Finite Element Analysis of Reciprocating Screw for Injection Molding Machine

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Abstract

This paper deals with, the solution of problem occurred for reciprocating screw of Injection molding machine. It identifies and solves the problem by using the modeling and simulation techniques. The problem occurred in the reciprocating screw of machine which was wearing of threads due to affect of temperature of mold materials (flow materials) i.e. Nylon, low density polypropylene, polystyrene, PVC etc., The main work was to model the components of machine with dimensions, assemble those components and then simulate the whole assembly for rotation of the screw. The modeling software used is PRO-E wildfire 4.0 for modeling the machine components like body, movable platen, fixed platen, barrel, screw, nozzle, etc. The analysis software ANSYS is used to analyze the reciprocating screws. The objectives involved are:-

- To model all the components using modeling software Pro-E 4.0
- To assemble all the components of the machine in the software.
- To make the assembly run in Pro-E software.
- Analysis of screw of machine using Ansys 11.0 software.
- To identify the wearing of threads and to provide the possible solutions.

This problem is major for all industrial injection molding machines which the industries are facing and they need the permanent solution, so if the better solution is achieved then the industries will think for implementing it. The industries are having temporary solution but it will affect the life of the screw, because the stresses will be more in machined screw on lathe machine as compared to normal screw. Also if the screw will fail after some years of operation, the new screw available in the market will have the same problem. Also the cost associated with new screw and its mounting is much more as it is the main component of machine.

Key Words - Reciprocating, Wearing, FEM

Introduction

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 mould. The plastic is melted in the injection molding machine and then injected into the mold, where it cools and solidifies into the final part.

The barrel contains the mechanism for heating and injecting the material into the mould. This mechanism is usually a reciprocating screw. A reciprocating screw advance the material forward by either a hydraulic or electric motor. During this process the material is melted by heat & pressure. The material enters the grooves of the screw. The screw completes the shot volume & returns to reverse position.

The problem occurred in the reciprocating screw is of the wearing of threads due to affect of high melting temperature & pressure of mold materials. Industries are having temporary solution to make repair of threads on Lathe machine. This reduces weight & strength of screw resulting misalignment in assembly. The screw is the most crucial part of a machine. The material for the screw is EN-41B (SAE 52100), other alternate materials are EN9 (SAE1055), EN8 (SAE 1040), EN24 (SAE4340).

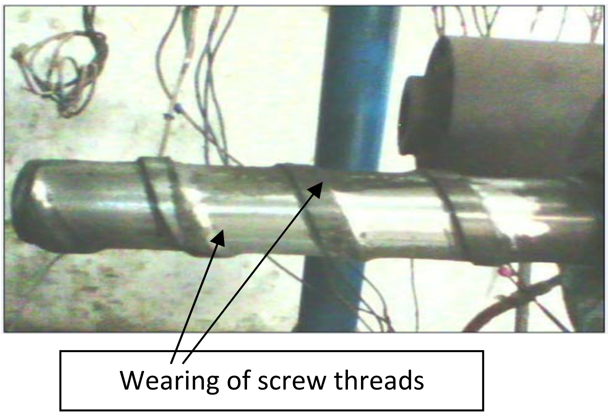


Fig. 1.1 wearing of threads of reciprocating screw

Objectives

The problem occurred in the reciprocating screw of injection molding machine, was wearing of threads. The objective of the project was to find out the cause of wearing and provide the solution. The industries have temporary solution of making threads on Lathe machine, but this will affect the strength of the screw. Other than this it will be difficult to align the screw with the motor. The objectives involved are:-

a. To model reciprocating screw using modeling Software Pro-E 4.0
b. Analysis of reciprocating screw using Ansys 11.0 software
c. To identify the wearing of threads and provide the possible solution.

