iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** IX **Month of publication:** September 2016

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Structural and Thermal Analysis on Hot Runner Nozzle by FEA

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Abstract- Hot-runner systems can provide an array of benefits, including reduced material use, faster cycles, and overall better part quality. Hot runner system is an assembly of heated components used in plastic injection molds that inject molten plastic into the cavities of the mold. 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. In some hot-runner systems, it can be difficult to keep temperatures uniform in the nozzles and tips areas where evenly distributed heat is needed to prevent flow-channel hot spots. With many hot-runner systems, and with certain resins, you may need to lower the temperature of the material right at the gate to prevent drooling, stringing, or other part-quality problems. Sometimes, the cause is related to a less-than-optimal match between standard heaters and the nozzles and other components of the system. Special heaters particularly flexible heaters that are designed specifically for compatibility with a given system will achieve better distribution of heat. On the heater head, a more heat-retaining material, such as TZM, will also help prevent heat dissipation. TZM is beneficial for the same reason in the nozzles and tips..A closer examination will more likely reveal that the molding machine isn't set to your material manufacturer's recommended temperatures, causing the resin to overheat. In addition to keeping your system at proper temperatures. Hot runner technology is continuing to experience a phase of intensive development brought by the increasing demands of the plastics processing industry .The 3D model is then tested for deformation & stresses using Finite Element Analysis. 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.

Key words- Design of model by using Catia, thermal and structural analysis by using FEA. Calculating deformation and heat flux

I. INTRODUCTION

A hot runner system is used to inject molten plastic into the cavities of the mould is an assembly of heated components. Hot runner system constitutes hot manifold and a multiple heated nozzles the molten plastic poured is received by the hot manifold which distributes to the heated manifolds. They direct the molten plastic to the injection points of the cavities present in the mold. Use of hot runners makes the process more expensive to manufacture and run. It is an edge over the convectional runner in allowing savings by reducing plastic waste and by reducing the cycle time. Hot runner systems were first used in early 60s which was unsuccessful. The increasing in the plastic material prices has demanded the use of hot runners in the manufacturing process to increase. In hot runners, fairly complicated systems, the temperature of the plastic material is maintained uniformly. While the rest of the injection mould is quickly cooled in order to solidify the product. Hot runner system plays a critical role in optimising the thermal profile of a production mold providing consistency in material flow and fill from part to part. Hot runner molds are to plate molds with a heated runner system inside one half of the mold. They are injection molds in which the runner are kept and insulated from the chilled cavities. Plastic freeze off occur at gate of cavity, runners are in separate plates they don't usually get ejected with the piece. The main type of hot runners is 1) Externally heated hot runners 2) Internally heated hot runners 3) Insulated hot runners.

II. PROBLEM STATEMENT

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.

The cost of a standard nozzle is higher than that of a hot runner nozzle.

Polymer melt leaking from the hot-runner unit can create problems.

Polymer material at the gate may solidify and interrupt production.

Heat expansion of the hot-runner unit can create difficulties for operation process.

A. Objective

The objectives of this study are:

1) S tress analysis determination due to injecting flow pressure.
2) To design and develop cost effective hot runner nozzle with good design aspects.
3) The process to reduce the manufacturing costs, increase reliability, decrease down time and increase output.
4) The expansion of the nozzle in all the three dimensions shouldn't be overlooked which has to be considered as design factor.

B. Scope of work

The scope of work includes:

1) Literature review associated with hot runner nozzle and its design and analysis.
2) This study will concentrate on hot runner nozzle.
3) Simulation and experimental work on the existing hot runner nozzle.
4) Correlation of simulation and experimental results.
5) Model optimizing process, which include parameters adjustment in order to obtain a good model of hot runner nozzle.
6) Improvement of hot runner nozzle characteristic by improving the geometry, material to the existing model.

III.DESIGN AND ANALYSIS

A. Design

Injection and distribution of molten polymer to the cavities which in later stages results in the plastic components is the main function of the hot runner nozzles this 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. Hot runner nozzle can be divided into open nozzle and closed nozzle. Inaddition, 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, pingate, subsurface gate, and winkle gate. The designs of hot runner nozzle design and gate system depend on the products. Hot runner nozzle tip design is the key to hot runner nozzle design. The most common gate system is the Pinpoint gate in hot runner. Because pin point gate nozzle can cut-off itself and the plastic parts cancool 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 molten state and reduce the heat transfers much as possible
3) Pay attention to the sea l: Leakageshould 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.

A hot runner system has to fulfil the following requirements: Molten plastic flow path, thermal homogeneity and stable temperature maintenance are always a goal.

Thermal degradation of the melt must be avoided.

Dead spots must be avoided.

Unavoidable pressure losses should be kept as low as possible. This issues is a addressed most effectively by natural balancing of runners. This condition is reached, when flow channels with identical cross section also have identical flow lengths, and when all respective branches exhibit equal flow resistance. The modification of process parameters has no effect on the natural equal balance of runners. Therefore, natural balancing preferred over geometrically balanced runners.

