



MODELLING AND SIMULATION ANALYSIS OF METAL CASTINGS

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ABSTRACT

The modelling of liquid- solid change in castings is extremely important casting simulation studies. In particular the solidification of the molten metals in metal casting methods provides a source of important practical problems. Filling the mold casting process affects significantly the solidification of the melt. Basically solidification is a transient heat transfer problem. For this reason accurate prediction of the temperature field in the castings is to be achieved. Experimental design analysis is often expensive and the geometry and complex boundary conditions encountered preclude any analytical solutions to the problems posed. Thus the motivation of computational modelling techniques has been brought to bear in this area during recent years. This Paper deals with the finite element technique, which has facility in modelling complex domain configurations and handling of non-linear boundary conditions. In this study the finite elements analysis package ANSYS is used to perform the thermal analysis of two-dimensional piston casting model with Al 12% wt. silicon alloy. The latent heat evaluation is incorporated in the heat transfer analysis. The time taken for the completion of solidification, the cooling curves at selective nodes for the combination of casting temperatures 700 °C & 800 °C and punch & mold temperature of 100 °C, 200 °C & 400 °C are estimated, because it seems to be the appropriate value, for the casting process considered. The results of the simulation study helps in identifying the solidification time, progress of solidification, estimation of various zones (liquid, mushy and solid), change in their configuration during solidification, locating the hotspot, and indicating the source of shrinkage cavity.

Keyword: casting, solidification, mold

1. INTRODUCTION

Casting is one of the most ancient techniques used for manufacturing metal parts. The liquid metal is directly poured into the shaped cavity of the mold to get the finished product. The process of casting involves the basic operation of pattern making, molding, melting of metal, pouring in molds, cooling, shakeout, heat treatment finishing and inspection. A finite element modelling of metal solidification applied to an Aluminium silicon alloy castings. Earlier studies on solidification have been mostly confined to one dimensional problem where as the present one deals with two dimensional problems by taking three sectional views.

- Near top of the casting where shell thickness is thin.
- Middle of the casting where shell thickness is higher.
- Near bottom of the casting.

This work has significantly reduced the cost & time of experimental verification by evolving the mold design through simulation studies. Eventually optimum mold can be achieved which leads to good quality of casting.

Casting is the process of filling the liquid metal into a shaped mould to get the desired shape of the product. Filling the mold casting process affects significantly the heat transfer & solidification of the melt. A finite element formulation is to be used for it, which gives temperature profiles at different time steps.

Development of mould through experimental study is difficult & costly process to achieve the optimum mould design. Alternatively, modelling of solidification process helps to achieve a optimum mould design by considering various factors. The process parameters

affecting quality of castings are pouring temperature, Mould Temperature, Shape of the castings and cooling rate. Chapter II explains Thermal Analysis using ANSYS. Chapter III describes Material composition of the work. Chapter IV gives performance Evaluation and finally Chapter V gives Conclusion.

2. THERMAL ANALYSIS USING ANSYS

Solidification of a casting is a transient heat transfer problem and hence the temperature distribution in the metal casting & the mold during the solidification process is to be tracked. Two-dimensional analysis can be performed by creating accurate mathematical model of a physical prototype. In the broadest sense, this model comprises all the nodes, elements material properties boundary conditions and other features that are used to represent the physical system. The ANSYS program can be used to generate the mathematical model with the nodes & elements that represent spatial volume & connectivity of the actual system. The ANSYS software can use this model for solving nonlinear heat transient problem.

A. Steps followed in carrying out the thermal analysis

- 2D modeling of 0.11m dia& 0.148m Height Aluminum-12%wt Silicon alloy piston casting with mold size of 0.225m x 0.24m size.
- Meshing of the given 2D model.
- Simulation of the model with casting temperature of 700 °C & 800 °C combined with mold temperature of 100 °C, 200 °C and 400 °C.
- Cooling curve for the above combinations is taken.
- Determination of solidification time and Temperature profiles at different time steps at 3 different sections



(bottom, middle, top sections) are calculated.

B. Physical dimension of the piston casting

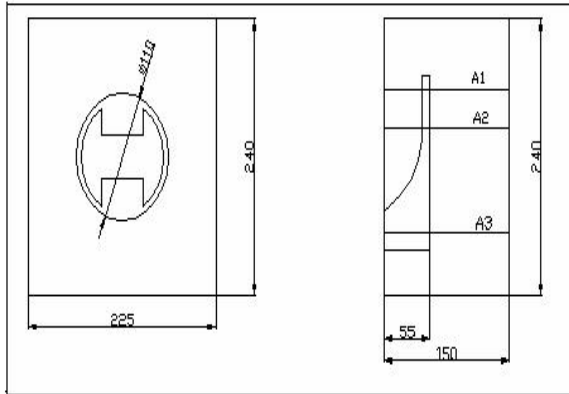


Figure-1. Top and section views showing locations for temperature profiles.

