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Analysys and Validation of Reciprocating Screw and Coupling of Injection Molding Machine

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Abstract— *The injection molding machine melts and plasticizes the molding material inside the heating barrel and injects this into the mold tool to create the molded product by solidifying inside it. Reciprocating screw acts like a shaft in this machine and plays vital role in handling of molten material. Problem faced in the industry is the wearing of threads due to effect of high temperature of molten materials like nylon, low density polypropylene, polystyrene, PVC etc. Production is struck because of failure of the screw leading to loss of time and money. This work involves modelling of the components of machine with dimensions, assembling of those components and then simulating the whole assembly for rotation of the screw using modelling software CATIA V5R20. The thermal and stress analysis rotating screw is done using software ANSYS 14.5. After obtaining the results, new material will be suggested for screw and barrel as a permanent solution for new machines which will come in the market. For existing machines, design and analysis will be done for coupling so that coupling will be made as a weaker part in the rotating system and which will fail before failure of screw which will save large amount of cost and time.*

Keywords—Injection molding machine, Reciprocating screw.

I. INTRODUCTION

The injection machine melts and plasticizes the molding material inside the heating cylinder. It further injects this into the mold tool to create the molded product by solidifying inside it. The injection machine is constructed of a mold clamping device that opens and closes the mold tool, and device that plasticize and inject the molding material. Injections molding machines can be classified based on the arrangements as given below.

（1） Horizontal injection machine： both mold clamping device and injection device compounded horizontally

（2） Vertical injection machine： both mold clamping device and injection device compounded vertically

（3） Two-color injection machine

（4） Rotary injection machine

（5） Low foam injection machine

（6） Multi material injection machine

（7） Sandwich injection machine.

Injection molding is the most commonly used manufacturing process for the fabrication of plastic parts. A wide variety of products are manufactured using injection molding machine, such as plastics housings, consumer electronics, and medical devices Including valves & syringes which vary greatly in their size, complexity and application. The injection molding process requires the use of an injection molding machine, raw plastic material, and a mold. The plastic is melted in the injection molding machine and then injected into the mold, where it cools and solidifies into the final part.

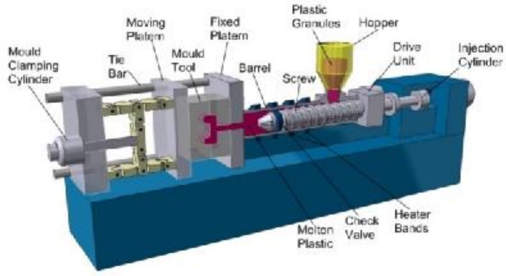

Fig.1 : Injection molding machine

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Fig.1 shows the generalized diagram of Injection molding machine.The barrel contains the mechanism for heating and injecting the material into the mold. This mechanism is run by a reciprocating screw. Reciprocating screw advances the material forward by either a hydraulic or electric motor. During this process the material is melted by heat & pressure. The material enters into the grooves of the screw. The screw completes the shot volume & returns to reverse position that is as the screw moves back, plastic moves forward.

II. FAILURE OF THE RECIPROCATING SCREW

Barrel of the Injection molding machine is surrounded by number of heating elements. As this heating element fails, the temperature of the molten material will be decreased which turns to solidification. This increases the stresses on the reciprocating screw which results into the failure of the shaft. Sometimes many times it is observed that shaft fails though there is no failure of heating elements. This is frequent problem observed in the plastic industry. Cost of the reciprocating screw is high and also the time required replacing the shaft with newer one takes long time which is about 4 to 5 working days. This large loss of time and money leads to very high economical loss for industry due to struck of the production. Fig.2 refers to the photograph of broken reciprocating screw.

Fig.2: Photograph of failed reciprocating screw.

The long term solution for above problem includes redesign of reciprocating screw with new material. But the machines which are in running condition needs some immediate remedy by which there will be minimum loss of time and money after the failure of reciprocating screw.

This temporary and immediate remedy includes redesigning the coupling of the machine which connects driver and screw. This coupling design should be such that the coupling will be weaker part in the system. Before the stress limit reaches the breaking point of the reciprocating screw, coupling should break which will save the reciprocating screw. The cost of coupling is very negligible compared to the reciprocating screw. Also time required to mount the new coupling is 3 hours which is negligible. This solution will very much economical for current running injection molding machines.

This paper is about the FEM analysis of reciprocating screw and coupling and then verifying the results of both to verify the idea of breaking the coupling to protect the high values reciprocating screw.

