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Design and Analysis of Hot Runner Nozzle Using Fem

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***Abstract*: A hot runner system is an assembly of heated components used in plastic injection molds that inject molten plastic into the cavities of the mold. By contrast, a cold runner is simply a channel formed between the two halves of the mold, for the purpose of carrying plastic from the injection molding machine nozzle to the cavities. Each time the mold opens to eject the newly formed plastic parts; the material in the runner is ejected as well, resulting in waste. A hot runner system usually includes a heated manifold and a number of heated nozzles. The main task of the manifold is to distribute the plastic entering the mold to the various nozzles which then meter it precisely to the injection points in the cavities. Hot runner technology is continuing to experience a phase of intensive development brought about by the increasing demands of the plastics processing industry. This industry is faced with a need to meet the following requirements. In this thesis, the effect of material, pressure, temperature on hot runner nozzle assembly is investigated by ensuring proper nozzle design. Hot runner nozzle design considerations are calculated theoretically and Model led in 3D. The 3D Model is then tested for deformation & stresses using Finite Element Analysis. Furthermore, DFMEA is done to check for failures in design of hot runner nozzle. A complete study on pin point gate type hot runner nozzle is done to reduce the cost, leakage due to wear between parts and to determine the stress analysis due to injection pressure.**

***Keywords: Hot Runner* Nozzle, Hot runner technology, Material degradation, Temperature control, Flow imbalance.**

I. INTRODUCTION

A hot runner system is an assembly of heated components used in plastic injection molds that inject molten plastic into the cavities of the mold. (The cavities are the part of the mold shaped like the parts to be produced.) By contrast, a cold runner is simply a channel formed between the two halves of the mold, for the purpose of carrying plastic from the injection molding machine nozzle to the cavities. Each time the mold opens to eject the newly formed plastic parts, the material in the runner is ejected as well, resulting in waste. A hot runner system usually includes a heated manifold and a number of heated nozzles. The main task of the manifold is to distribute the plastic entering the mold to the various nozzles which then meter it precisely to the injection points in the cavities. Hot runners usually make the mold more expensive to manufacture and run, but allow savings by reducing plastic waste and by reducing the cycle time. (do not have to wait until the conventional runners freeze).The function of hot runner nozzle is to keep the plastic melt in injection sprue in a stable temperature,so the plastic parts will be molded without sprue and have a bright surface.

Hot runner systems were first developed and came into sporadic use in the early 60s with generally negative results. They gained popularity in the 80s and 90s as technological advantages allowed improved reliability and the escalation of plastic materials prices made hot runner systems more desirable and cost effective. Hot runners are fairly complicated systems, they have to maintain the plastic material within them heated uniformly, while the rest of the injection mold is being cooled in order to solidify the product quickly. For this reason they are usually assembled from components premanufactured by specialized companies.

II. LITERATURE

Many Hot runner unit mould which contains a heated runner manifold block within its structure. The block suitably insulate from the rest of the mould, is maintained at a closely controlled elevated temperature to keep the runner permanently as a melt. The polymer material can thereby be directed to the mould extremities without loss of heat and without the pressure loss associated with the temperature variations.

[1] According to Harold Godwin, Mold Making Technology - Competitiveness and price pressure in the injection molding industry has influenced many OEM's, molders and mold manufacturers to look for new ways to survive and thrive in their regional and global markets. At the same time, the basic operational costs related to resin, energy, manpower and overhead continue to creep up year-after-year, putting more strain on profitability. These combined factors make hot runners a more attractive solution compared to cold runners than ever before. The purpose of the hot-runner unit is to provide, a flow path for the polymer melt from the injection machine's nozzle to the entry point (sprue or gate) in the cavity plate. The polymer material in the flow-way must be kept at an elevated temperature so that it remains in the melt condition during its passage to the impression. For medium and large molded part volumes, the choice to use a hot runner has been obvious. But once the volumes became smaller and the molding application became more challenging, the hot runner versus cold runner decision became more difficult. To make a fair, unbiased value-based economic assessment, one needs to look at the total cost—assessing both capital and operational cost factors for both the hot and cold runner options. (An alternative to the traditional method of justifying the tool purchase is an electronic hot runner justification tool). For instance, injection molding cycle times are typically driven by the cooling time of the thickest section of the part or the runner. In the case of a hot runner, there is no runner to be cooled, so the maximum wall thickness in the molded part is the key influencing factor. However, in the case of cold runners, the runner sizes are typically larger than the maximum part thickness, so the cycle time is lengthened accordingly. The molding cycles with cold runners can typically be 50 to 100 percent longer than hot runners depending on the size of the runner and the part being molded. These extended cycle times result in an increased piece part cost due to the higher accrual of overheads, manpower and capital costs. Further affecting the economics are the higher resin and energy costs from molding with cold runners. To help manage resin costs, the scrap cold runners are usually ground and blended back into the molded parts. Practical regrind limits are 15 percent with the remaining scrap runners being sold for pennies per pound or being sent to the landfill. Beyond the resin cost, there is also additional energy dollars spent on drying, heating, cooling and regrinding the wasted cold runners. These combined economic factors can easily result in the piece part cost from a cold runner being more than twice the cost of the same part made with a hot runner. So from an economic total cost perspective, it is quickly evident that the lower hot runner operational costs can quickly overcome the associated higher capital cost, making hot runners the more attractive choice compared to a cold runner. Beyond the cost perspective, the resulting higher productivity yields for hot runners will speed the ability for molders to earn profits sooner, and free up injection press time for other production runs.