Reason for selecting problem:

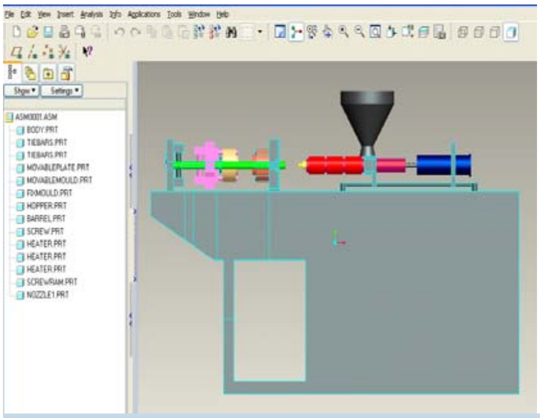
a) Problems can arise using different materials with same screw without knowing its temperature affect on screw. When the demand is more wrong material can affect the threads of screw and a major loss to the screw can occur.
b) Melt temperature control is critical to control the melt due to low quality grains causes overheating of screw.
c) The molding machine has specified for its working capacity, an excessive assigned work load causes high temperature & high pressure resulting wear and bending of screw.
d) Faulty heater cause uneven temperature distribution of molding flow over the screw causing tiger marks on the surface.
e) Materials left inside the machine gets stick to the surface of screw. The materials if not removed before starting of machine, which affect the life of screw.
f) Some grains contain lot of moisture in their chemical properties which stick to reciprocating screw causing corrosion to the screw.
g) The material used for the injection molding process must be clean and free from impurities such as metal, water and volatiles. Metal contamination to the polymer, plastic gets chocked which causes blocking of barrel.
h) The pressure flow control board has a transistor failure that causes over current flow. The temperature inside the barrel increases which affect damage of screw.

Modeling of reciprocating screw using Pro-E Wildfire 4.0:

Pro-E Wildfire 4.0 has been developed by Parametric Technology Corporation (PTC) of U.S.A. This is CAD/CAM/CAE software but we are using this for only 3-D part modeling (CAD). This CAD includes.

1. Sketcher
2. Part Modeling (part design)

3. Advanced Part Design
4. Surface Design
5. Assembly Design



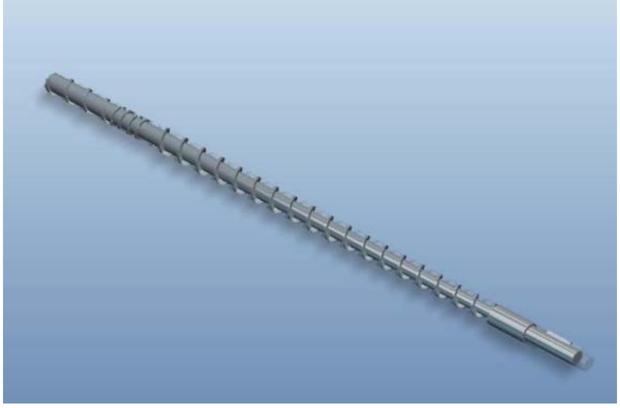


Fig 1.2 Complete Working Assembly using Pro-E   Fig 1.3 3-D model of screw using Pro-E

Need of Finite Element Method:

There are number of needs of finite element method. But we are considering some basic needs.

i) To reduce the amount of prototype testing.

ii)To simulate design that is not suitable for prototype Testing.

iii) The bottom line

iv) Cost saving.

v)Time saving.

Finite Element Analysis of screw using ANSYS 11.0 (workbench): Reciprocating screw. Model Analysis of Screw is done using following steps:-

a. Click on new simulation file.
b. Give name as EN41B (Flex. PVC).
c. Import geometry (screw. part) from folder of Pro-E files.
d. Meshing the model using the option generate mesh.
e. Select new analysis, Select static structural.
f. Apply boundary conditions.
g. Select the area for fixed support.

h. Find the total deformation for each mode by selecting solve option.
i. Find von- mises stress selecting von-mises option.
j. Find directional heat flux by selecting the option.
k. Find total heat flux by selecting the option.
l. Generate report preview.
m. Save the file.
n. In discretization the no. of nodes formed are 12992 and no of elements are 5909

