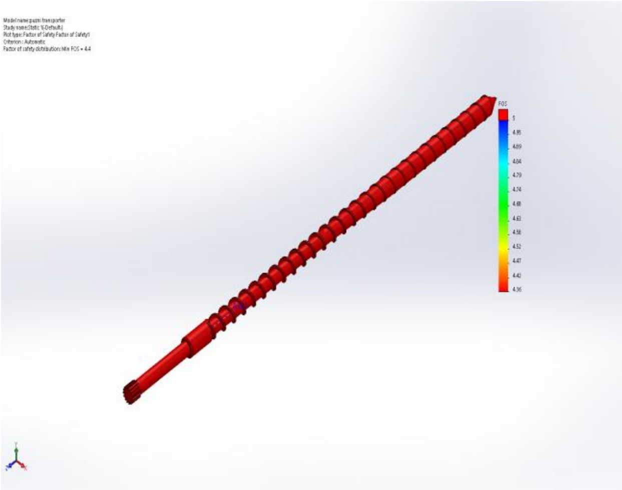

Fig 5:-Analysis of screw feeder for Carbon Steel 135(FOS=4.4)

V. CONCLUSION

The initial design of the screw feeder of the injection moulding was studied and based on that it was redesigned with respect to dimensions and material to gain a control over the output. The capacity of the injection moulding was optimised taking the inputs and constraints into consideration. The analysis was performed on the designed screw feeder to check or verify its functioning under working conditions. It was found out that D-2 Tool steel as a material would be best to select for the screw feeder. The calculations and analysis were successfully completed.

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