Design and Analysis of Plastic Moulding Die and Runner Shape Optimization by Using Analytical Hierarchy Process

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ABSTRACT

The designing of mold is a complicated process. In mold designing various parameters are to be adjusted for successful mold design. Here I use the CAD software to design the mold and to analysis of various parameters for design of mold. The CAD software's use are CREO 2.0 and ANSYS. Here I design the molds by using both analytical and software methods for different parameters. The main failure modes of the plastic mold surface wear, deformation and fracture. The crash reasons depend on working conditions, mold materials and thermal properties, stresses due to ingates etc. Material assortment of plastic mold is resolute by their using performances and life of material. By analytic calculations of gate types, gate size, sprue, runners, margin of clamping holes and all other parameters and locations in mold plate. The analysis of mold we can suggest a proper material selection, size, and optimizing the shape of the ingate or runner and the position of the runner.
The runner provides the liquid material to the mold but the runner is cut over the die so it produces the stresses in the die if the stress produce is more than the material properties of the die then the failure of the die is occurs. To avoid the collapse of shape of the runner and the position of the runner is to be selected properly so the stress is minimizes and the crash of the die is avoided and the stress can be minimized. Here we use the analytical hierarchy process of the optimization of the runner cross section. We take the ANSYS results and apply this technique on it so that i get the optimum cross section for the runner and we take that runner cross section and design the moulding die, past deceitful the moulding, create the die on CNC machine.

Keywords: *Plastic Moulding Die, Analytical Hierchey Process, Optimum Runner Cross Section*.
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1. INTRODUCTION

Injection moulding is the most generally used manufacturing process for the fabrication of plastic parts. A wide variety of products are pretend using injection moulding, which vary greatly in their size, complexity, and application. The injection moulding process requires the use of an machine, plastic material, and a mould. It is melted in the injection moulding machine and injected into the mould, where it cools and solidifies into the final part. It is used to produce thin-walled plastic parts for a broad range of applications, one of the most common being plastic housings. Plastic housing is a thin-walled enclosure, requiring many ribs and bosses on the interior. These housings are used in a variety of products including family appliances, consumer electronics, power tools, and as automotive dashboards. Other general thin-walled products include similar types of open containers, such as buckets. It is also used to produce a number of daily substance like tooth brushes or small plastic toys. Many medical devices, with valves and syringes. There are manufactured using injection moulding.

1.1 Basic operations on injection moulding machines are:

Plastic material Powder or granules from a hopper passed into a steel barrel with a rotating screw.

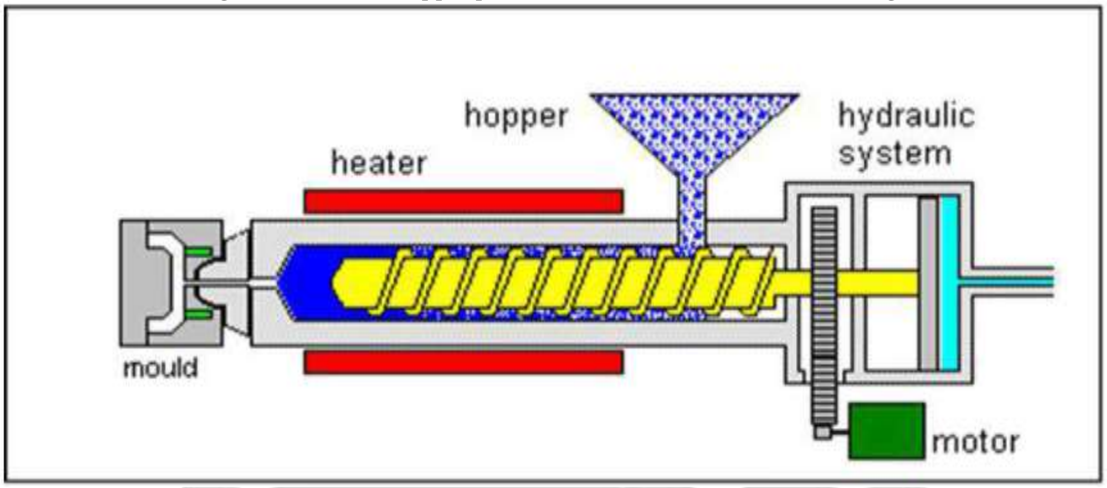

Fig-1 Machine preparation

The cask is bordered by heaters the screw is forced back as plastic collects at the end of the cask.
The process flow as shown in figure.