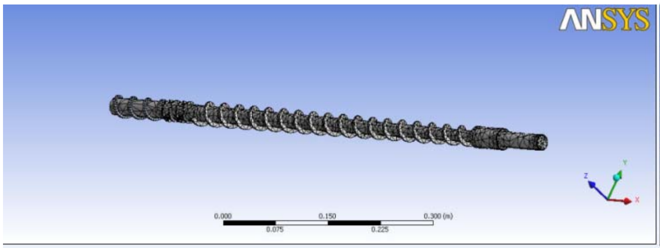


Fig 1.4 Meshed model of screw

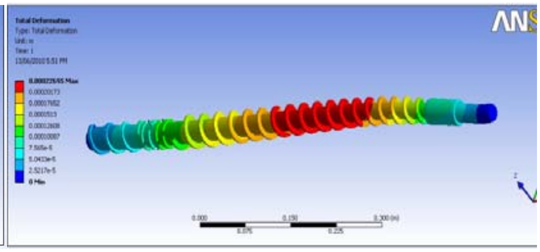


Fig 1.5 Modal Analysis of screw

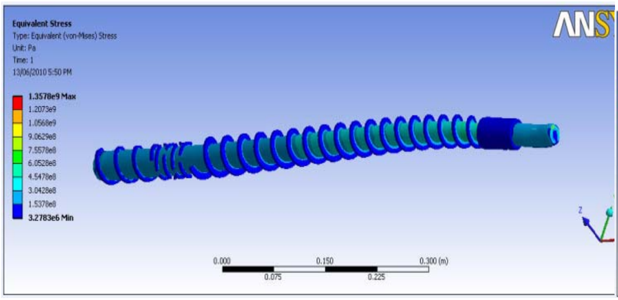


Fig 1.6 Structural Analysis of screw

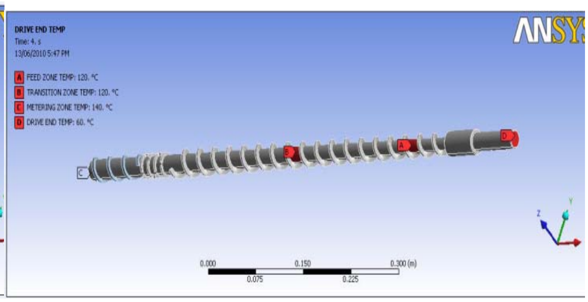


Fig 1.7 Structural Analysis of screw (Temperatures)

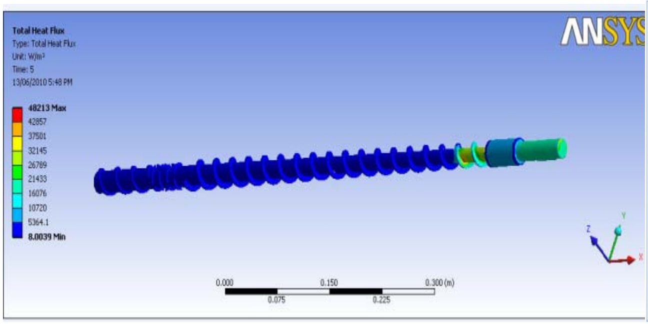


Fig 1.8 Structural Analysis of screw (Total heat flux)

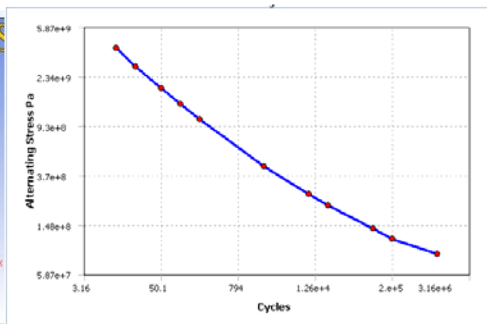


Fig 1.9 Alternating stress parameters of screw

Screw material EN41B (SAE 52100)