III. PAST RESEARCH WORK

Y. Bereauxrecommended a model of a single-screw extruder or the metering time of an injection molding machine for a given screw geometry, set of processing conditions and polymeric material is important both for practical and designing purposes. The model is based on viewing the entire screw as a pump, conveying a solid and a molten fraction.The model also shows that the screw geometry is the mostimportant parameter, then polymer properties andprocessing conditions.

P. Boey says that Glass-filled polymers areknown to produce considerable wear on the barrels and screws of injection moulding machines. A few model tests with the tribological conditions in the injection moulding machine has developed to find the suitable coatings and treatments to the wear. Made a new wear tester that developed to simulate more closely the wear which occurs inside the barrel of an injection moulding machine.

IV. FEM ANALYSIS

FEM analysis includes following steps.

A. Making CAD model of reciprocating screw
B. Stress analysis of reciprocating screw at increased temperature
C. Design of suitable coupling
D. Making CAD model of coupling
E. Stress analysis of coupling

A. *Making of CAD model of reciprocating screw*

Computer aided model of reciprocating screw is created using suitable design software CATIA V5. Dimensions are as actually measured on site. Fig.3 is the CAD model of reciprocating screw.

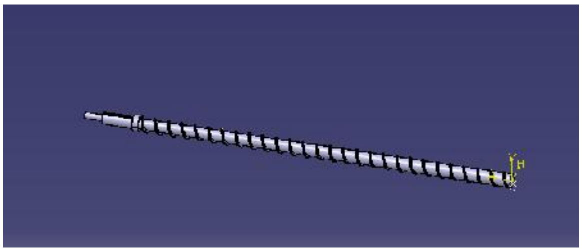

Fig.3: CAD model of reciprocating screw

B. *Stress analysis of reciprocating screw at increased temperature*

Stress analysis of the reciprocating screw is carried out with analysis software ANSYS 14.5. Analysis is done by using tetrahedron type meshing and boundary conditions as one side fixed at temperature more than 300ºC. Torque applied to the shaft is equal to 1.112×10^5 Nmm which is based on motor power 11.1855 kW available on site. Material of the screw is EN41B (SAE52100).Maximum stress value to be noted from the analysis. Fig.4 refers to stress analysis of reciprocating screw.

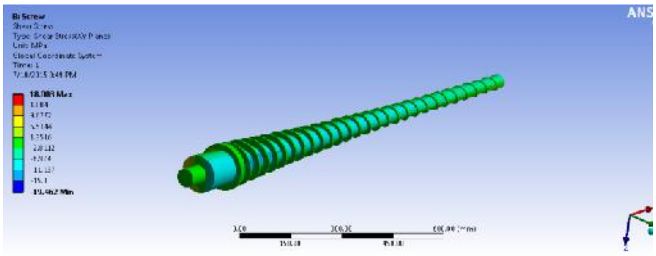

Fig.4 : Equivalent Stresses of reciprocating screw (MPa)

C. *Design of coupling*

Step I- Shaft diameter (d)

The diameter of the shaft on which reciprocating screw is mounted is equal to 37mm.

$d = 37\text{mm}$

Step II- Flange dimensions

Outside diameter of the hub (d_h).

$$
\begin{aligned}
d_h &= 1.8.d \\
&= 1.8 \times 37\text{mm} \\
&= 75\text{mm}
\end{aligned}
$$

Length of the hub (l_h).

$$
\begin{aligned}
l_h &= 1.5.d \\
&= 1.5 \times 37\text{mm} \\
&= 55.5\text{mm}
\end{aligned}
$$

Pitch circle diameter for the bolts (D).

$$
\begin{aligned}
D &= 3.d \\
&= 3 \times 37\text{mm} \\
&= 111\text{mm}
\end{aligned}
$$

Thickness of the flange (t).

$$
\begin{aligned}
t &= 0.5.d \\
&= 0.5 \times 37\text{mm} \\
&= 18.5\text{mm}
\end{aligned}
$$

Thickness of the protecting rim (t_1).

$$
\begin{aligned}
t_1 &= 0.5.d \\
&= 0.25 \times 37\text{mm} \\
&= 9.25\text{mm}
\end{aligned}
$$

Diameter of spigot and recess (d_r).

$$
\begin{aligned}
d_r &= 1.5.d \\
&= 1.5 \times 37\text{mm} \\
&= 55.7\text{mm}
\end{aligned}
$$

Outside diameter of the flange (D_o).

$$
\begin{aligned}
D_o &= (4d + 2t_1) \\
&= (4 \times 37 + 2 \times 9.25)\text{mm} \\
&= 166.5\text{mm}
\end{aligned}
$$

Step III – Torsional shear stresses

Torque (T) transmitted.