Molded Part Performance:

Cold runners typically generate more shear in the molten resin causing imbalance and higher fill pressures. The extra shear in the resin from molding with cold runners can cause undesirable effects in the molded part, affecting part strength, hinge performance and gate quality. These higher pressures create a greater chance for mold core shift on long cores, resulting in part weight and wall thickness variations. These variations can lead to downstream molded part failures and product liabilities. Higher fill pressures attributable to cold runners can also create more wear and tear on the injection molding machine with maintenance implications and higher energy consumption rates. During prototyping, by using a single cavity hot runner tool more representative part performance characteristics and cycle time expectations will be achieved.

Hot Runner Technology:

Advances in hot runner technology have expanded the range of possible applications from micro-sized nozzles for inside gating and tight pitch applications, to the other end of the spectrum of very large automotive parts and shipping containers. And unlike cold-runners of the past, hot runners are ideally suited to shear sensitive resins.

Further optimizations in flow and thermal characteristics allow for more balanced fill and faster injection fill rates. Additional developments in hot runner technology include more sophisticated multi-material applications for many personal care applications, as well as reliable edge gating technology that is favorable for long, thin, medical syringe-type applications.

[2] According to Sal Benenati, Mold Making Technology - Hot runner systems are such a common part of injection molds that hot runner suppliers must adjust component designs in order to meet increasingly stringent requirements in performance and materials, often adding to system complexity. For instance, some designs use stepping motors to operate valve gates, others use special heaters, and still others require special tolerances in the mold for it to function properly. When selecting a hot runner system, however, keep in mind that, oftentimes, with each increase in complexity or sophistication, comes a decrease in utility that is not always obvious. As you evaluate options for an appropriate hot runner system for your next job, consider every feature's positive and negative aspects, and then carefully determine if the benefits outweigh the drawbacks.

For example, a special nozzle heater may be a good solution for stabilizing the nozzle's heat profile (which otherwise may not work well with sensitive resins), but you also may face restricted availability, high cost, durability challenges, and difficult heater replacement. With a little investigation, you'd find out that the clearance between the nozzle body and the heater is prone to oxidation, which bonds the heater to the nozzle body and makes removal without damage almost impossible. If the chosen nozzle is the only type that will work with the required resin, the use of a special heater may be justified. However, if other nozzles fit the available mold space and can do the job without employing a special heater, and then exposure to the drawbacks of such a heater would be unjustified. The question is, how can one know about potential problems before they occur? The design looks sleek, the product data is appealing, and the manufacturing methods and materials used seem high-tech and sophisticated Hot Runner Design Evaluation One way to avoid potential problems is to evaluate the design of a hot runner system in a critical but constructive way. Here are three basic hot runner design considerations:

1. Purity. Although innovation in design is very important, you need to consider its positive and negative effects on your specific application. A good rule of thumb is to keep it simple and direct. For example, use a direct approach to keep the manifold and nozzles at the desired temperature, and the plastic material flowing evenly. Over-simplified or over-designed system features could be signs of potential problems. The system's design should have everything it needs and nothing more. Let's take a closer look at the use of exotic materials in hot runner component design. For example, nozzle tip shut-off rings made of titanium. At the design stage, titanium's high strength and low heat-transfer rate may make it more desirable for the component than tool or stainless steel. However, the fact that titanium facilitates steam condensation might be overlooked. Moisture (due to weather or mold-cooling temperatures) can get into the manifold housing and condense around the tip's shut-off area, remaining there at temperatures close to boiling point. Rust and corrosion can then develop within the highly precise fit area, and if the mold cavity is not made of stainless, the plastic can start to seep into the manifold-retaining cavity.

2. Practicality. The hot runner system should be easy to assemble into the molds without requiring special tolerances or tools. It should be responsive to the controls and able to maintain a stable processing temperature window that is close to the resin manufacturer's specifications without using special controls or critical settings. You can find tolerance requirements in the manufacturer's system specifications or literature, but you also need to ensure that there are no tolerance restrictions in nozzle lengths. In addition, some systems shut off at the front of the nozzles, which means that the nozzles must be kept at a precise temperature while in operation. If they become overheated, they can expand enough to damage the cavity or system. While the main objective is always system performance, the hot runner design should also help reduce the probability of a system failure.

III. OVERVIEW OF HOT RUNNER NOZZLES

Hot-runner nozzles are designed to inject and to distribute molten polymer to a number of cavities which give the later plastic component its shape. More cavities improve productivity but also mean more material which has to be melted to required viscosity. Some high performance polymers need fairly high temperatures to ensure proper viscosity. Therefore high temperatures within the nozzle are desired but heat dissipation to the surrounding housing should be as low as possible. These requirements can be realized by combining materials with different heat conductivity. Vacuum brazing enables to design a sophisticated hot-runner nozzle made of a high-conductive copper alloy, an isolating titanium alloy and wear resistant hot-work steel.

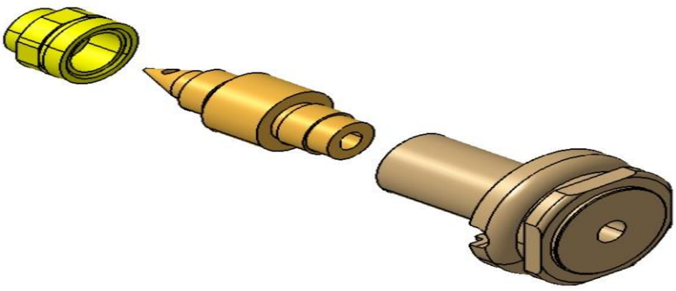

Figure: 1 Exploded view of hot runner nozzle system.

Hot runner nozzle design:

The function of hot runner nozzle is to keep the plastic melt in injection sprue in a stable temperature,so the plastic parts will be molded without sprue and have a brightly surface.We introduce hot runner nozzle design in this paper. Hot runner nozzle can be divided into open nozzle and close nozzle.In addition,there are many kind of hot runner nozzle gate,such as rectangular edge gate,round edge gate,overlap gate,fan gate,tab gate,diaphragm gate,ring gate,film gate,pin gate,subsurface gate,winkle gate.Hot runner nozzle design and gate design depend on the products. Hot runner nozzle tip design is the key to hot runner nozzle design. Pin point gate is a common gate in hot runner. Because pin point gate nozzle can cut-off itself and the plastic parts can cool down quickly.