C. Assumptions

The following are the assumptions made for this analysis.

- Heat transfer takes place between mold & cast is only by pure conduction.
- Heat transfer from mold wall to air is by thermal convection only.
- The mold is filled with liquid metal with uniform initial temperature.
- Three different initial mold temperatures are 100 °C, 200 °C & 400 °C.
- Two different Initial casting temperatures are 700 °C & 800 °C
- No heat transfer during pouring of the molten metal to the mold.
- Good contact between castings and mold & punch during cooling process.

3. MATERIAL COMPOSITION

Piston Castings - Aluminum Silicon alloy

Standards:		
IS	:	7793 - 4625
BS	:	1490 - LM13

A. Material propositions

i.	Aluminum	-	86.1%
ii.	Silicon	-	12%
iii.	Copper	-	0.9%
iv.	Nickel	-	0.8%

B. Process parameter details

Table-1. Temperatures for various cases.

Case	Pouring	Mold & punch
	Temperature	Temperature
	T _p in K	T _m in K
1	973	373
2	973	473
3	973	673
4	1073	373
5	1073	473
6	1073	673

4. PERFORMANCE EVALUATION

The present work concerned with Simulation analysis of Aluminum - 12% wt silicon alloy piston castings using 2D finite element method. The analysis indicates clearly that solidification time is varying at different sections of the casting and it dependent upon casting and mold temperature. The following is the outcome of this simulation study.

- Thermal behavior of the casting and mold are studied at three different sections
- Time taken for solidification at three different cross section of the casting is determined for the casting temperature of 700 °C, 800 °C. and mold temperature of 100 °C, 200 °C & 400 °C.
- Cooling curves for the above casting and mold temperature are plotted.

The cooling curves are the locus of the temperature profile at a selected location with in the casting, as a function of time.

The Figures 2, 4, and 6 show that the temperature profile at top, mid and bottom section of the casting respectively. The Figures 3, 5 and 7 show that time vs casting temperature details at three different sections of the casting for the cast temperature of 973 deg k and mold temperature of 373 deg k at various nodal points.

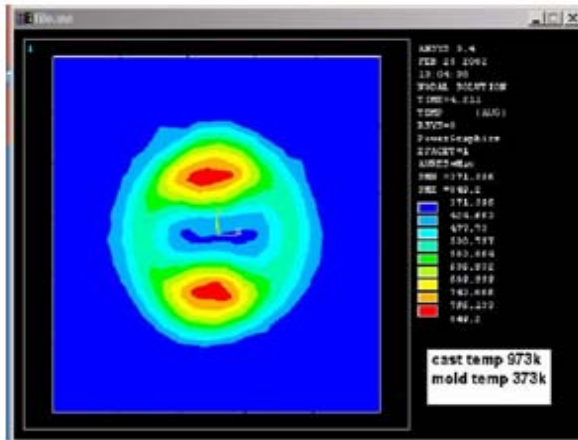


Figure-2. Temperature profile at top section of casting.

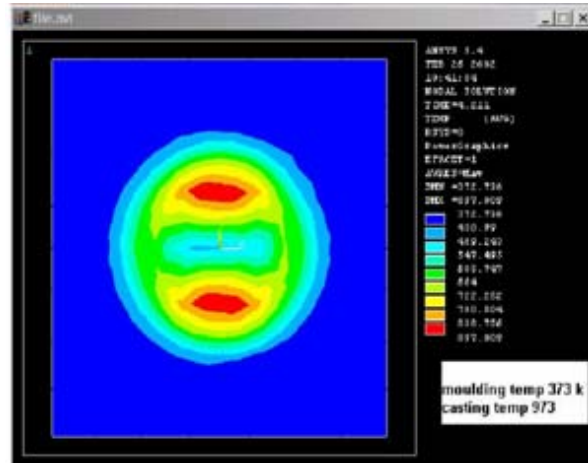


Figure-4. Temperature profile at mid section of casting.

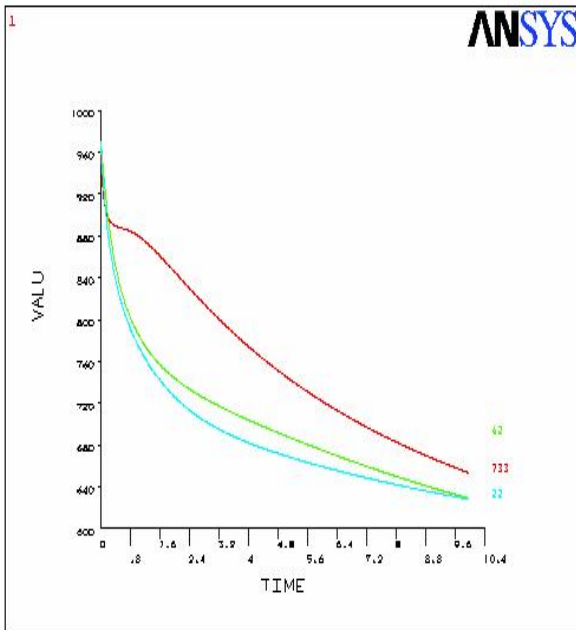


Figure-3. Variation of time at top section of casting.