Property	**Nylon**	**Low density polyethylene**	**Polypropylene**	**Flexible PVC**	**Polystyrene**
Temp. °C	Min : 60 Max : 280	Min : 60. Max : 190.	Min : 60. Max : 240.	Min : 60. Max : 170.	Min : 60. Max : 230.
Therma flux W/m²	Min : 4.0093 Max : 1.0849e+005	Min : 16.002 Max :54243	Min : 8.0065 Max :84380	Min : 8.0039 Max : 48213	Min : 8.0127 Max : 66263
Directional Heat Flux W/m²	Min :29145 Max :1.0353e+005	Min :-14572 Max :51765	Min :-22667 Max :80524	Min :-12952 Max :46014	Min :-17801 Max :63272
Von-mises stress Pa	Min : 6.7294e+006 Max : 1.9885e+009	Min : 3.6393e+006 Max : 1.4309e+009	Min : 5.3559e+006 Max :1.7433e+009	Min : 3.2783e+006 Max : 1.3578e+009	Min : 4.4946e+006 Max : 1.6499e+009
Total deformation m	Min :0. Max : 4.1441e-004	Min :0. Max 2.5447e-004	Min :0. Max : 3.4539e-004	Min :0. Max : 2.2695e-004	Min :0. Max : 3.4761e-004

- Table 1.1 Results of screw material EN41B

- **Screw material EN9 (SAE 1055)**

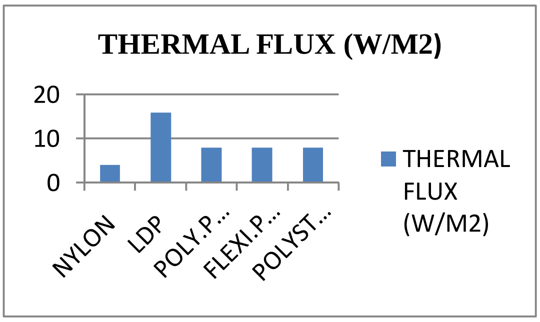
Property	**Nylon**	**Low density polyethylene**	**Polypropylene**	**Flexible PVC**	**Polystyrene**
Temp. °C	Min :60. °C Max :280. °C	Min : 60. °C Max : 190.°C	Min : 60. °C Max : 240. °C	Min : 60. °C Max : 170. °C	Min : 60. °C Max : 230. °C
Therma flux W/m²	Min : 4.0093 W/m² Max : 1.0849e+005 W/m²	Min : 16.002 W/m² Max : 54243 W/m²	Min : 8.0065 W/m² Max : 84380 W/m²	Min : 8.0039 W/m² Max : 48213 W/m²	Min : 8.0131 W/m² Max : 66263 W/m²
Directional Heat flux W/m²	Min : -29145 W/m² Max :1.0353e+005 W/m²	Min : -14572 W/m² Max : 51765 W/m²	Min : -22667 W/m² Max : 80524 W/m²	Min : -12952 W/m² Max :46014 W/m²	Min : -17801 W/m² Max : 63272 W/m²
Von-mises stress Pa	Min : 6.7294e+006 Pa Max : 1.9885e+009 Pa	Min : 2.5591e+006 Pa Max :1.2603e+009 Pa	Min : 3.607e+006 Pa Max :1.5358e+009 Pa	Min : 3.2783e+006 Pa Max : 1.3578e+009 Pa	Min : 1.128e+007 Pa Max : 1.508e+009 Pa
Total deformation m	Min : 0. m Max : 4.1441e-004 m	Min : 0. m Max : 2.3451e-004 m	Min :0. m Max : 3.1833e-004 m	Min : 0. m Max : 2.2695e-004 m	Min : 0. m Max : 3.2159e-004 m

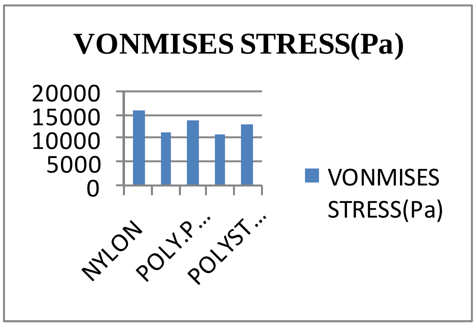
Table 1.2Results of screw material EN9

- For reciprocating screw of injection molding machine, Steady state Thermal analysis & Static structural analysis performed on screw using finite element analysis applying temp. At various points & and fixed support. The reciprocating screw material is EN41B, EN9, EN8 & EN 24.The flowing mould material is Nylon, Low density roly-poly prop, Flexible PVC & Polystyrene. The results obtained are plotted on charts.