Hot runner nozzle design principle:

(1) It should suit and can be settled on the fixed plate.

(2) Heat control: It must keep the plastic in melting, and reduce the heat lose as much as possible.

(3) Pay attention to the seal: Leakage should be avoided between the nozzle tip and core.

(4) It should easy to be maintained when the heater coil broken.

(5) Easy to be processed.

Hot tip nozzle also called pin point gate nozzle. Hot tip nozzle is open gate nozzle in hot runner system. Hot runner nozzle can be divided into open gate nozzle and close gate nozzle. Open gate nozzle has two types, hot tip nozzle and large gate nozzle.

IV. NOZZLE DESIGN

There are many factors to consider when designing a nozzle. Plastic injection molding is a process used for the manufacture of plastic products. Liquid plastic is transported through a hot runner. This plastic is injected into a mold through the hot runner. Many plastics require an extremely precise processing temperature. If the temperature is slightly too warm, the material may be damaged. If the temperature falls too sharply, the plastic hardens and no longer flows optimally into the mold. Heat transfer in the hot runner nozzle is therefore essential. To keep the plastic at the right temperature, the nozzle is externally heated using heating coils. Only at the very end - in the so-called nozzle tip - is no further heating equipment used. The heated nozzle itself must transfer the heat to the plastic. Consequently, the thermal conductivity of the material is crucial.

Optimization of a mold design with a hot runner system can be done with CAE (computer aided engineering) simulations. Similar to performing a mold flow analysis on a plastic part to enhance its design for injection molding, the same can be done with a FEA (finite element analysis) of a hot runner system. The results of this analysis, used in conjunction with a hot runner system that can take advantage of those results, will help you finalize the best design for your mold. As previously mentioned, performing a FEA of a hot runner system is similar to running a mold flow simulation on an injection molded part. Instead of simulating the flow in the part, the flow in the hot runner system will be simulated.

First, the initial design of the hot runner system is needed. The design needs to show the number of drops needed, the approximate nozzle locations in the mold and approximate part weight(s). As with any FEA, a CAE model must be generated that represents the hot half design. The flow sizing and distances can be later adjusted based on initial results.

Since this is a FEA of the hot runner system, the plastic parts are simply represented for the analysis. The FEA of the hot runner system should be used in combination with data attained by a part mold flow analysis for more accurate results.

Next, the material properties are chosen from a materials database for the analysis. The final step is inputting the molding parameters that will be used on the tool: mold temperature, melt temperature and holding pressure. With this information in place, the FEA can now be performed.

Nozzle design calculation:

Input parameters

- Nozzle operating temperature - 220°C
- Mould operating temperature - 40°C
- Gate land - 0.2 mm
- Tip offset distance - 0.2 mm

Nozzle Length at Operating Temperature:

- Actual Nozzle Length cold - 50.000 mm
- Nozzle Expansion @ 220°C - +0.145 mm
- Nozzle Length @ 220°C - 50.145 mm

Note: The expansion rate used is unique to every nozzle lengths & tip configuration is only be used for the nozzle listed.

Mold Expansion at Operating Temperature:

Mold Expansion @ 40°C - 0.013 mm

Required Nozzle Cavity Depth:

Nozzle Length @ 220°C	-	50.145 mm
Mold Expansion @ 40°C	-	-0.013 mm
Tip offset distance	-	0.2 mm
		50.332 mm

Seating face for nozzle

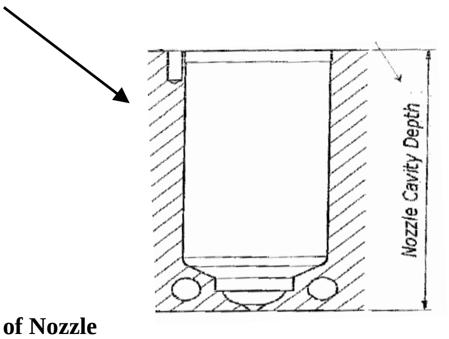

Figure 2: Block diagram of Nozzle

Deformation & Thermal stress calculations:

Formulas

Deformation acting on the Nozzle can be calculated using the following equations:

$$\sigma = \varepsilon . E$$

$$\sigma = \Delta l . E/L$$

where,

ε (epsilon) = strain (%), E = Young's modulus of the material (MPa or kgf/mm^2)., In the case of Copper E = 130 GPa, for TZM E = 315 GPa. , Δl (delta) = Amount of thermal expansion of length (mm)., L = Overall length of the Nozzle (mm).

Here, Δl can be calculated as follows.

Deformation: $\Delta l = \alpha . \Delta T . L$

where,

α (alpha) : Linear thermal expansion coefficient of the Nozzle material (m/m-K).

In the case of Copper, α is about 17×10^{-6} m/m-K & TZM, α is about 5.3×10^{-6} m/m-K.

ΔT: Temperature change (Outer surface temperature of Nozzle to the inner surface temperature of the Nozzle (°C)).

