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INTEGRAL ANALYSIS OF INJECTION MOULD WITH HOT RUNNERS FOR GATE

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ABSTRACT

This paper presents an integrated approach to evaluate gating system configurations to optimize the filling conditions of thermoplastic injection moulded parts. Through data integration between the finite element (FE) analysis and the Design of Experiment approach, the filling of parts with complex geometries was studied to optimize injection process parameters and improve the product quality. The numerical simulation of an injection moulding process allows the evaluation of the component manufacturability at the early stage of the development cycle, without fabricating prototypes and minimizing experimental tests. Normally, the FE analysis interests concerns filling, post-filling and cooling phases of the injection process, the simulation will presents the hot runner gating system design of multi cavity mould. The main challenge is to design and produce a mold that is straightforward to manufacture, while providing uniform filling and cooling of plastic parts. 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.

KEYWORDS: study on hot runner design, heat flux, gate nozzle analysis, ANSYS 15.0 .

INTRODUCTION

An injection mold is a high precision tool required for the production of plastic parts. Its main purpose is to replicate the desired geometry of the final plastic part by transforming molten plastic into its final shape and dimensional details. Currently, the design of an injection mold is a highly interactive and manual process involving substantial knowledge of multiple areas, such as mold design features, mold making processes, molding equipment and part design, all of which are highly coupled to each other. The main challenge is to design and produce a mold that is straightforward to manufacture, while providing uniform filling and cooling of plastic parts.

LITERATURE REVIEW

[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.

[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

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feature's positive and negative aspects, and then carefully determine if the benefits outweigh the drawbacks.[3]flow and heat transfer in a thin liquid slag or flux layer. Steady state Navier–Stokes equations were solved using a commercial finite volume software, FLUENT. The combined effects of natural convection, bottom shear velocity and strongly temperature dependent viscosity were investigated. Lee and Lin et al. designed a runner and gating system for a multi-cavity injection mould using Finite Element Method (FEM) and neural network. In order to select the optimal runner system parameter to minimise the warp of an injection mould, FEM, Taguchi's method and an adductive network were used. A satisfactory result as compared to the corresponding finite element verification was obtained.[4] Kumar et. al. performed a computer simulation for the transport processes during an injection mold filling and managed to optimise the molding condition. The computer simulation of injection mold filling at constant flow rate was modeled for the production of a cylindrical part under isothermal and non isothermal conditions. The finite difference method used to solve the governing differential equation for both the processes yield good agreement with the analytical solutions.

MATERIALS

Mterial 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.
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.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

THEORETICAL CALCULATIONS

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

<u>Heat transfer rate & Heat Flux: For copper</u>
$Q = -KA\Delta T/t$
= 385 x 0.785 x (13.42-9.22) x (220°c-200°c)/ 2.1
Q = 273211.4 W where area is Area = π/4 x (D2-d2)
D = Outer diameter of Nozzle
d = Inner diameter of Nozzle
heat flux = q = Q/A
= 273211.4 /69.312 x 10^{-4}
q = 3.94 x 108 W/m^2 where area A= surface area.

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

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Heat transfer
$Q = -KA\Delta T/t = 126 \times 0.785 \times (13.4^2 - 9.2^2) \times (220°c - 200°c)/2.1$
Q = 89414.6 W
Heat flux
$q = Q/A = 89414.6/69.312 \times 10^{-4}$
$q = 1.29 \times 10^8$ W/m^2