Results plot one shaft material four mould materials.

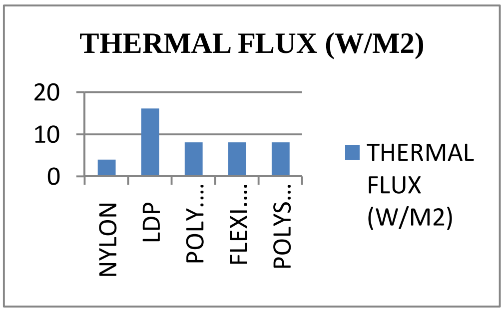
RESULTS FOR SHAFT MATERIAL (EN-41B)

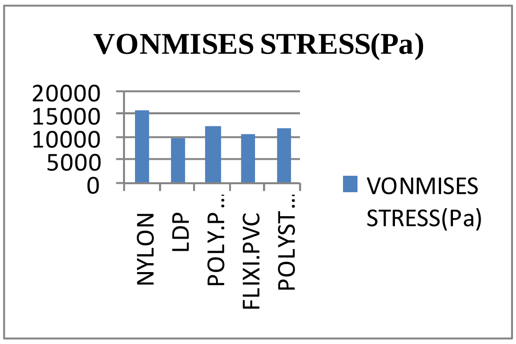




FOR SCREW MATERIAL EN-41B SUITABLE MOULD MATERIAL IS NYLON-66 & POLYPROPYLENE.

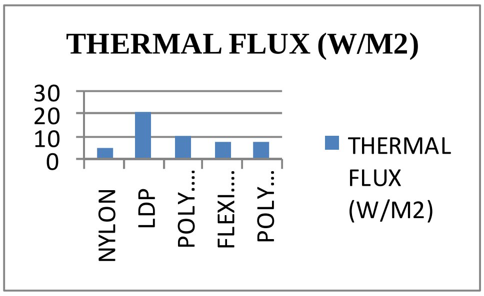
RESULTS FOR SHAFT MATERIAL (EN-9)

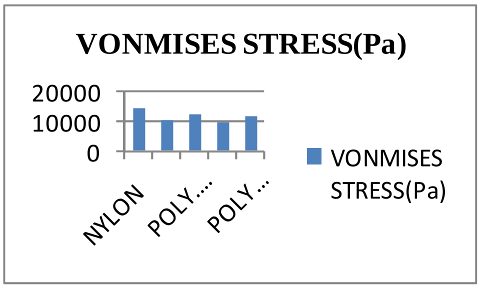




FOR SCREW MATERIAL EN-9 SUITABLE MOULD MATERIAL IS NYLON-66, POLYPROPYLENE & POLYSTYRENE.

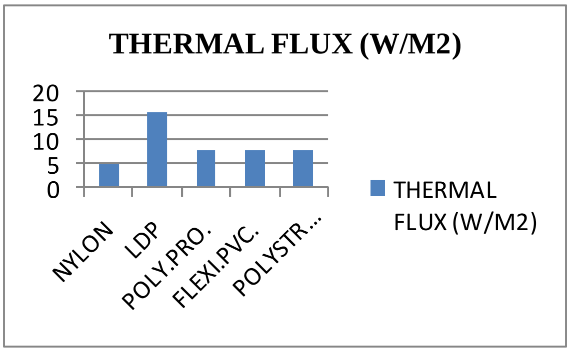
RESULTS FOR SHAFT MATERIAL (EN-8)

