DESIGN AND ANALYSIS OF NON-RETURN VALVE (MICROVALVE) FOR INJECTION MOLDING MACHINE WITH DIFFERENT MATERIALS USING FE BASED APPROACH

K P Chandraiah[1], Dr G R Selokar[2]
[1]Research Scholar, Dept of Mech Engg, SSSUTMS, Sehore, Bhopal (MP) India
[2]Registrar and Research Professor, Dept of Mech Engg, SSSUTMS, Sehore, Bhopal (MP) India

Abstract
Injection Molding Machine is the most commonly used manufacturing process for casting the plastic parts. The plastic granules are melted in the injection molding machine and then injected into the mold through reciprocating screw and Non-return valve (NRV). NRV is the major component in the injection molding machine which can be operated under high pressure and temperature to injected melted plastic. In the present work, NRV has been designed by using CATIA and analysis has been carried out using ANSYS. In this paper, the effect of pressure and temperature of NRV has been investigated by ensuring proper design of NRV of different materials like TZM, H13 Tool Steel and D2 Tool Steel. Static and thermal analyses have also been conducted at an operating pressure of 6 MPa and at a temperature of 220°C in order to suggest better design. The fatigue analysis has been conducted to estimate the life of the component (NRV). The outcome of the FE analyses suggests that the NRV of TZM and H13 Tool Steel materials offers better strength, thermal resistance and better life compared to D2 Tool Steel material.
Index Terms: NRV, Ansys, Fatigue, TZM.

I. INTRODUCTION

The 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 and NRV. A reciprocating screw and NRV 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 through NRV. The screw and NRV completes the shot volume & returns to reverse position. The problem occurred in the NRV 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 NRV resulting misalignment in assembly. The NRV is the most crucial part of a machine.
The manufacturing process of injection molding is a primary form of manufacturing of plastic products in the world today. The demands of high molded part tolerances, dimensional stability, and shot-to-shot repeatability are increasing and better controls and mechanical components of the injection machines are required to meet the demands. A major component that contributes to this process of improvement is the plasticizing unit and

specifically, the non-return valve which is one of the components of the assembly.

The non-return valve controls the volume of molten plastic material that is injected into the mold. Any imperfection in the operation of this component is reflected in the molded part. Imperfect molded parts cost the industry billions of dollars per year. An improvement in the non-return valve is needed to eliminate imperfect molded parts.

THE VALVE EXPERIMENT

The basic functions of Good Non-Return Valve are:

- To allow plastic to flow through it, not over it, during screw rotation to develop the required shot size for the part. There should be no dead spots for the plastic to accumulate or get hung up, and the flow path for the polymer should have minimum pressure drop and no shear stress due to sharp corners.
- To provide a nearly perfect seal so that upon injection this valve slides shut and acts like the plunger in a syringe to push plastic forward into the sprue, runner, gate, and cavity—not allowing any melt to slip back into the screw during injection, pack, or hold. We want it to seal under pressures up to 40,000 or 50,000 or even 60,000 psi.
- To seal instantly, or as quickly as possible, at the start of injection. Most of all, it should do so repeatedly.
- To do the above without excessive wear on the barrel inside diameter. It is possible for a non-return valve to work properly but still not hold a cushion due to wear on the inside diameter of the barrel.
- To last at least six months to a year under normal use, understanding that some abrasive resins or filler will influence functional life.

