International Journal of Thermal Technologies
ISSN 2277 - 4114

Available at http://inpressco.com/category/ijcet

Research Article

Investigations on Design and Thermal Analysis of Apple Type Wind Hub

Mohan Kumara Mangalam.S[a], Vivekanandhan.P[b*], Devi.P[c] Anand.S[b]

[a]Department of Mechanical Engineering Sathyabama University, Chennai- 603 103, India.
[b]Department of Mechanical Engineering SRM Easwari Engineering College, Chennai-89, India
[c]Anand Institute of Higher Technology, Chennai – 603 103, India.

Accepted 8 Nov.2012, Available online 1Dec. 2012, **Vol.2, No.4(Dec. 2012)**

Abstract

In the Manufacturing industries making of parts are originate with design stage and where the keen attention must be focused. The end quality of final finished part eventually gets enhanced once the efficient and effective design and analysis is carried out by means of providing the better key parameters. Thus the determination of the quality of end part to be held various steps in a manufacturing becomes inevitable so as to ensure the optimal cost and quality. At the same time, it is must to analysis the thermal characteristics during the pouring and curing of molten material during preparation of hub. This research work concerned with the design and thermal analysis of apple model windmill hub. This work comprises of two sections. The first section is concern with material selection and design of the apple type wind mill hub, which is the portion of the windmill which houses the bearings and has provisions for the attachment of the blades. In that section, the parameters required were calculated for casting design such as pouring time, gate and riser and the areas of chills. In the second section, the efforts have been made to investigate the thermal characteristics of designed hub. On observing that the prevalent design results in sound casting and from the simulation made in ANSYS, it witnessed the temperature distribution in different regions of the mould helps to study the thermal stresses in different regions. With this eventual experience the suggestions is made to improve the efficiency of the design aspect to reduce unnecessary losses that leads to flawless production of wind mill hub.

Keywords: *Apple model wind hub, Parameters, Casting, Design and Thermal Analysis*

1. Introduction

The hub is the part which houses the bearings and has the provisions for the attachment of the blades. Due to the continuous cyclic loading conditions it will result in fatigue which may lead to the failure of the rotating system. The hub should possess the better strength to withstand the physical stresses and it is based on the quality of the way it has manufactured especially casting process. Casting of a wind mill hub is the manufacturing process by which a molten Spheroidal Graphite Iron (SG Iron) material is poured in to a mould which contains a hollow cavity of the desired apple shape and then allowed to solidify. Based from the Industry observations, we planned to reduce the count of the risers used during the casting process what exists now, so as it will result in reduction of over flow in molten material without compromising in the quality as existed. In this work we have investigated and worked with the inevitable parameters which play a vital role in designing the apple model wind mill hub. From that we proposed the optimum parameters so as it will leads to achieve the optimum material usage and quality as well.

The rest of the paper structured as follows: Section II gives the broader view on the metallurgical background, Section III explains the process in the manufacturing of wind mill hub pattern, section IV details the results of thermal analysis, and finally the research work ends with conclusion.

2. Metallurgical background

Casting of wind mill hub is used by S.G.Iron, which stands for spheroidal graphite iron .It is also called nodular iron or ductile iron. In S.G.Iron, graphite is in the form of spheroids (nodules) and since it is more ductile than C.I. It is also called ductile iron .S.G.Iron consists of graphite spheroids of graphite dispersed in a matrix similar to that of steel. The only difference between grey cast iron and ductile cast iron (S.G.Iron) is in the shape of graphite phase.

S.G.iron is therefore a family of alloys which combine the principal advantages of grey iron (low melting point, good fluidity,castability ,excellent machinability and good wear resistance)with the engineering advantages of steel(high strength,toughness,ductility,hot workability and hardenability)

Mohan Kumara Mangalam.S, Vivekanandhan.P , Anand.S are working as Assistant Professor and Devi.P as senior Lecturer.
* Corresponding author's Email: vivekjpv@yahoo.co.in

Table1: Composition of S.G.Iron

Element	C	Combined C	Si	Mn	P	Ni	Mg
Percentage	3.6-4.2	0-0.02	1.25-2	0.35	0.08	0-1	0.05-0.08

It involves the use of magnesium as the modularizing elements often with cerium and other rare earth elements for neutralizing subversive elements, improving inoculation and limiting inoculation fade.