Heat Flux (thermal analysis) acting on the Nozzle can be calculated using the following equations:

According to Fourier's law of heat conduction

Rate of heat transfer is given by

$Q = -KA\Delta T/t$

Where, Q = Heat transfer rate 'W' , K = Thermal conductivity of material 'W/mK', A = Area of cross section, ΔT = Temperature change, t = Thickness

Heat Flux Rate is given by

$q = Q/A$

Where, Q = Heat transfer rate 'W', A = Surface Area of Nozzle

Deformation and stress:

For Copper

Table 1: Deformation of Copper Nozzle

Deformation: $\Delta l = \alpha . \Delta t . L$ $= 17 \times 10^{-6} \times (220°c-25°c) \times 50.145$ $= 0.016623$ mm $\Delta l = 1.662 \times 10^{-5}$ m.	Stress: $\sigma = \Delta l . E/L$ $= 0.016623 \times 13256.31/50.145$ $\sigma = 0.04303$ GPa

For TZM

Table 2: Deformation of TZM Nozzle

Deformation: $\Delta l = \alpha . \Delta t . L$ $= 5.3 \times 10^{-6} \times (220°c-25°c) \times 50.145$ $= 0.0518248$ mm $\Delta l = 5.1824 \times 10^{-5}$ m	Stress: $\sigma = \Delta l . E/L$ $= 0.0518248 \times 32121.06/50.145$ $\sigma = 0.32552$ GPa

Heat transfer rate & Heat Flux:

For Copper

Table 3: Thermal analysis of Copper Nozzle

$Q = -KA\Delta T/t$ $= 385 \times 0.785 \times (13.4^2-9.2^2) \times (220°c-200°c)/ 2.1$ $Q = 273211.4$ W	Area $= \pi/4 \times (D^2-d^2)$ D = Outer diameter of Nozzle d = Inner diameter of Nozzle
$q = Q/A$ $= 273211.4 / 69.312 \times 10^{-4}$ $q = 3.94 \times 10^{8}$ W/m^2	A = Surface Area

For TZM

Table 4: Thermal analysis of TZM Nozzle

$Q = -KA\Delta T/t$ $= 126 \times 0.785 \times (13.4^2 - 9.2^2) \times (220°c - 200°c)/ 2.1$ Q = 89414.6 W	Area = $\pi/4 \times (D^2 - d^2)$ D = Outer diameter of Nozzle d = Inner diameter of Nozzle
$q = Q/A$ $= 89414.6/69.312 \times 10^{-4}$ $q = 1.29 \times 10^8 \ W/m^2$	A = Surface Area

V. FINITE ELEMENT ANALYSIS

Modal Analysis of Finite Element (FE) Method:

The development of Finite Element (FE) model was conducted using the ANSYS software simulation system. The Hot Runner Nozzle is modeled in CATIA modeling software and it was exported into the ANSYS for simulation system. The tetrahedral-10 element was used in the meshing process because some of the critical point or area in the geometry needs to have a small meshing size in order to give an accurate model for the 3D-elements.

FEA of Hot Runner Nozzle:

Hot Runner Nozzle assembly is tested for:

- Structural Analysis
- Thermal Analysis

STRUCTURAL ANALYSIS:

FEA is done on Hot Runner Nozzle assembly to check for Deformation and Stress Distribution of Copper Material with injection pressure of 60 Kgf /cm2 for time period of 1 sec. The results are shown in below figures.

Steps:

1 Upload Basic Model.

2 Mesh the Model.

3 Application of Load.

4 Total Deformation

1 Upload Basic Model

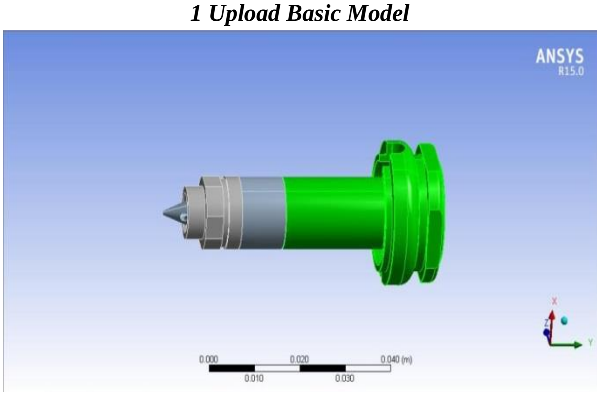

Figure 3: Structural Analysis of Model using Copper material

2 Mesh the Model

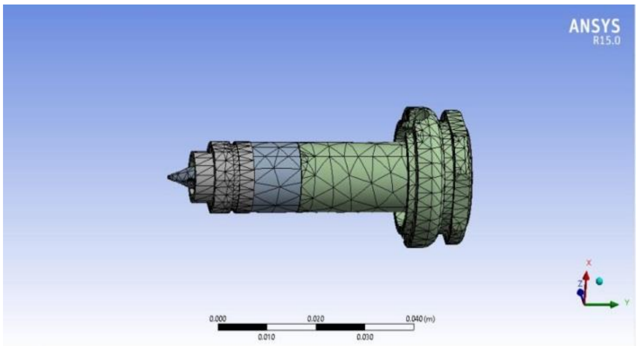

Figure 4: Meshing the Model

3 Application of Load

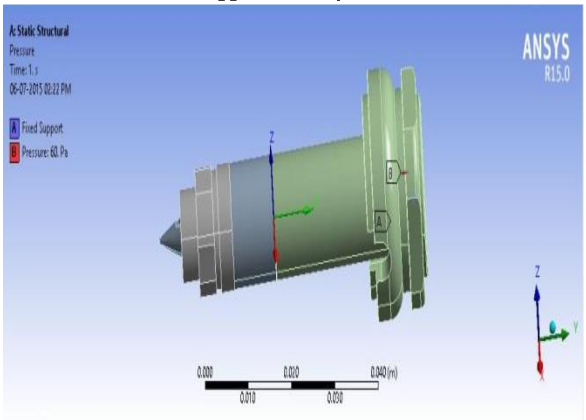

Figure 5: Application of Load

4 Total Deformation

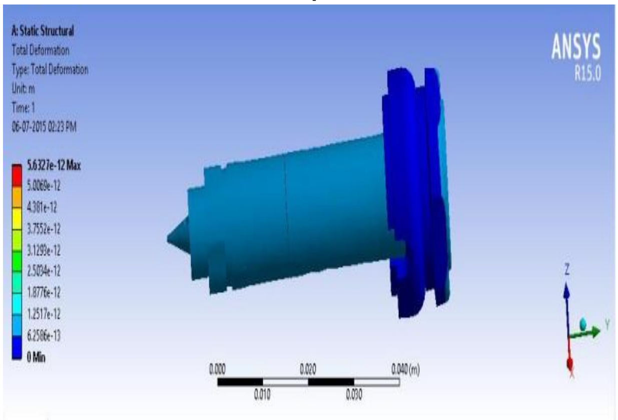

Figure 6: Deformation of Model

THERMAL ANALYSIS:

FEA is done on Hot Runner Nozzle assembly to check for Thermal analysis of Copper Material with temperature of 220°C for time period of 1 sec. The results are shown in below figures.