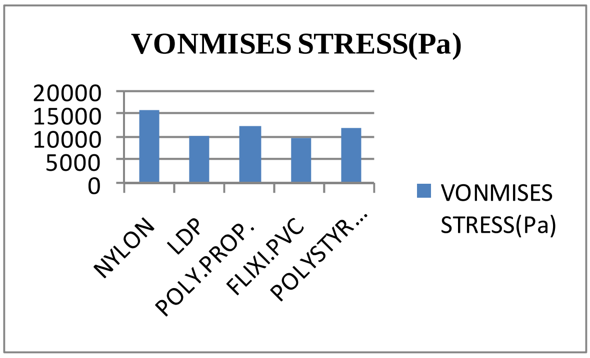




FOR SCREW MATERIAL EN-8 SUITABLE MOULD MATERIAL IS NYLON-66 & POLYSTYRENE.

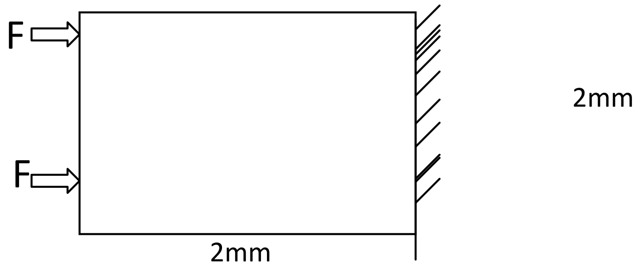
RESULTS FOR SHAFT MATERIAL (EN-24)





FOR SCREW MATERIAL EN-24 SUITABLE MOULD MATERIAL IS NYLON-66 & POLYPROPYLENE .

Finite Element Method to find the von-mises stress in the RECIPROCATING SCREW:



F = Force on screw = $\frac{AE\alpha\Delta T}{\text{Number of threads}}$

$= \frac{2x1x202x10^6x10.7x10^{-6}x\,(280-60)}{22} = 43228\text{ N}$

$= \frac{389052}{2}$

$= 22\text{ x }10^3$ KN.

ν = Poisson's ratio = 0.292

t = Thickness of element, 1 mm

Cross sectional Area = bx t =2x1= 2 mm^2

Von-Mises Stresses in Each Element= Von-Mises stress in element is given as:

$$\sigma_{VM} = \sqrt{I_1^{\,2} - 3I_2}$$

Where $I_1 = \sigma_x + \sigma_y$ = 5.703 x 10^{14}MPa

$I_2 = \sigma_x \sigma_y - \tau_{xy}^{\,2}$ = -2.98 x 10^{28} MPa

$$\sigma_{VM} = \sqrt{\left(5.703\times10^{14}\right)^2 - 3\left(-2.98\times10^{28}\right)} = 6.43\times10^{14}\ MPa\ \sigma_{VM} = 6.43\times10^{8}\ Pa$$

$$\sigma_{VM} = \sqrt{I_1^{\,2} - 3I_2}$$

Where $I_1 = \sigma_x + \sigma_y$ = 3.57×10^{14} MPa $I_2 = \sigma_x\sigma_y - \tau_{xy}^{\,2}$ =

1.77×10^{28} MPa $\sigma_{VM} = \sqrt{\left(3.57\times10^{14}\right)^2 - 3\left(1.77\times10^{28}\right)} = 2.71\times10^{14}\ MPa\ \sigma_{VM} = 2.71\times10^{8}\ Pa$

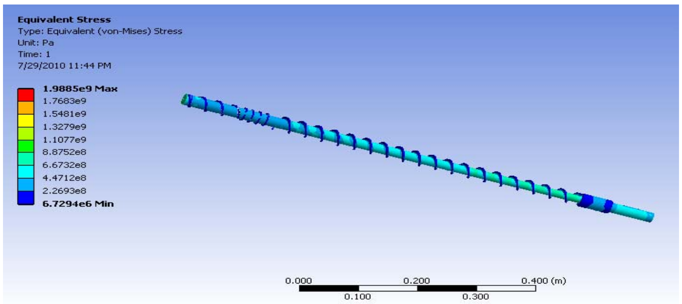


Fig 1.10 Results validation (Equivalent stress-EN9 Nylon)

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