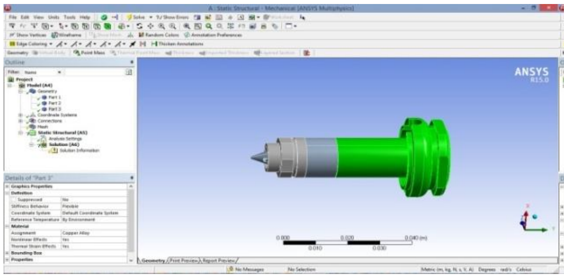
Selection of Material: Selection of the material is very much vital as it allows the melt through the hot runner nozzle and to the mold . The temperature should be very precise as required. Variations in the temperature would would damage he material or hardens the material and the flow may get disrupted. Cu is used as the material and heating elements are supplied around the nozzle for maintaining the temperature but at the tip of the nozzle heat loss is on its own. And thermal stresses should not be over looked.

B. Simulation in ANSYS software

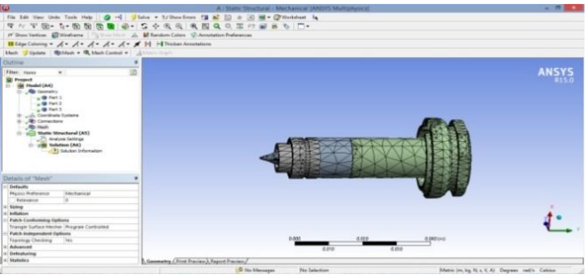
The development of Finite Element (FE) model was conducted using the ANSYS software simulation system .The Hot Runner Nozzle is modelled in CATIA modelling software and it was exported into the ANSYS for simulation system with the tetrahedral-

Volume 4 Issue IX, September 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

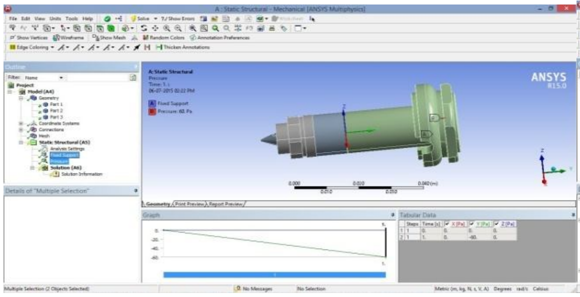
10 element for meshing because some of the critical point or area in the geometry needs to have a small meshing size in order to give an accurate model for the 3D-element FEA is done on Hot Runner Nozzle assembly to check for Deformation and Stress Distribution of TZM Material with injection pressure of 60Kgf/cm^{2}for time period of1 sec. The results are shown in below figures.



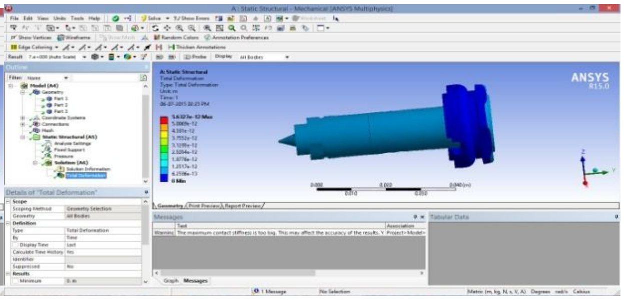
Structural Analysis of Model using TZM material



meshing the model



Application of Load



Deformation of Model

IV.RESULTS

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 G Pa.

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 about17 x10^{-6} m/m-K&TZM, αisabout5.3 x 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 TZM Nozzle

Deformation	Stress
$\Delta l=\alpha\Delta tL$ $5.3x10^{-6}x(220^0{}_c - 25^0{}_c)x50.145$ =0.0518248mm $\Delta l = 5.1824x10^{-5}m$	$\sigma = \Delta l.\ E/L$ 0.0518248x32121.06/50.145 = 0.32552Gpa

Rate of heat transfer and Heat flux for TZM Nozzle

$Q = -KA\Delta T/t$ $126x0.785x(13.4^2 - 9.2^2)\ x\ (220^0{}_c - 200^0{}_c)/2.1$ Q = 89414.6 W	Area = Area= $\pi/4x\ (D^2 - d^2)$ D = Outer diameter of Nozzle d = Inner diameter of Nozzle
q=Q/A $89414.6/69.312x10^{-4}$ $q = 1.29\ x\ 10^8\ W/m^2$	A =Surface Area of Nozzle

Theoretical calculation

S. no	Type of analysis	Copper	EN24	BECU	TZM
1	Structural Deformation	$1.662\ x10^{-5}\ m$	$1.567x\ 10^{-5}\ m$	$1.893x\ 10^{-5}\ m$	$5.1824\ x10^{-5}m$
2	Thermal(Total Heat Flux)	$3.94\ x10^8 W/m^2$	$2.40x10^8\ W/m^2$	$3.\ 14x10^8\ W/m^2$	$1.29x10^8\ W/m^2$