5. ANALYSIS

Figure 5.1 shows runner assembly models of hot runners

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

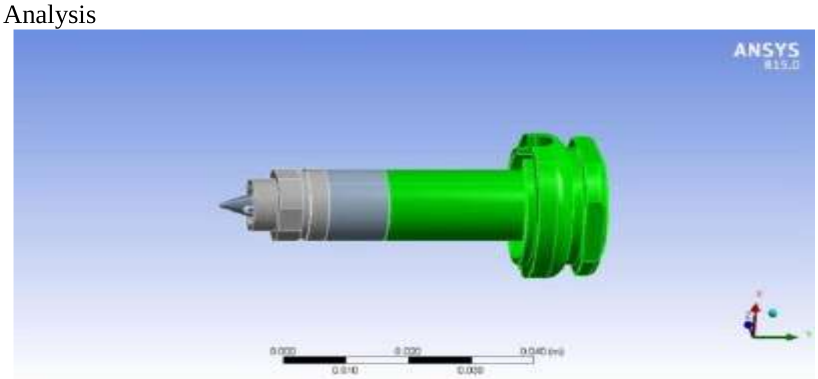

Figure 5.2 shows runner assembly

<u>Boundary conditions</u>

<u>Input parameters</u>

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

<u>Nozzle Length at Operating Temperature:</u>

1. Actual Nozzle Length cold - 50.000 mm
2. Nozzle Expansion @ 220°C - +0.145 mm
3. Nozzle Length @ 220°C - 50.145 mm

Mold Expansion at Operating Temperature:

Mold Expansion @ 40°C - 0.013 mm
Required Nozzle Cavity Depth:
Nozzle Length @ 220°C - 50.145 mm

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Mold Expansion @ 40°C - -0.013 mm
Tip offset distance - 0.2 mm
Total depth=50.332 mm

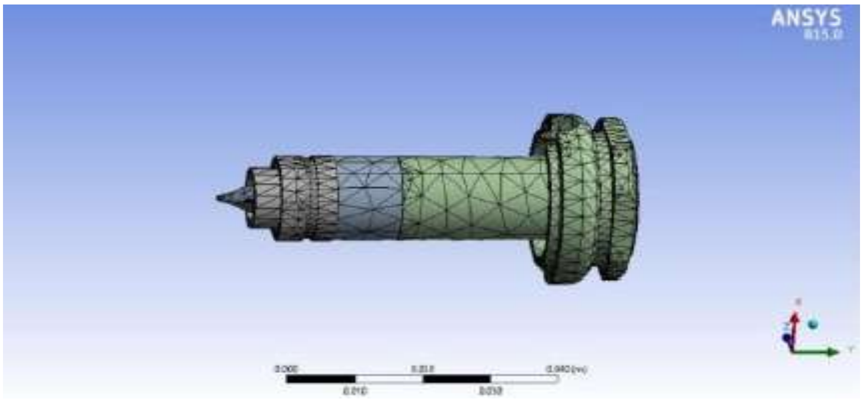

Figure 5.3 shows the meshing of the model.