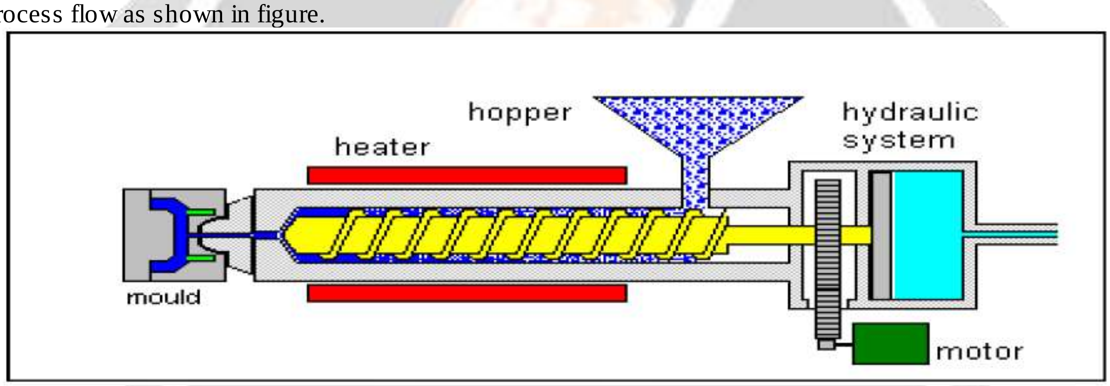

Fig-2 Moulding process

When a sufficient amount of melted plastic by accumulated a hydraulic ram forces the screw forward injecting the plastic flow through a sprue into the mould cavity.
Now Pressure applied on the mould until the plastic has cooled perfectly for the mould to be open and the component ejected.

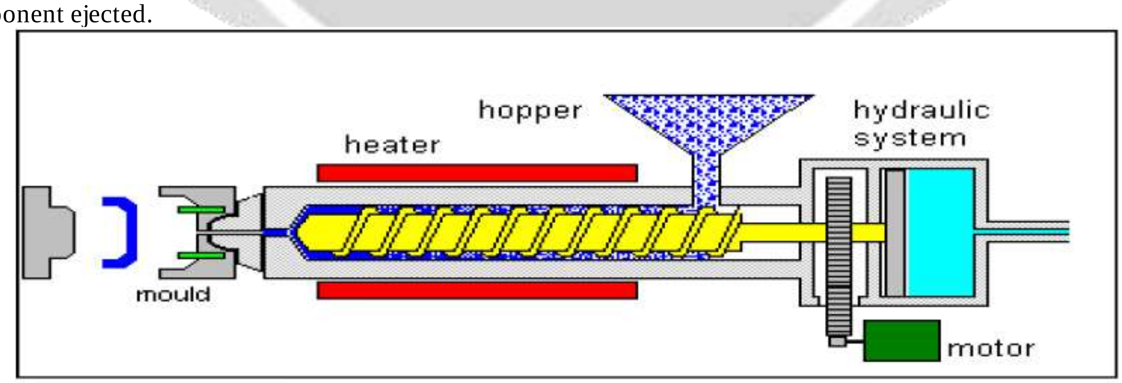

Fig-3 Moulding complete

Analytic Hierarchy Process (AHP) Method is one of Multi Criteria decision-making method. It is a method to derive relation scales from paired comparisons. The input can be obtained from actual measurement such as price, weight etc. In addition, from subjective opinion such as satisfaction feelings and preference. It allow some small variation in decision because human is not always dependable. The relation scales are resultant from the major Eigen vectors and the reliability index is derived from the major Eigen value.

Analytical Hierarchy Process having two stages:
1. Determination of Relative Weightage
2. Determination of Relative Ranking

2. PROBLEM STATEMENT

Problem for Selecting Multi Criteria Decision Making:
1. Objective (Goal):
- Selection of Design of Runner Cross Section.

2. Criteria (Problem Factors):
- Total deformation
- Equivalent Elastic Strain
- Equivalent Stress
- Maximum Principal Stress

3. Alternatives (Runner shape):
- Circular Cross Section
- Hexagonal Cross Section
- Square Cross Section
- Rectangular Cross Section

3. PROBLEM FORMULATION STEPS FOR AHP METHOD

Step I: Structure a hierarchy. Define the problem, determine the criteria and identify the alternatives.
Step II: Make pairwise comparisons. Rate the relation meaning among each pair of decision alternatives and criteria.
Step III: Manufacture the results to decide the best alternative. Obtain the results. The output of AHP is the set of priorities of the alternatives.