Take the motor power P as 11.1855kW and number of revolutions N of the reciprocating screw as 96 rpm.

$$
\begin{aligned}
T &= \frac{P \times 60 \times 10^6}{2 \times \text{®} \times N} \\
&= \frac{18.1855 \times 60 \times 10^6}{2 \times \text{®} \times 96} \\
&= 1.112 \times 10^5 \ \text{Nmm}
\end{aligned}
$$

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Polar moment of inertia (J) for the coupling.

$$J = \frac{\pi(d_h^4 - d^4)}{32}$$

$$= \frac{\pi(74^4 - 37^4)}{32}$$

$$= 2759929.889 \text{mm}^4$$

Shear stress (τ) on reciprocating screw.

$$\tau = \frac{T.r}{J} = \frac{T.\left(\frac{d_h}{2}\right)}{J}$$

$$= \frac{1.112 \times 10^6 \times 37}{2759929.889}$$

$$= 14.908 \ \text{N/mm}^2$$

Step IV- Diameter of bolts

For shaft diameter less than 40mm ,the number of bolts N_b recommended are 3.

$$N_b = 3$$

Material of the bolt as C-45. Yield strength S_{yt} for this material is 380 N/mm^2. Hence permissible shear stress τ_p of the bolts is equal to $\frac{S_{yt}}{3} = 126.67 \text{N/mm}^2$.

Diameter of the bolt (d_b).

$$d_b^2 = \frac{8T}{\pi D N_b \tau_p}$$

$$= \frac{8 \times 1.112 \times 10^6}{\pi \times 111 \times 3 \times 126.67}$$

$$d_b = 8.1934 \text{mm}$$

D. Making CAD model coupling

Computer aided model of reciprocating screw is created using suitable design software CATIA V5. Dimensions are as per the design of coupling step mentioned earlier. Fig.5 refers to CAD model of coupling.

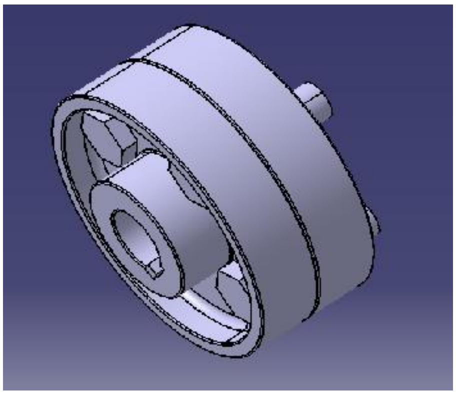

Fig. 5: CAD model of the coupling

E. Stress analysis of coupling

Stress analysis of the coupling is carried out with analysis software ANSYS 14.5. Analysis is done by using tetrahedron type meshing Torque applied to the coupling is equal to 1.112×10^5 Nmm which is based on motor power 11.1855kW available on site. Material of the coupling is considered as Mild Steel variant. Maximum stress value noted from the analysis. Fig.6 refers to stress analysis of coupling.

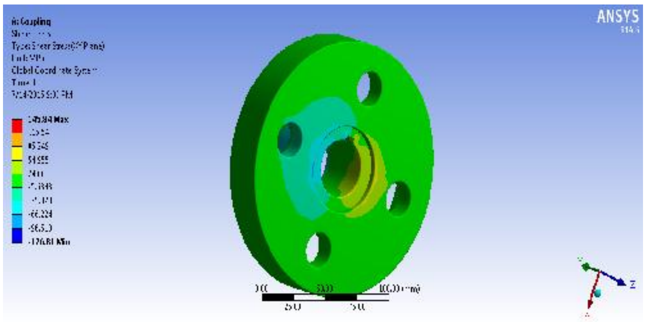

Fig. 6: Equivalent stress analysis of coupling

V. RESULT

TABLE I

Sr. No.	Part	Maximum Stress induced (MPa)
1	Screw	18.0
2	Coupling	85.2

VI. Conclusions

From the result it is clear that the stresses induced in the coupling are more when we make the coupling of weaker material than that of reciprocating screw. In case of the failure of heaters, there is large chance of breaking of the reciprocating screw. If coupling of weaker material as suggested here mounted in the system, and then it can protect the reciprocating screw which leads to avoid high wastage of time and money. Definitely this is short term solution which is applicable for the currently running machines in the plastic industry. For long term solution, the work is being done on reciprocating screw design improvement.

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