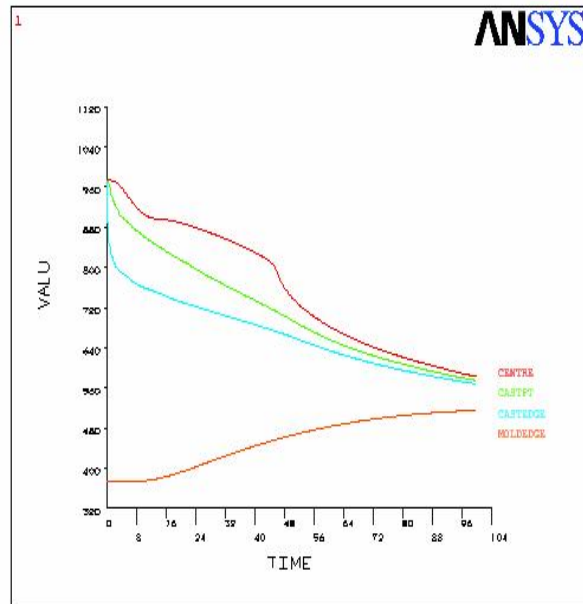


Figure-5. Variation of time at mid section of casting.

The thermal behaviour of the casting is studied at the different nodal positions of the casting such as near punch, at mid side, near mold side and at moldside.

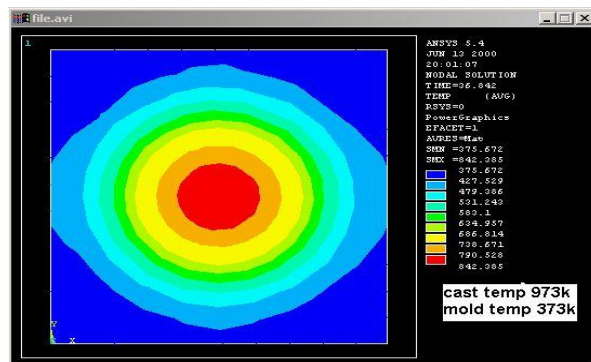


Figure-6. Temperature profile at bottom section of casting.

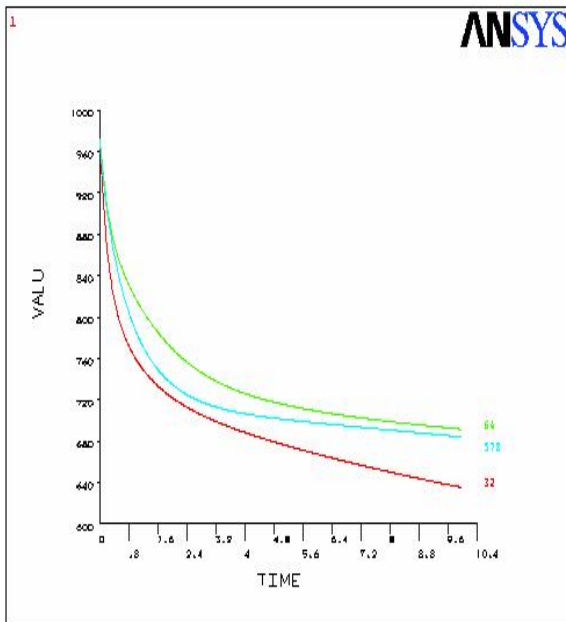


Figure-7. Variation of time at bottom section of casting.

5. CONCLUSIONS

In this paper an attempt is made to simulate thermal analysis of Al-12% Wt Si alloy piston castings at three different cross sections using ANSYS software package. A two dimensional view of Diesel engine piston casting size of 110mm dia and 148 mm Height with metallic mold size of 225 x 240mm were considered for the analysis.

Three different section views, one at top, one at middle and other one at bottom were considered. Two casting temperature of 700 °C, 800 °C with combination of mold temperature of 100 °C, 200 °C & 400 °C were considered for analysis which seems to be the appropriate value, for the casting process of the material system considered. From the analysis, it is observed that, minimum solidification time of 46 seconds achieved for casting temperature of 973 K and mold temperature of 373 K. For the same condition, in top section view, the skirt region solidifies first within one sec, and similar results are observed at bottom section also. It is also observed that at cast temperature of 1073 K and mold temperature of 673 K, solidification time is extended and it takes about 285 seconds. For the similar condition in top section view, it took 30 seconds and at mid section, it took about 75 seconds. The last point to solidify is mid side of the casting which takes 46 seconds for cast temperature 973 K and mold temperature 373 K.

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