3.1 Hierarchy Tree Algorithm:

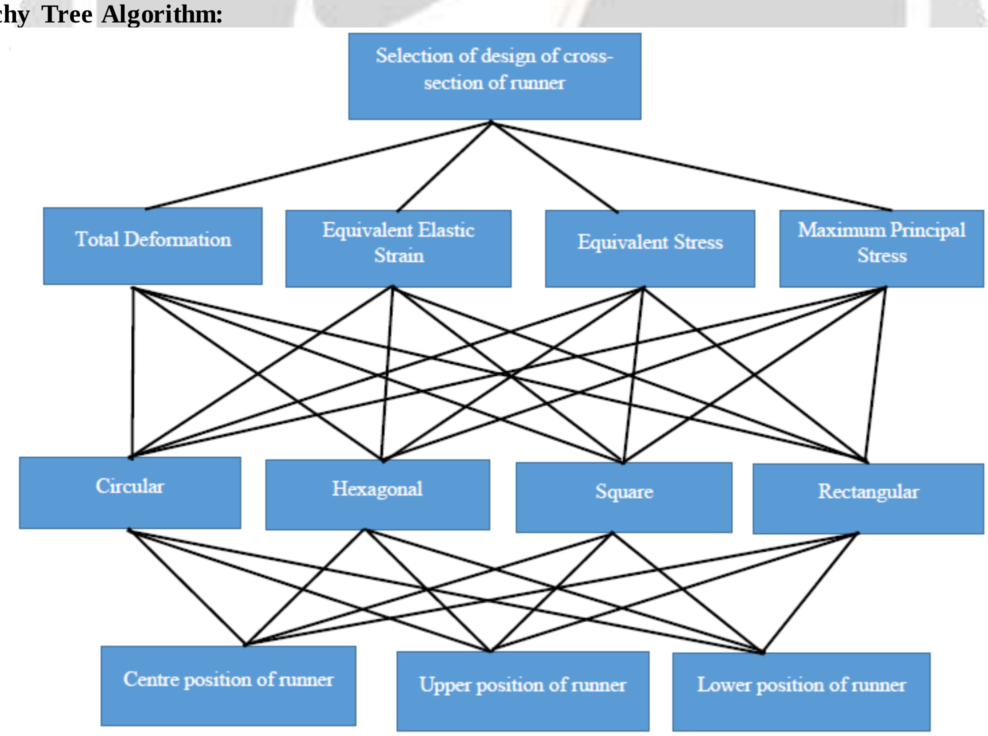

Fig-4 Analytical Hierarchy Diagram tree

3.2 Ranking of Criteria and Alternatives:

Pairwise comparison made with Grades 1-9.
It Contributes A is important that Contribute B and is rated at nine than B must be totally fewer central than A and is graded as 1/9.
Pairwise comparisons are carried out for all factor to be considered usually not more than seven.

3.3 Ranking Scale:

Table-1 Ranking Scale for AHP

Numerical Ratings	Judgments
1	Equally important (preferred)
3	Moderately more important
5	powerfully more important
7	Very powerfully more important
9	Extremely more important
2, 4, 6 & 8	Intermediate

3.4 Pairwise comparisons for Selection of Runner Cross-section:

Table-2 Pairwise comparison of AHP method

Parameters	Total deformation	Equivalent Elastic Strain	Equivalent Elastic Strain	Maximum Principal stress
Total deformation	1	5	3	5
Equivalent Elastic Strain	1/5	1	7	3
Equivalent Elastic Strain	1/3	1/7	1	2
Maximum Principal stress	1/5	1/3	1/2	1

Geometric Mean of row is:
For row 1 $[1 * 5 * 3 * 5]^{1/4} = 2.9428$
For row 2 $[1/5 * 1 * 7 * 3]^{1/4} = 1.5244$
For row 3 $[1/3 * 1/7 * 1 * 2]^{1/4} = 0.5555$
For row 4 $[1/5 * 1/3 * 1/2 * 1]^{1/4} = 0.42728$
Sum of each row G.M. = (2.9428+1.5244+0.5555+0.42728) = 5.44998
Now, G.M. to sum of G.M. ratio calculates weightage for each row:
For row 1 2.9428/5.44998 = 0.53996
For row 2 1.5244/5.44998 = 0.27970
For row 3 0.5555/5.44998 = 0.10193
For row 4 0.42728/5.44998 = 0.07841
Total sum of all weightage are = (0.53996+0.27970+0.10193+0.07841) = 1.0000
That shows sum of all Criteria weightage are = 100%.