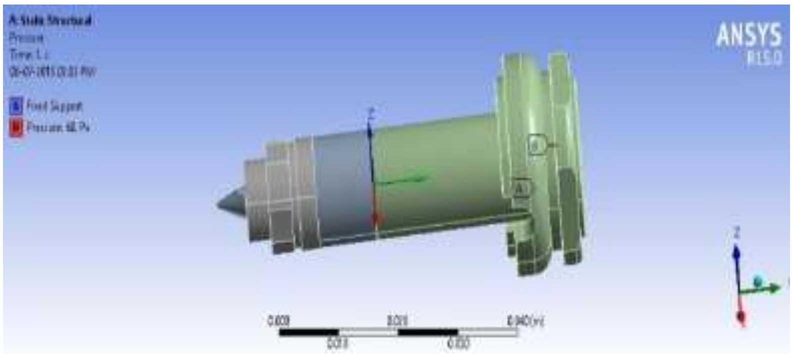

Figure 5.4 shows the application of load

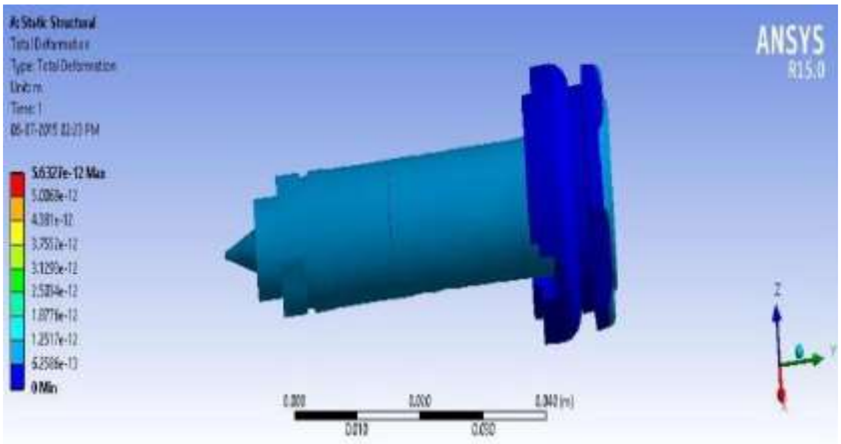

Figure 5.5shows the total deformation

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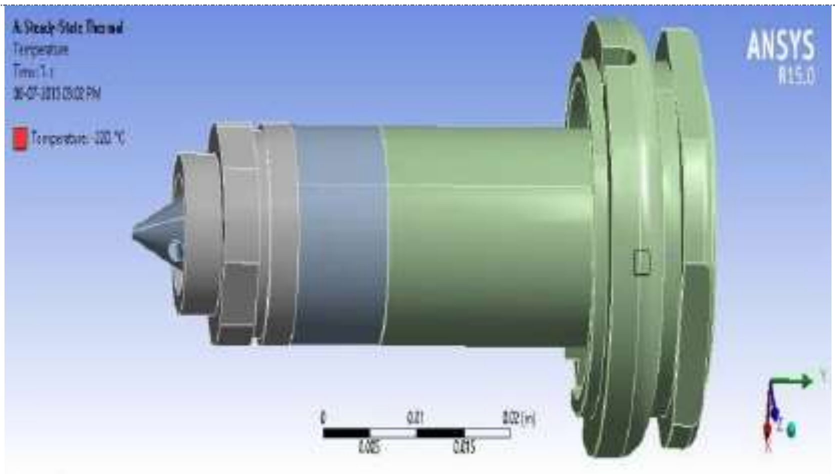

Figure 5.6 shows the thermal environment.

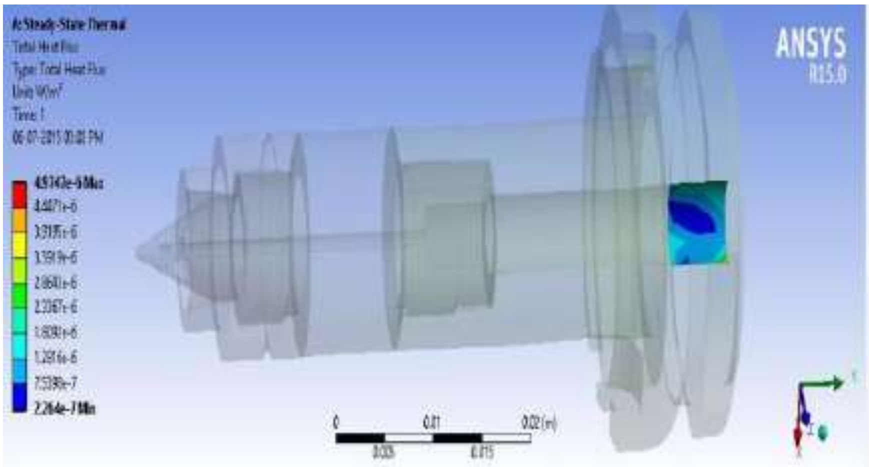

Figure 5.7 shows total heat flux

RESULTS

Theoretical results with normal conditions

S.NO	Type of analysis	Copper	TZM
1	Structural deformation	1.662 x 10^{-5} m	5.1824 x 10^{-5}m
2	Total heat flux	3.94x10^{8}w/m^{2}	1.29x10^{8}w/m^{2}

Simulation results table 6.2 with hot runers

S.NO	Type of analysis	Copper	TZM
1	Structural deformation	5.632x10^{-12}	6.391x10^{-12}
2	Total heat flux	4.974x10^{-6}w/m^{2}	2.48x10^{-7}w/m^{2}

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.

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CONCLUSIONS

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.

FUTURE SCOPE

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. 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.

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