The problems of adding magnesium to molten cast iron are:

1. Low solubility
2. Low boiling point
3. Low relative density
4. Fume
5. Dross formation

A. Need of Magnesium Recovery (In percentage)

In the casting of hub, Magnesium reacts first with any sulphur present in the molten iron and only the free magnesium present in excess of this requirement is effective in producing nodular graphite. The level of residual magnesium in the iron and the amount, which combines, with sulphur in the base metal can be compared with the magnesium added to indicate the efficiency of the process.

This may be expressed as

Magnesium recovery (in %)=[0.75x(S% in base metal-S% residual) +residual%]xMg% added --------- **Eqn.1**

B. Treatment Method

Sandwich ladle method is a direct ladle treatment, where the alloy is continued in a recess built into the bottom of the ladle and is covered with small scrap or a plate of steel nodular iron. It is suitable only for alloys containing up to 10-15% magnesium.

3. Manufacturing of wind mill hub pattern

The manufacturing of windmill hub pattern involves the following steps:-

The first step is to represent the product specifications and requirements demand by the customer in the form of machine drawing. With the machine drawing as standard, the casting drawing is prepared considering the machine allowances. The next step is the process drawing, which involves selection of the parting line, the core details, tapering, print and pattern drafts. In the wind mill hub pattern, a print draft of 5 degree and a pattern draft of 1to 2 degree are provided. The pattern layout is drawn in 1:1 scale adding the contraction and other allowances to the process drawing dimensions, which are derived out of the original component drawing. It is used for direct reading of measurements for the use of pattern making and for the inspection of pattern.

From the layout pattern makers manufacture the master pattern in soft wood. Soft wood is used since it is a single use pattern. By casting aluminum pattern is made. The aluminum pattern is then machined to produce the required dimensions and surface finish. This aluminum pattern is used for the actual manufacture of casting.

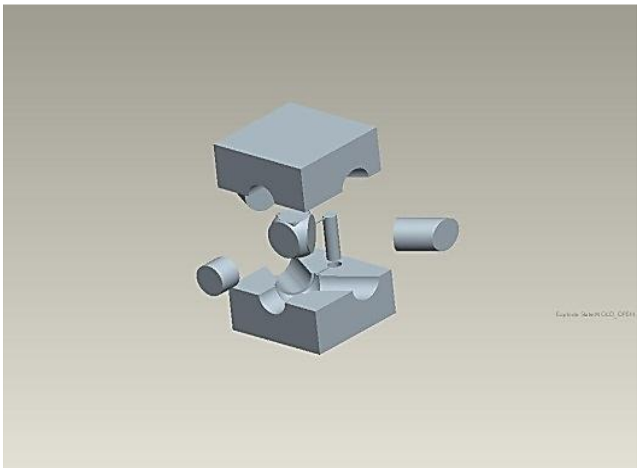

Fig.1 Model of apple shapel windmill hub in Pro-E

A. Core Making

Core sands are used for creating interior cavities of casting of the apple model hub. In the casting of wind mill hub the core used is shown in the figure.

1) Core Sand Specifications (CO_2 Sand)

Standard mixing shop for core sand of 600kg batch data is as follows:

Table 2: Core sand specification

Core chemicals and additives	Amount(in kg)
Sand	600
Sodium silicate	22.5(4.5% of silica sand)
Iron oxide	2.5(0.5% of silica sand)
Yellow dextrin	2.5(0.5% of silica sand)

4. Design and testing of core and moulding sand

The core and mould are tested for the following properties.

A. Moisture Content

Moisture content of sand is important for ensuring the ease of moulding, good quality mould and good castings. It is tested using infrared moisture balance which is direct reading machine.

B. Permeability

Permeability is the property of the moulding sand to allow the gases, formed upon freezing of the molten metal to pass through the mould. This is important to eliminate gas holes and pores in the castings. Permeability no. is defined as the volume of the air in cubic centimeter that will pass under a pressure of 1gm/cm2 through a specimen which is 1cm2 cross sectional area and 1cm deep. This is tested by using the direct reading permeability meter.