II. LITERATURE SURVEY

R. H. Huang et al., "The Effect of Non-Return Valve on Micro Injection Molding Machine". In this paper the micro injection molding machine (MIMM) is used to produce precision plastic products. The non-return valve (NRV) on the screw head of injection machine plays the role of preventing the melt back discharge during injection process. The sensitivity of non-return valves opening and closing affects the quality of the product. In this paper, numerical simulation of three-dimensional flow field is generalized by the Newtonian isothermal fluid method. Then, five kinds of different structural parameters of NRV are designed, and the pressure field, the pressure difference is simulated by the Polyflow software. At last, the pressure field, and the pressure difference on both side of NRV are analyzed and compared. The best structure parameter of NRV is decided. The simulation results are useful for the NRV design [1]. Most injection screws have a non-return valve (NRV) at the end of the screw to prevent the molten plastic flowing back into the screw during injection. It is possible to incorporate mixing capability into the NRV to combine two functions within one device. Since the NRV is short, there is little room available to incorporate mixing capability into the NRV. The slide ring NRV is the most suitable with respect to adding mixing capability[2]. Vikas .R.R .et .al., has done FEA of Reciprocating Screw for injection molding machine (IMM).In this paper, the study deals with the problem occurred in Reciprocating Screw of IMM, in which the paper identifies and solves the problem using FEA and it has been identified the problem occurred in the thread due to the effect of temperature of mould material. Finally this paper concluded that steel grade SAE4040 is the most suitable material for the reciprocating screw which exhibits the minimum heat flux generated while processing [3,4]. Sanjay Rao et al., has done the design and analysis of Hot Runner Nozzle using FEM. In this paper the investigation reveals that, the effect of material, pressure, temperature of Hot Runner Nozzle and ensures proper nozzle design. In this paper the effect of pressure is simulated on NRV. The effect of pressure on both sides is analyzed and compared [5, 6].

CONCLUSION OF LITERATURE REVIEW:

On the basis of this extensive literature survey, the problem occurred in the rotating screw and Non-Return Valve was the wearing of threads due to high melting temperature and pressure of mould materials. The NRV in the most crucial part of an injection molding machine. The wear rate on the NRV of untreated steel, chrome plated steel, and SAE 4040 increases as the temperature rises but the wear rate of the nitride steel was effectively constant, but some glass filled material having problem that is wear is takes place on the NRV in plastic injection molding machine.

The present investigation is aimed at selecting a suitable material for Non Return Valve. As some of the properties of the materials such as Titanium Zirconium Molybdenum (TZM), H13 and D2 steel material are matching the requirements of the NRV, these materials have been selected as the candidate materials for Non Return Materials.

III. OBJECTIVES AND METHODOLOGY

The following are the Objectives and Methodology of the Project:

1. To study the design of existing NRV.
2. Identifying the problem in the NRV.
3. Selection of proper material
4. To analyze the strength, thermal stability and life of the different material (TZM/D2/H13TS).
5. Generating the 3D Model of NRV using CATIA.
6. Generating the Meshing using HYPERMESH.
7. Generating the FE results using ANSYS.
8. Optimization of material
9. Validation of the results

IV. MATERIAL PROPERTIES

Material	Young's Modulus (Mpa)	Poisson's Ratio	Thermal Expansion Co-ef (M/M-K)
TZM	315	0.32	5.3×10-6
H13 TS	206.8	0.32	10.4×10-8
D2 TS	190	0.32	10.4×10-6