3.5 Percentage Weightage of those Criteria as:
Total Deformation = 53.996%
Equivalent Elastic Strain = 27.970%

Equivalent Stress = 10.193%
Maximum Principal = 7.841%

3.6 Result of analysis and calculation of AHP for the Die

Table-3 Result of analysis of die

Cross-sectionof runner	Position of runner	Total deformation (m)	Equivalent elastic strain	Equivalent stress (Pa)	Maximum principal stress (Pa)
Circular crross-section	Centre	$1.19174*10^{-6}$	$1.6589*10^{-5}$	0.52984	0.52451
	Upper	$1.18858*10^{-6}$	$1.10638*10^{-5}$	0.34886	0.27677
	Lower	$1.19624*10^{-6}$	$1.08955*10^{-5}$	0.34444	0.26920
Hexagonal cross-section	Centre	$1.19615*10^{-6}$	$1.46478*10^{-5}$	0.42747	0.41536
	Upper	$1.20663*10^{-6}$	$1.03155*10^{-5}$	0.32681	0.25103
	Lower	$1.20039*10^{-6}$	$0.98344*10^{-5}$	0.31217	0.23492
Square cross-section	Centre	$1.65648*10^{-6}$	$1.53906*10^{-5}$	0.41020	0.31202
	Upper	$1.46332*10^{-6}$	$1.58182*10^{-5}$	0.42088	0.25775
	Lower	$1.19241*10^{-6}$	$0.86356*10^{-5}$	0.25940	0.24373
Rectangular cross-section	Centre	$1.19790*10^{-6}$	$1.71626*10^{-5}$	0.55424	0.39851
	Upper	$1.19307*10^{-6}$	$1.74114*10^{-5}$	0.54542	0.25302
	Lower	$1.82362*10^{-6}$	$0.90602*10^{-5}$	0.27713	0.28284

By using the value and the weightage

A1 = ($1.19174*10^{-6}$*0.53996) + ($1.67589*10^{-5}$*0.27970) + (0.52984*0.10193) + (0.52451*0.07841)
A2 = ($1.18858*10^{-6}$*0.53996) + ($1.10638*10^{-5}$*0.27970) + (0.34886*0.10193) + (0.27677*0.07841)
A3 = ($1.19624*10^{-6}$*0.53996) + ($1008955*10^{-5}$*0.27970) + (0.34444*0.10193) + (0.26920*0.07841)
A4 = ($1.19615*10^{-6}$*1.53996) + ($1.46478*10^{-5}$*0.27970) + (0.42747*0.10193) + (0.41536*0.07841)
A5 = ($1.20663*10^{-6}$*0.53996) + ($1.031551*10^{-5}$*0.27970) + (0.32681*0.10193) + (0.25103*0.07841)
A6 = ($1.20039*10^{-6}$*0.53996) + ($0.98344*10^{-5}$*0.27970) + (0.31217*0.10193) + (0.23492*0.07841)
A7 = (1.65648910^{-6}*0.53996) + ($1.53906*10^{-5}$*0.27970) + (0.41020*0.10193) + (0.31202*0.07841)
A8 = ($1.46332*10^{-6}$*0.53996) + ($1.58182*10^{-5}$*0.27970) + (0.42088*0.10193) + (0.25775*0.07841)
A9 = ($1.19241*10^{-6}$*0.53996) + ($0.86356*10^{-5}$*0.27970) + (0.25940*0.10193) + (0.24373*0.07841)
A10 = ($1.19790*10^{-6}$*0.53996) + ($1.71626*10^{-5}$*0.27970) + (0.54542*0.10193) + (0.39851*0.07841)
A11 = ($1.19307*10^{-6}$*0.53996) + ($1.74114*10^{-5}$*0.27970) + (0.54542*0.10193) + (0.25302*0.07841)
A12 = ($1.82362*10^{-6}$*0.53996) + ($0.90602*10^{-5}$*0.27970) + (0.27713*0.10193) + (0.28284*0.07841)
A13 = ($2.24321*10^{-6}$*0.53996) + ($0.67021*10^{-5}$*0.27970) + (0.20259*0.10193) + (0.17222*0.07841)

By calculation value:-

A1=0.095138
A2=0.057264
A3=0.056220
A4=0.076145
A5=0.052998
A6=0.050242
A7=0.066282
A8=0.063115
A9=0.045554
A10=0.087746
A11=0.075439
A12=0.050428
A13=0.034156

4. RESULTS OF AHP METHOD

By above value we have concluded that from different four cross-sections and positions of runner we have selected the maximum for Maximize the value and for Minimize select minimum.

Table-4 Results of AHP Process

Cross-section of runner	Position of runner	Final Values by AHP Method of die
Circular cross-section	Centre	0.095138
	Upper	0.057264
	Lower	0.056220
Hexagonal cross-section	Centre	0.076145
	Upper	0.052998
	Lower	0.050242
Square cross-section	Centre	0.066282
	Upper	0.063115
	Lower	0.045554
Rectangular cross-section	Centre	0.087746
	Upper	0.075439
	Lower	0.050428

5. CONCLUSION FROM AHP METHOD

Form the table we get the result of AHP for different cross-sections of runners and their different position. Result shows that if we want to maximize the value, we select the maximum value and if we want to minimize the value, we select minimum value. For circular cross-section all the Criteria will be minimum. So I can select the '**Circular Cross-section'** as best selection. By using the AHP as multi Criteria Decision making process we select from twelve different position and shapes of runner of die one optimum best selection.

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