C. Dry Compression Strength

It is the compression strength of dry sand after passing CO2 gas. Sand mixing properties is shown in the below table.

Table 3: Sand mixing properties (as tested)

Sand properties	**Unit**	**Facing/tested**	**Backing/tested**
Permeability	No	200-300/300	200-300/280
Moisture	%	2-2.5/2.1	2-2.5/2.1
Dry compression strength	Psi	180-240/202	180-240/180

For the wind mill hub design, the CO_2 process of sand preparation is used. This is a gas-hardened process. The sand is mixed manually and rammed into the core box by pneumatic rammers.(A core box is essentially a type of pattern made of wood or metal into which sand is rammed to form a core). A solid core is thus made. In addition, a fabricated grid is provided as reinforcement to maintain the rigidity and strength of the core, considering the large size of the core. In addition, hooks are attached to the fabricated grid to facilitate handling the core. For the placement of the core in the mould cavity, core prints are used.

Pouring time in seconds (T) = 0.97 X (pouring wt) kg.
Pouring w. = riser wt. +casting wt. +
(pouring basin wt. +runner wt.)
Riser wt = {(casting wt) X 3.5 X5} /100
= {(4000) X 3.5 X 5}/100
= 700 kg
Casting wt = 4000 kg
Pouring basin + runner wt. + miscellaneous wt. = 950 kg.
Therefore, pouring wt in kg = 700+4000+950
= 5650 kg
Pouring time (T) = 0.97 x (5650)
= 5480.5 kg
= 62 sec.

Once the pouring time in seconds is calculated, the next step is to calculate the choke area, which means the lowest cross sectional area anywhere is the gating system.

The formula as devised by Mr. R.W. White for this choke area is-

Total choke area is cm^2 = Pouring wt in kg/ (1.1 X Pouring time)
Pouring wt in kg = 5650 kg.
Total choke area in cm^2 = 5650/ (1.1X62)
= $82.84 cm^2$
Choke area of each gate = 82.84/12
= $6.9 cm^2$

(Since there are, twelve gates present in the design)
Dia of the ingate (d) = √ {(choke area of each gate X4)/ π}
= √ {(690X4) / π}
= 2.96cm approximated to 30mm

A minimum of 30 mm distance is to be maintained between the neighboring gates. The junction between the gates and runner should be in the bottom runner and the bottom gate should be in the same plane. The position of the first gate is kept well past the sprue by100mm or more.

Thickness of gate = √ {cross sectional area of each gate}/4
= √ {6.9}/4=0.65 cm
Width of gate = 4X0.65=2.6cm

5. Steps in casting

A. Design of Riser
1) Riser 1

Riser diameter = modulus of riser X 4
Modulus of riser = modulus of casting X 1.2
Modulus of casting for rectangular riser (from data book)
M.C = a x b/ {2 X (a+b)}
a = 770/2 = 385 cm
b = 8.3 cm
So, M.C = 4.06 cm
Modulus of riser = 4.06 X 1.2
= 4.87
Riser diameter in cm = 4.87 X 4
= 19.5 cm
Riser height = 1.5 X diameter of riser
= 1.5 X 195 = 292.5 mm
= ~300 mm

2) Riser 2

a = 150 cm
b = 8.5 cm

Modulus of casting (M.C) = (8.5 X 150/ (2 X (8.5 + 150)))
= 4.02 cm

Modulus of riser (MR) = MC X 1.21
= 4.87 cm
Riser diameter = modulus of riser X 4
= 3.27 X 4 = 130.2mm
=150 mm approximated
= 300 mm

B. Design of runner

Total runner area for pressurized system = (8/3) X choke area
Total runner area = (8/3) X 82.84 cm^2
= 220.91 cm^2
The runner is diverted in to two since in the casting

Gross sectional area for each runner = 11045.33 mm^2
Runner diameter (d) = √ {(cross sectional area X 4)/π}
= 118.59 mm

Since there is no standard runner of 118.59 mm, two sleeves having diameter 70mm each is use as runners so that net area of the two sleeves is same as that of the cross sectional area of single runner. The runner is extended beyond the last gate as far as the condition permits generally by 100mm.
Area of runner bar =cross sectional area of the runner
= 11045.33mm^2
However, from the figure, area of runner bar = $2a^2$
= 11045.33
a = 74.32 mm (Take "a" as 70)
But a = (b+c)/2 = 70
So b = 65, c = 75
Runner bar is having a dimension of a= 70mm, b=65mm, c = 75mm.