V. RESULTS AND DISCUSSIONS

CAD Model of Non-return valve

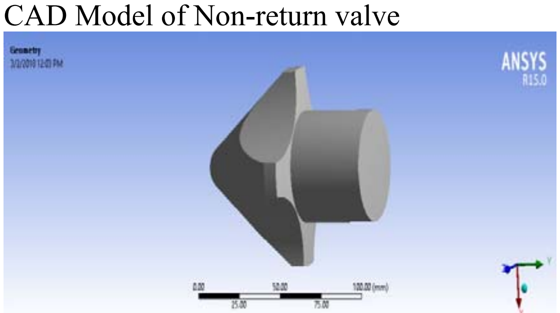

Fig 1: CAD Model

Above fig1 shows the CAD model of NRV

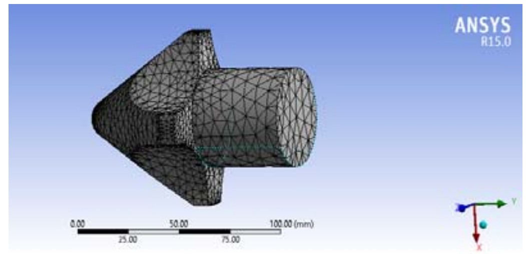

Fig2: FE Model

Above fig 2 shows the Finite Element Model of NRV

ANALYSIS OF NRV FOR TZM MATERIAL

STATIC STRUCTURAL ANALYSIS

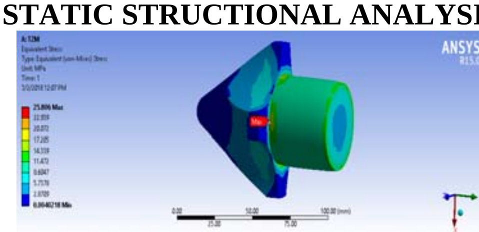

Fig 3: von-mises stress plot of TZM

Above figure shows the von-mises stress plot of TZM material which is having Max Stress=25.8 MPa

DEFORMATION PLOT

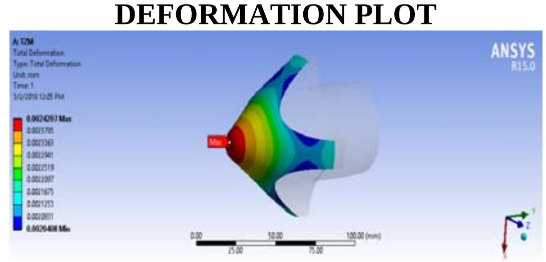

Fig: Deformation plot of TZM

Above figure shows the deformation plot of TZM material which is having Max Deformation = 0.00242 mm

FATIGUE ANALYSIS OF TZM MATERIAL

Fatigue test has been conducted to evaluate life of the component in terms of number of life cycles.

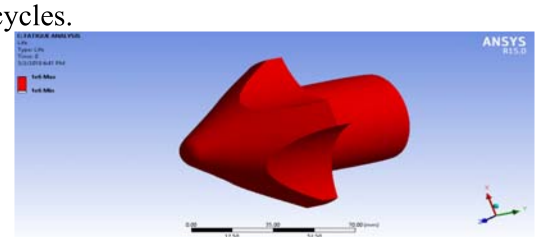

Fig: Fatigue test plot of TZM

Above fig shows the plot of fatigue test and it is estimated that the component of TZM material can serve 106 Cycles.

THERMAL ANALYSIS OF TZM MATERIAL

DEFORMATION DUE TO TEMPERATURE RISE AT 220°C

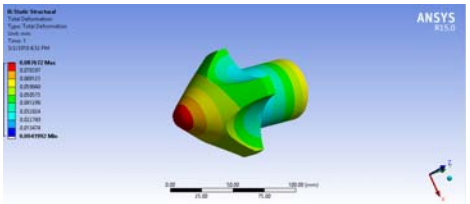

Fig: Deformation plot of TZM due to temp rise

Above fig shows the maximum deformation plot for temperature rise in component of 220°C and it is estimated that the maximum deformation as 0.0876mm

STRESSES DUE TO TEMPERATURE RISE AT 220°C

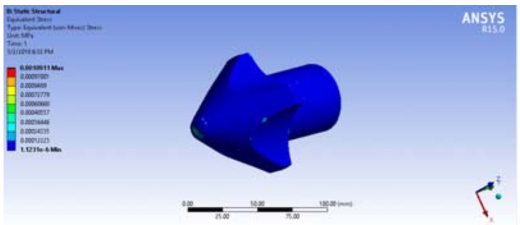

Fig: Stress plot of TZM due to temp rise

Above fig shows the maximum stress plot for temperature rise in component of 220°C and it is estimated that the maximum stress as 1.09×10-3 MPa.

ANALYSIS OF NRV FOR H13 TOOL STEEL MATERIAL

STATIC STRUCTIONAL ANALYSIS

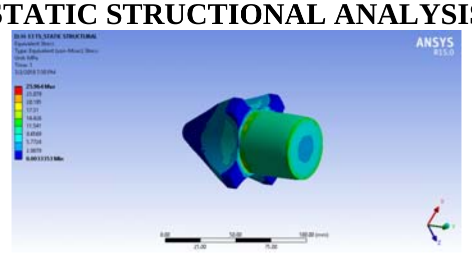

Fig: von-mises stress plot of H-13 Tool Steel

Above figure shows the von-mises stress plot of H-13 Tool Steel material which is having Max Stress=25.9 MPa