Steps:

1 Upload Basic Model.

2 Mesh the Model.

3 Application of Temperature.

4 Total Heat Flux.

1 Upload Basic Model

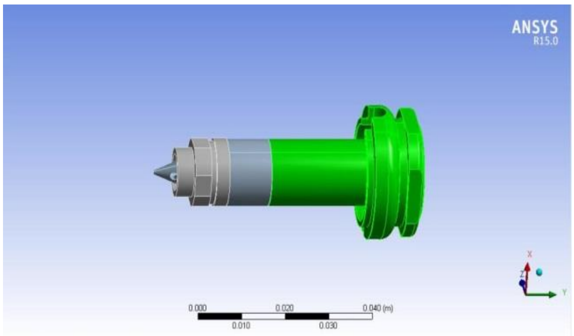

Figure 7: Thermal Analysis of Model using Copper material

2 Mesh the Model

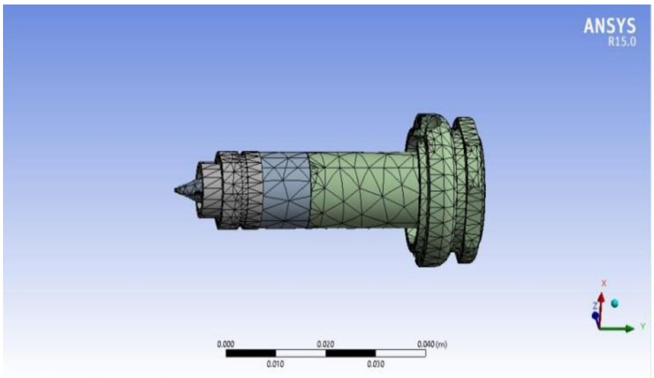

Figure 8: Meshing the Model

3 Application of Temperature

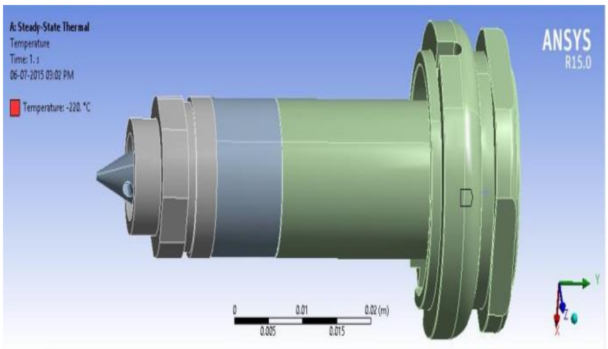

Figure 9: Application of Temperature

4 Total Heat Flux

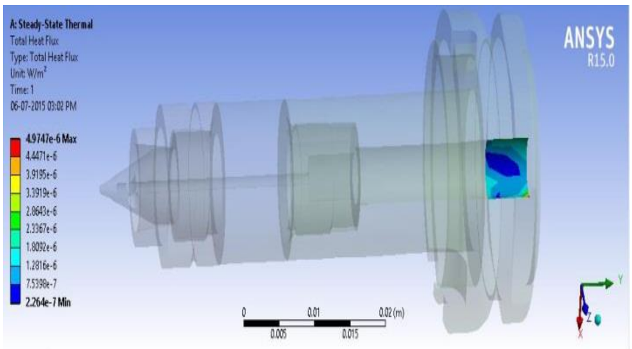

Figure 10: Thermal Deformation of Model

VI. DFMEA

DFMEA Procedure:

The process for conducting a DFMEA is straight forward. The basic steps are outlined below.

Describe the product/process and its function. An understanding of the product or process under consideration is important to have clearly articulated. Complete the header on the FMEA Form worksheet: Product/System, Subsys. /Assy., Component, Design Lead, Prepared By, Date, Revision (letter or number), and Revision Date. Revision (letter or number), and Revision Date. Modify said headings if needed. Identify Failure Modes. A failure mode is defined as the manner in which a component, subsystem, system, process, etc. could potentially fail to meet the design intent. Examples of potential failure modes include:

- Corrosion
- Hydrogen embrittlement
- Torque Fatigue
- Deformation
- Cracking

Establish a numerical ranking for the severity of the effect. A common industry standard scale uses 1 to represent no effect and 10 to indicate very severe with failure affecting system operation and safety without warning. The intent of the ranking is to help the analyst determine whether a failure would be a minor nuisance or a catastrophic occurrence to the customer. This enables the engineer to prioritize the failures and address the real big issues first.