C. Sprue (Pressurized)

The shape of the sprue should be generally downward tapering to prevent excessive turbulence and air aspiration.
The cross sectional area of bottom of the sprue
= 4/3 X choke area
= 11045.33 mm^2.
Since sprue area is same as that or runner area it is also having same dia of runner i.e., sprue diameter = 118.59 mm
Since there is no standard sprue of 118.59 mm, two sprue having 70mm each is used because the cross sectional area is same.

6. Analysis and discussions

A.Solid fraction

The Fig.1 shows the solid fraction profile at a section along the X-axis.

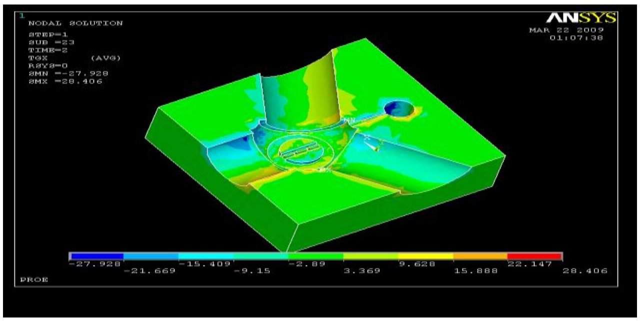

Fig.2 Solid Fraction Result

The Fig.2 represents the cooling rate at 75% solidification of casting. The blue region represents the maximum cooling rate.

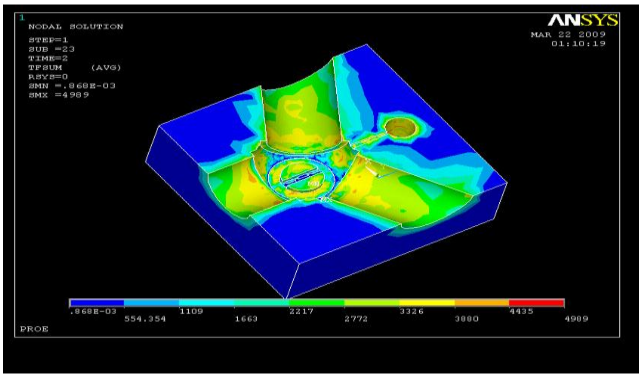

Fig.3 Cooling rate Result

B.Temperature distribution

The Fig. 4, the red colour indicates the highest temperature region in the hub. This temperature distribution corresponds to 75% solidification.

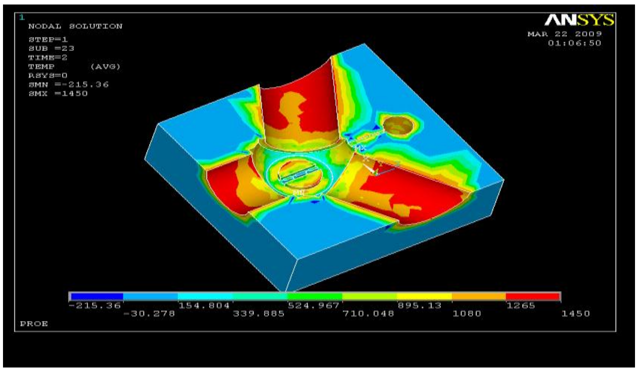

Fig.4 Temperature Distribution Result

C.Total solidification

The Fig.5, the red region has minimum solidification. This is the thicker portion of the hub. The solidifications in other portions are as shown in the solidification indicator.

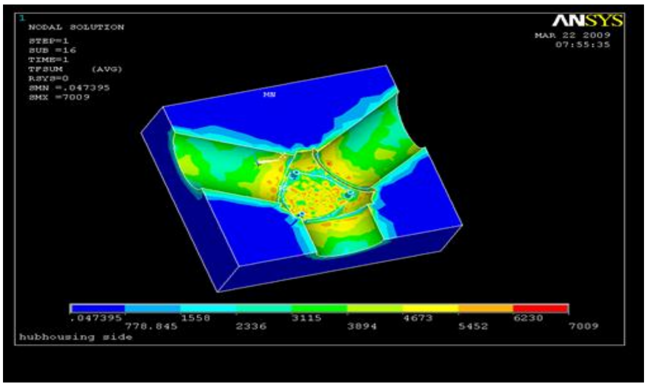

Fig.5. Distribution of heat during the solidification

D.Porosity

The Fig.6 represents the porosity at 75% solidification The diagram results about the less porosity due the better optimum casting parameters.