DEFORMATION PLOT

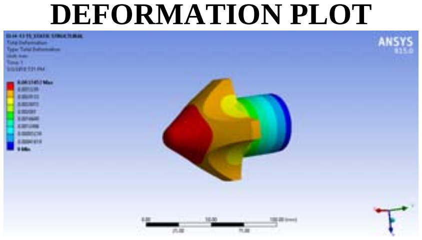

Fig: deformation plot of H-13 Tool Steel

Above figure shows the deformation plot of H-13 Tool Steel material which is having Max Deformation as 0.00374 mm.

FATIGUE ANALYSIS

Fatigue test has been conducted to evaluate life of the component in terms of number of life cycles.

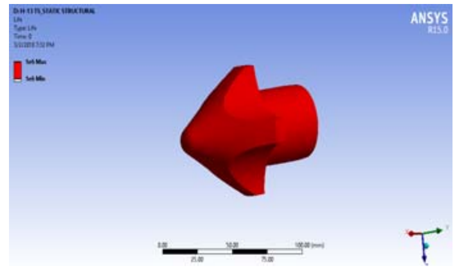

Fig: Fatigue test plot of H-13 Tool Steel

Above fig shows the plot of fatigue test and it is estimated that the component of H-13 Tool Steel material can serve 106 Cycles.

THERMAL ANALYSIS

DEFORMATION DUE TO TEMPERATURE RISE AT 220°C

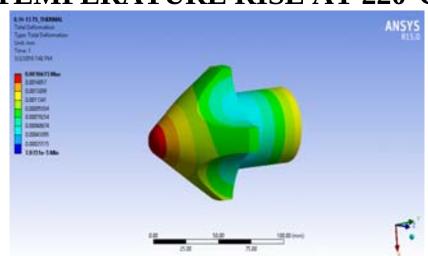

Fig: Deformation plot of H-13 Tool Steel due to temp rise

Above fig shows the maximum deformation plot for temperature rise in component of 220°C and it is estimated that the maximum deformation as 0.00166 mm

STRESSES DUE TO TEMPERATURE RISE AT 220°C

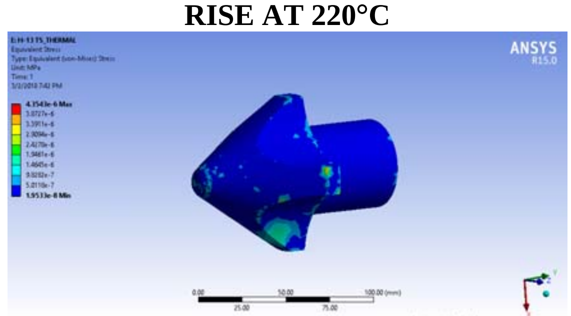

Fig: Stress plot of H-13 Tool Steel due to temp rise

Above fig shows the maximum stress plot for temperature rise in component of 220°C and it is estimated that the maximum stress as 4.34×10-6 MPa.

ANALYSIS OF NRV FOR D2 TOOL STEEL MATERIAL

STATIC STRUCTIONAL ANALYSIS

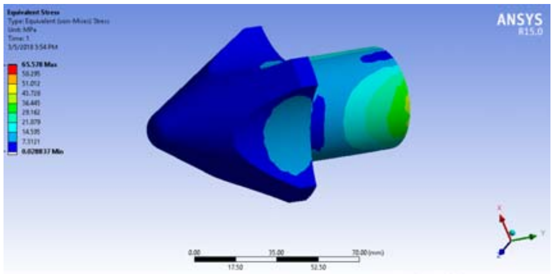

Fig: von-mises stress plot of D-2 Tool Steel

Above figure shows the von-mises stress plot of D-2 Tool Steel material which is having Max Stress=65.5 MPa

DEFORMATION PLOT

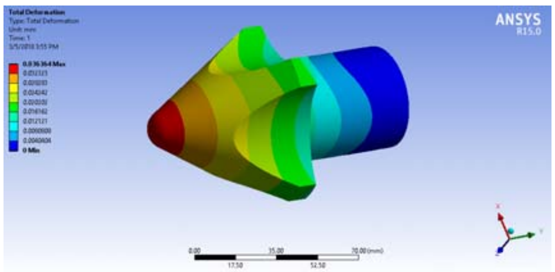

Fig: deformation plot of D-2 Tool Steel

Above figure shows the deformation plot of D-2 Tool Steel material which is having Max Deformation as 0.0363 mm.