Identify the causes for each failure mode. A failure cause is defined as a design weakness that may result in a failure. The causes should be listed in technical terms and not in terms of symptoms. Examples of potential causes include:

- Improper torque applied
- Improper operating conditions
- Improper alignment
- Excessive loading

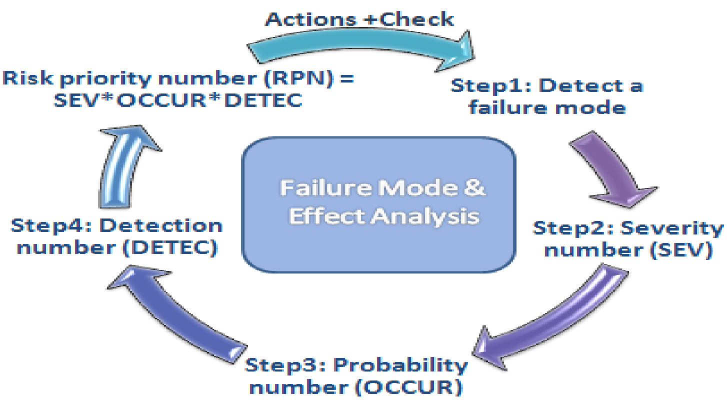

Figure 11: Cyclic view of DFMEA procedure

VII. MATERIAL MODIFICATION

Material modification has done from copper to TZM alloy to achieve better results. Molybdenum is alloyed with Titanium and Zirconium and is doped with extremely fine carbides to create TZM. TZM is an alloy of 0.50% Titanium, 0.08% Zirconium and 0.02% Carbon with the balance Molybdenum. TZM is of great utility due to its high strength/high temperature applications, especially above 2000°F. TZM has a higher recrystallization temperature, higher strength, hardness and good ductility at room and elevated temperatures than unalloyed Molybdenum. In addition, TZM exhibits good thermal conductivity, low vapor pressure, good corrosion resistance and is machinable.

TZM offers particularly high thermal conductivity of 140 W/mK coupled with excellent temperature and corrosion resistance. TZM is easier to machine. Compression nozzles are well suited to leave room for the expansion that occurs with excessive process temperatures, and absorb it without placing stress on the components. Above, an operator checks a machine's nozzle tips to ensure they're properly centered in the manifold nozzle seat to prevent material leakage.Hot-runner systems can provide an array of benefits, including reduced material use, faster cycles, and overall better part quality.Despite these advantages, hot-runner systems are not without challenges in terms of maximizing their performance.

FACTORS EFFECTING HOT RUNNER SYSTEM:

A complex variety of factors affecting the success of processing with a hot-runner system. Nevertheless, you can reduce this complexity and handle many of the issues by addressing a few key issues.

1 Maintain a flat Thermal profile

2 Minimize Resin Leakage

3 Prevent Bubbling / Drooling

4 Maintain even pressure

5 Start up system properly

6 Ensure uniform cooling

7 Use Thorough Hardened Pins

Characteristics:

Higher strength than pure Mo

Higher recrystallization temperature than pure Mo

Greater creep resistance than pure Mo

Applications:

Forging tools

Rotating anodes in X-ray tubes

Other high temperature/high load applications

Structural furnace components, die inserts for casting aluminum, hot stamping tooling. rocket nozzles, and electrodes.

TZM Properties

Table 5: TZM properties

Density	10.15 g/cc
Young's Modulus	315 GPa
Poisson's Ratio	0.32
Yield Strength	862 MPa
Thermal Expansion co-efficient	5.3 x 10-6 m/m-K
Thermal conductivity	126 W/mK

FEA on Hot Runner Nozzle Assembly

Hot Runner Nozzle assembly is tested for:

1 Structural Analysis

2 Thermal Analysis

1 STRUCTURAL ANALYSIS:

FEA is done on Hot Runner Nozzle assembly to check for Deformation and Stress Distribution of TZM Material with injection pressure of 60 Kgf /cm2 for time period of 1 sec. The results are shown in below figures.

Steps:

1 Upload Basic Model.

2 Mesh the Model.

3 Application of Load.

4 Total Deformation

1 Upload Basic Model

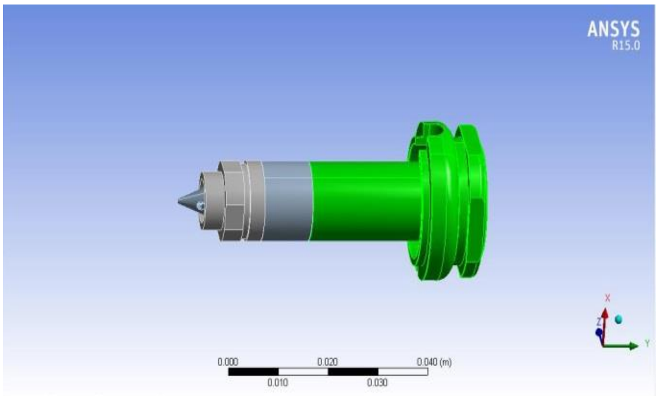

Figure 12: Structural Analysis of Model using TZM material

2 Mesh the Model

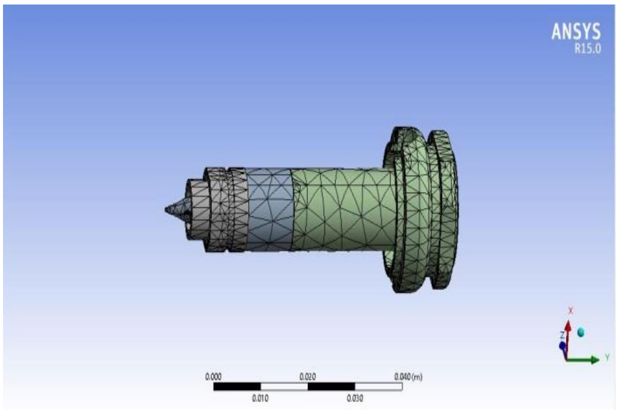

Figure 13: Meshing the Model

3 Application of Load

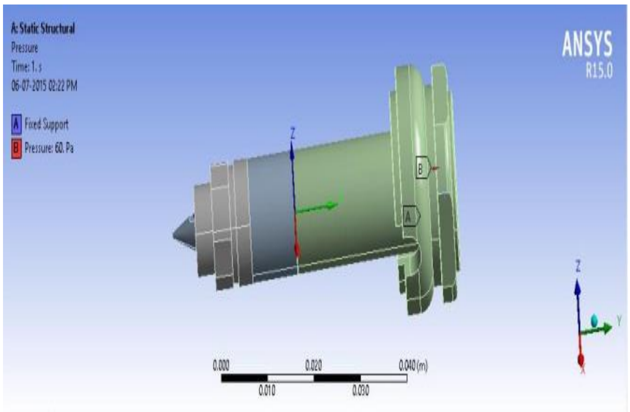

Figure 14: Application of Load

4 Total Deformation

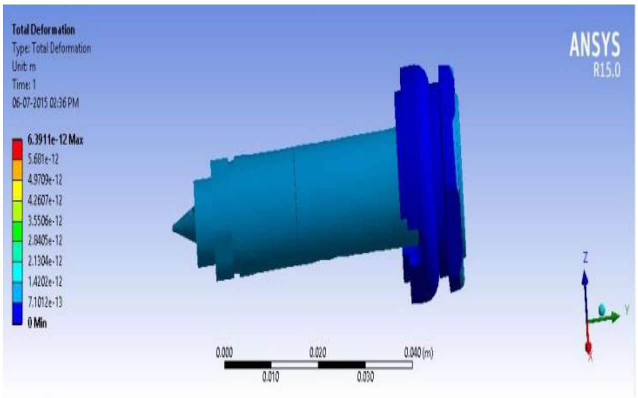

Figure 15: Deformation

THERMAL ANALYSIS:

FEA is done on Hot Runner Nozzle assembly to check for Thermal analysis of Copper Material with temperature of 220°C for time period of 1 sec. The results are shown in below figures.

Steps:

1. Upload Basic Model.

2. Mesh the Model.

3. Application of Temperature.

4. Total Heat Flux.

1 Upload Basic Model

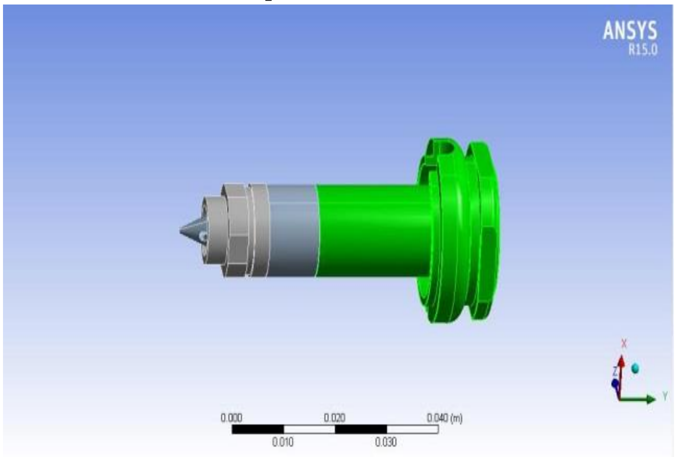

Figure 16: Thermal Analysis of Model using TZM material

2 Mesh the Model

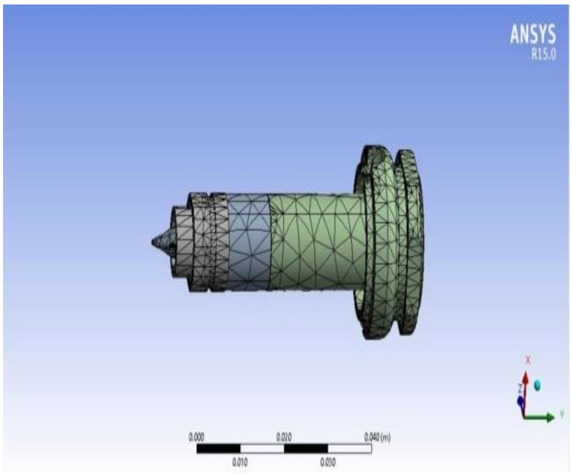

Figure 17: Meshing the Model

3 Application of Temperature

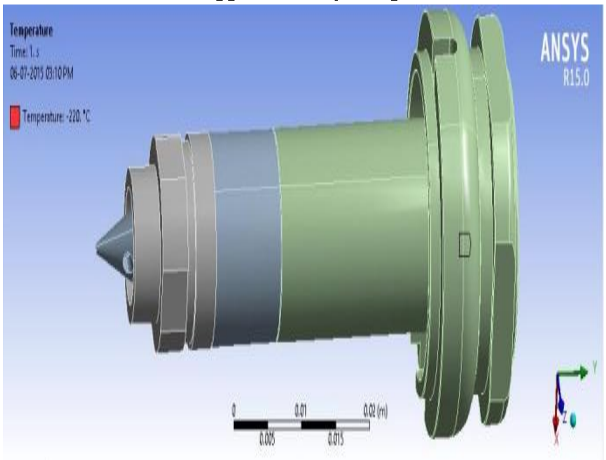

Figure 18: Application of Temperature

4 Total Heat Flux

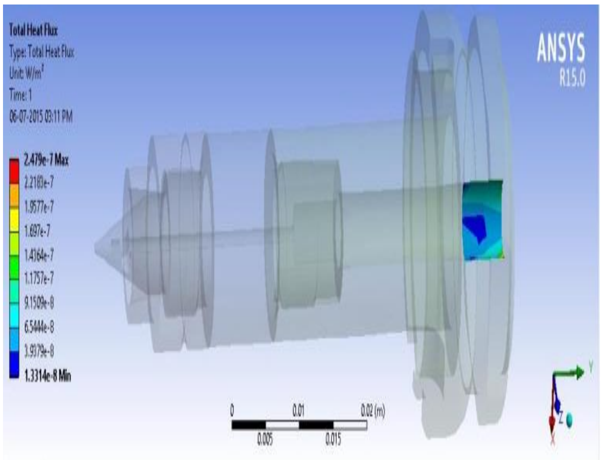

Figure 19: Thermal Analysis of Model

RESULTS AND DISCUSSION:

Theoretical and Practical values for copper and TZM material have been tabulated below

1. Theoretical calculation

2. Practical calculation

1. Theoretical calculation

Table 6: Theoretical comparison of Materials

S.No	Type of analysis	Copper	TZM
1	Structural Deformation	1.662 x 10-5 m	5.1824 x 10-5m
2	Thermal (Total Heat Flux)	3.94 x 108W/m2	1.29 x 108 W/m2

2. Practical calculation

Table 7: Practical comparison of Materials

S.No	Type of analysis	Copper	TZM
1	Structural Deformation	5.6327 x 10-12 m	6.3911 x 10-12 m
2	Thermal (Total Heat Flux)	4.9747 x 10-6 W/m2	2.479 x 10-7 W/m2

DFMEA RESULTS

Table 8: DFMEA Comparison of Materials

S.No	Type of Material	RPN Value
1	Copper	252
2	TZM	150

Note:

The RPN value in DFMEA is very high for copper material i.e., RPN>200 because of failure occurred in the Hot Runner Nozzle. Recommended action is required to minimize the RPN value i.e., RPN<200 for safe design. So TZM alloy material is tested for Nozzle design & found that RPN =150 which is under 200. so TZM alloy material is recommended for safe design.

VIII. CONCLUSIONS AND RECOMMENDATION

This chapter discusses on the overall results presented in the earlier chapters. Based on the overall results, it can be improved further and include several recommendations for future research especially in structural dynamic behavior to any system.

Summary:

The study of static and dynamic behaviour of Hot Runner Nozzle had been executed successfully. The application of dynamic correlation technique together with Finite Element Tools had been utilized in order to verify the simulation and experimental analysis of the hot runner nozzle. Experimental results were used in conjunction with the finite element to predict the dynamic characteristic of hot runner nozzle such as the pressure, temperature and corresponding mode shape. Basically, the pressure, and mode shapes are important parameters in hot runner nozzle design. Damage can occur if the hot runner nozzle is subjected to high injection pressure during operation. Therefore, based on the result gained from the finite element analysis, further enhancement of the current hot runner nozzle had been done through the hot runner nozzle FE model in order to improve its Strength as well as reduce damage of the component. Modifications were done by changing the materials in order to strengthen the hot runner nozzle as well as the overall performances.

Conclusion:

As conclusion, this study has achieved its core objectives. The dynamic characteristic such as the pressure of the hot runner nozzle were determined using FEA analysis. The basic model was used to compare with the updated finite element model representing the real structure. The FE model presented an average of 40% control in damage of hot runner nozzle than the real hot runner nozzle. These facts were due to the imperfection of the model and real structure.

Recommendations for Future Research

This hot runner nozzle should be further analyzed and improved on the overall performance especially on structural dynamic behavior and quality auditing for better refinement. Based on these factors, the overall recommendation should include:

1. The study of structural analysis should be covered on the hot runner nozzle system and after that focus on the specific area such as material. This analysis will help to make full body refinement and improvement.

2. Von-misses stress applied to the updated model for finding our maximum stresses induced on the hot runner nozzle and tried to reduce those stress by introducing further improvements on the hot runner nozzle. Other tests should be included in the structural analysis such as fatigue analysis and bending test. This because with the recent technology, the computer added engineering codes for fatigue life estimation have improved severely and it is now possible to estimate the fatigue damage to a structure using the full-time history loads from a multi-body simulation as well as bending analysis. This technology has greatly proven and enhances durability of the structure.

REFERENCES

[1] Peter Unger, "Hot Runner Technology", Hanser Gardener Publication, 2006.

[2] D.Frenkler, H. Zawistowski, "Hot Runners in Injection Moulds", Rapra publishers, Shawbury 1998, p.267.

[3] 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.

[4] 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.

[5] F. P. Incropera and D. P. DeWitt, "Introduction to Heat Transfer", John Wiley & Sons Inc, 1996.

[6] T. A. Osswald, L Turng and P. J. Gramann, Injection Molding Handbook, 2nd Ed., Hanser Gardner Publications, 2007.

[7] Kapoor, D., Multi Cavity Melt Control in Injection Molding, M. S. Thesis, Submitted to the University of Massachusetts, Amherst, December 1997.

[8] KegelanguB, SchirmanguB, RinganguB, BandanuB. Technical Information, 4.2.1, BASF, Ludwigshafen/Rh., 1969.

[9] SpritzgieBen von Thermoplasten. Publication, Farbwerke Hoechst AG, Frankfurt/M., 1971.

[10] Sowa, H.: Wirtschaftlicher fertigen durch verbesserte AnguBsysteme. Plastverarbeiter, 29 (1978), 11, pp. 587-590.

[11] Kohlhepp, K. G.; Mohnberg, J.: SpritzgieBen von Formteilen hoher Prazision, dargestellt am Beispiel von Polyacetal, Kunstsoff-Berater, 10 (1974), pp 577-584.

[12] Crastin-Sortiment, Eigenschaften, Verarbeitung, Publication, Ciba-Geigy, Basel, August 1977.

[13] Christoffers, K.E.: Formteilgestaltung, verarbeitungsgerecht. Das SpritzguBteil. VDI-Verlag, Dusseldorf, 1980.

[14] Tunnelangub, AbreiB-Punkt-AnguB, Technical Information, 4.2.3, BASF, Ludwigs-hafen/Rh., 1969.

[15] Thonemann, O. E.: AnguBund Anschnitt-Technik fur die wirtschaftliche Herstellung von SpritzguBteilen aus Makrolon. Plastverarbeiter, 14 (1963), 9, pp. 509-524.