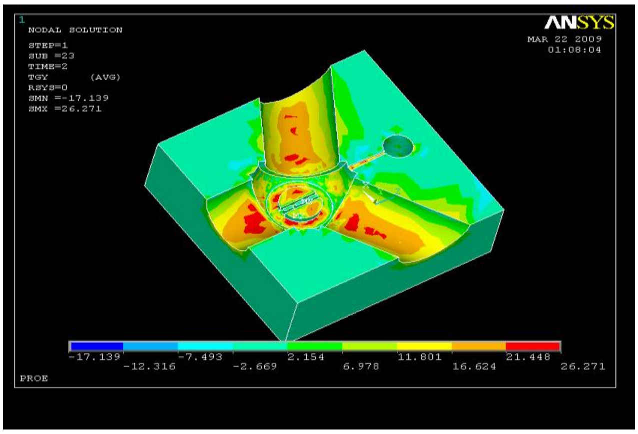

Fig.6 Porosity during the solidification

E.Hotspots

The Fig.7 mirrors the hot spots during the solidification.

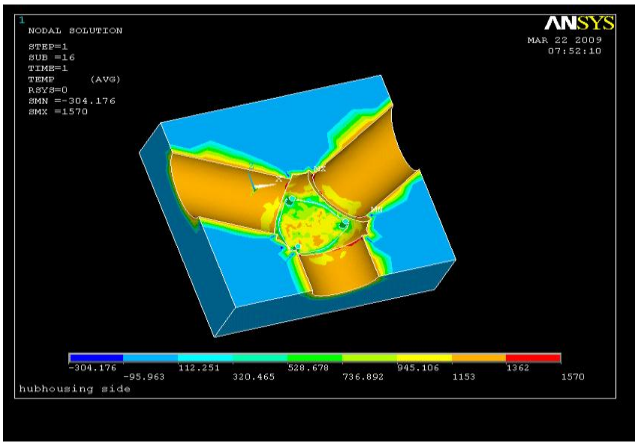

Fig.7. Hot spots

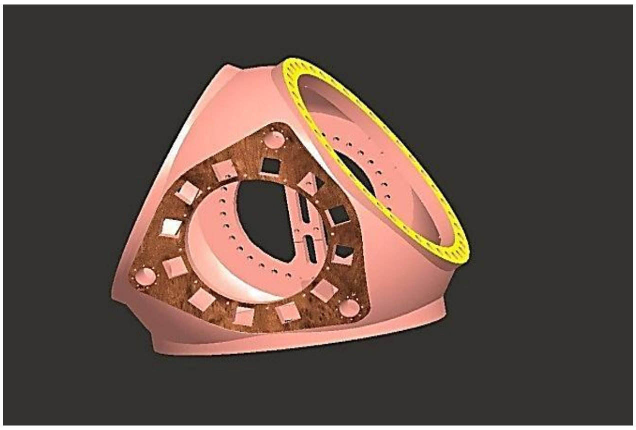

Fig.8. Apple model wind mill hub in Pro-E

7. Conclusions

From these investigations made , it is analyzed the optimum parameters to design, analysis and manufacturing of casting of windmill hub. On studying the existing gating system design being used in the company it was found to be using nine risers. The process of deciding the number of risers is not based on any calculations but purely based on the experience of the foundry man who employs various cut and try methods considering the fact of avoiding any defects in the final casting.

In the due course of the study it was found that the casting design was over risered, inefficient and incurred huge material losses. Therefore, the design was analyzed using 'ANSYS' software. Various process plots in analysis such as solid fraction, cooling rates, temperature distribution, total solidification, porosity and hotspots were predicted. This software predicted only three hotspots in windmill hub design which led to our conclusion of using three risers in the gating system design.

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