FATIGUE ANALYSIS

Fatigue test has been conducted to evaluate life of the component in terms of number of life cycles.

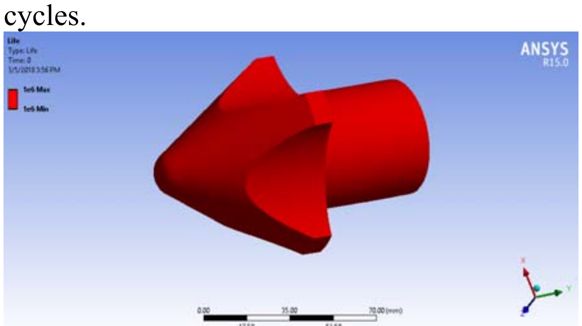

Fig: Fatigue test plot of D-2 Tool Steel

Above fig shows the plot of fatigue test and it is estimated that the component of D-2 Tool Steel material can serve 106 Cycles.

THERMAL ANALYSIS DEFORMATION DUE TO TEMPERATURE RISE AT 220°C

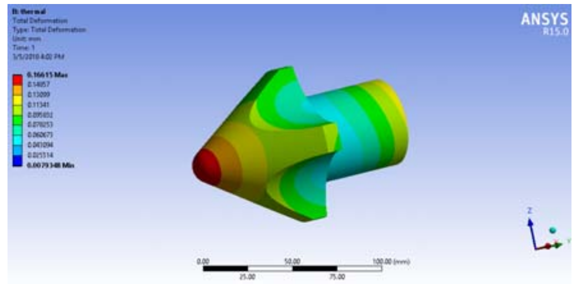

Fig: Deformation plot of D-2 Tool Steel due to temp rise

Above fig shows the maximum deformation plot for temperature rise in component of 220°C and it is estimated that the maximum deformation as 0.1661 mm.

STRESSES DUE TO TEMPERATURE RISE AT 220°C

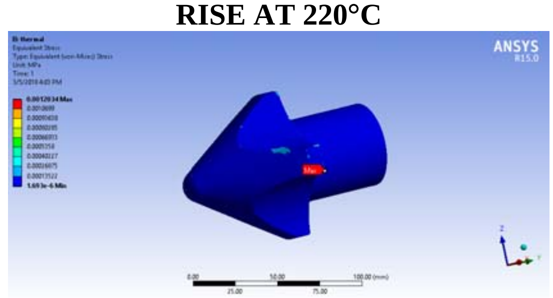

Fig: Stress plot of D-2 Tool Steel due to temp rise

Above fig shows the maximum stress plot for temperature rise in component of 220°C and it is estimated that the maximum stress as 1.2×10-2 MPa.

RESULTS OF STATIC AND FATIGUE ANALYSIS OF NON-RETURN VALVE (NRV)

Sl. No	Material	Max. Deformation (Mm)	Von-Mises Stress (Mpa)	No. Life Cycles
1	TZM	0.00242	25.8	106
2	H-13 TOOL STEEL	0.00374	25.9	106
3	D-2 TOOL STEEL	0.0363	65.5	106

RESULTS OF THERMAL ANALYSIS OF NON-RETURN VALVE (NRV)

Sl. No.	Material	Operating Temp (°C)	Max. Deformation (Mm)	Von-Mises Stress (Mpa)
1	TZM	220	0.0876	1.09×10-3
2	H-13 TOOL STEEL	220	0.00166	4.34×10-6
3	D-2 TOOL STEEL	220	0.1661	1.2×10-2

CONCLUSION

The study of static structural, fatigue test and thermal analysis of non-return valve of injection molding of different materials has been successfully executed. As per the above all analysis the following conclusions can be made:

1. The stresses and deformation is maximum in the material D-2 Tool Steel of 65.5 MPa and 0.0360 mm respectively than other two materials.
2. The stresses and deformation is minimum in the TZM and H-13 Tool Steel compared to D-2 Tool Steel material.
3. According to fatigue test it can be noted that the component can operate 106 Number of cycles.
4. Due to rise in temperature of 220°C in the component it can be noted that there is a maximum deformation in the D-2 Tool Steel material as compared to other two materials.
5. Finally it can be concluded that the TZM and H-13 tool steel can be used in the injection molding for better performance and for better life.

A. References

1. R. H. Huang et al., "The Effect of Non-Return Valve on Micro Injection Molding Machine", Advanced Materials Research, Vols. 753-755, pp. 1495-1498, 2013
2. Dr. Chris Rauwendaal, Rauwendaal Extrusion Engineering, Inc. Los Altos Hills, California 94022 – USA " Non-Return Value with Distrubutive and Dispersive Mixing Capability".
3. Vikas.R.Rajoria , Prof.P.K.Jadhao, "Finite Element Analysis Of Reciprocating Screw For Injection Moulding Machine" International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 7, July 2013
4. Mr.Venugopal P. Kulkarni1, Mr. Shailesh Pimpale, Mr. Baig Zakeer, "Finite Element Analysis and Validation of Reciprocating Screw and Coupling of Injection molding machine" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X.
5. P.Sanjay Rao, D.V.Subba Rao, "Design and Analysis of Hot Runner Nozzle Using Fem" International Journal of Mechanical and Industrial Technology ISSN 2348-7593 (Online) Vol. 3, Issue 1, pp: (228-241), Month: April 2015 - September 2015.
6. D.Frenkler, H. Zawistowski, "Hot Runners in Injection Moulds", Rapra publishers, Shawbury 1998, p.267.
7. Spina R. Injection moulding of automotive components: comparison between hot runner systems for a case study.J. Mat. Process. Tech. 155-156 (2004) 1497-1504.
8. Tang SH, Kong YM, Sapuan SM, Samin R and Sulaiman S. Design and thermal analysis of plastic injection mould.J. Mat. Process. Tech. 171(2) (2006) 259-267.
9. F. P. Incropera and D. P. DeWitt, ―Introduction to Heat Transfer‖, John Wiley & Sons Inc, 1996.
10. T. A. Osswald, L Turng and P. J. Gramann, Injection Molding Handbook, 2nd Ed., Hanser Gardner Publications, 2007.
11. Kapoor, D., Multi Cavity Melt Control in Injection Molding, M. S. Thesis, Submitted to the University of Massachusetts, Amherst, December 1997.
12. KegelanguB, SchirmanguB, RinganguB, BandanuB. Technical Information, 4.2.1, BASF, Ludwigshafen/Rh., 1969.

13. SpritzgieBen von Thermoplasten. Publication, Farbwerke Hoechst AG, Frankfurt/M., 1971.
14. Sowa, H.: Wirtschaftlicher fertigen durch verbesserte AnguBsysteme. Plastverarbeiter, 29 (1978), 11, pp. 587-590.
15. Kohlhepp, K. G.; Mohnberg, J.: SpritzgieBen von Formteilen hoher Prazision, dargestellt am Beispiel von Polyacetal, Kunstsoff-Berater, 10 (1974), pp 577-584.
16. Crastin-Sortiment, Eigenschaften, Verarbeitung, Publication, Ciba-Geigy, Basel, August 1977.
17. Christoffers, K.E.: Formteilgestaltung, verarbeitungsgerecht. Das SpritzguBteil. VDI-Verlag, Dusseldorf, 1980.
18. Tunnelangub, AbreiB-Punkt-AnguB, Technical Information, 4.2.3, BASF, Ludwigs-hafen/Rh., 1969.
19. Thonemann, O. E.: AnguBund Anschnitt-Technik furdie wirtschaftliche Herstellung von SpritzguBteilen aus Makrolon. Plastverarbeiter, 14 (1963), 9, pp. 509-524.