Practical calculation

S no	Type of analysis	Copper	TZM	EN24	BECU
1	Structural deformation	$5.6327x10^{-12}m$	$6.391x10^{-12}m$	$3.287x10^{-12}\ m$	$4.325x10^{-12}m$
2	Thermal(Total heat flux)	$4.97x10^{-6}\ W/m^2$	$2.47x10^{-7}\ W/m^2$	$3.24x10^{-6}\ W/m^2$	$3.935x10^{-6}\ W/m^2$

Risk priority number

S. no	Type of material	RPN value
1	Copper	252
2	TZM	150
3	EN 24	208
4	BECU	264

The RPN values is high for copper, EN24 and BECU materials i.e. RPN>200becauseof failure occurred in the Hot Runner Nozzle .Recommended action is required to minimize the RPN value i .e RPN<200for safe design .So TZM alloy material is tested for Nozzle design &found that RPN=150which is under200.SoTZM alloy materials recommended for safe design.

V. CONCLUSION

The application of dynamic correlation technique in addition with Finite Element tools to execute simulation and experimental analysis of the hot runner system has been successful .The dynamic and performance characteristic s such as pressure, temperature and corresponding mode shape which are design parameters of hot runner system were found in the finite element were used in conjunction with experimental result a gained from FEA .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 .

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

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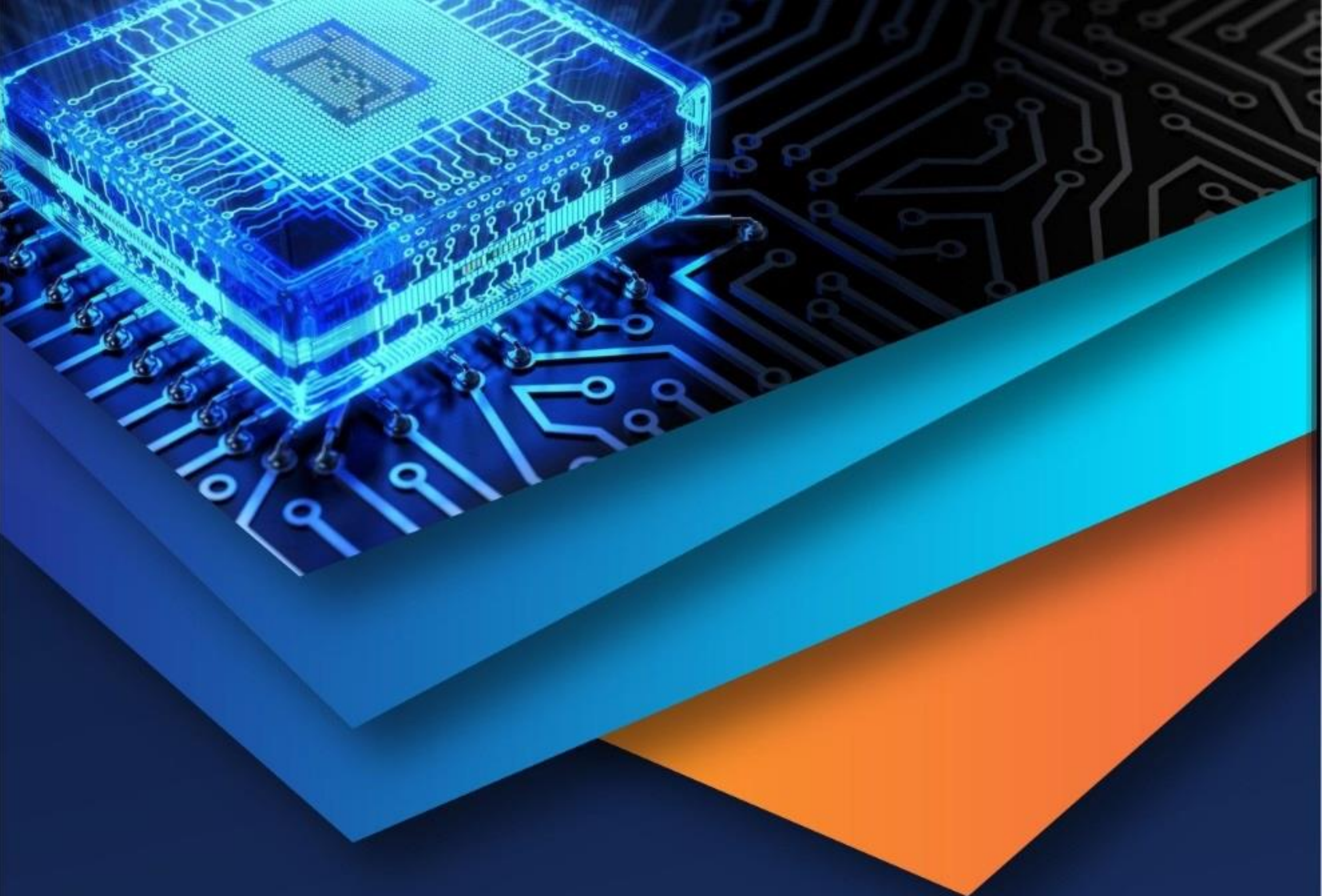

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