EXPERIMENTAL PROCESS TOWARDS METHODING OF GUIDE BLADE CARRIER CASTING

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Abstract— The present work experimentally investigates Methoding of Gudie Blade Carrier Casting based on the fact of utilizing maximum feeding distance of riser in the sand mould for medium size casting without defect in Guide Blade Carrier casting, to reduced the weight of GB Carrier & improve the rpm & efficiency which is simulated using the MAGMASOFT software. Casting is an ideal method for modeling. If the process of filling a mould with liquid metal and its subsequent solidification could be accurately and quickly modeled by computer, shrinkage cavities and other potential defects could be predicted. The effect of changing the gating system, the position and size of feeders and even the casting design could be simulated. The casting method could then be optimized before the design and method are finalized, so avoiding expensive and time consuming foundry trials.

Index Terms- AUTO-CAD, **SOLIDWORKS**, **MAGMASOFT**, **Feeding** *Distance* (FD) **Lateral Feeding Distance (**LFD). **End Zone Length** (EZL), *Riser Zone Length* (RZL)

1. INTRODUCTION

Methoding of Guide Blade Carrier casting need empirical rules as explained in experimental procedure. This was subsequently verified by modeling & Simulation using AUTO-CAD, SOLIDWORKS and MAGMASOFT software.

CFFP made 100 to 200 casting per annum. Guide Blade Carrier is a part of Gas Turbine or Steam Turbine made by cast steel, Grade G17CrMo9-10. The casting of GB Carrier has diameter 2666 mm & it is made in two half then bolted. So, radius is 1333mm.

Thus it is medium size casting. So pattern of GB Carrier is also medium in size & self core. In methoding of GB Carrier casting the problem comes in selection of the parting line so that moulding becomes easy, saves sand consumption and liquid metal requirement. The selection of number of risers for successful feeding was a critical problem.

During methoding, it was decided to provide self core after selecting parting line for ease of moulding. Then there was question of saving liquid metal. So threrfore.

It is decided to analyse the problem using MAG-MASOFT simulation software with exothermic/insulating risers *that* can give desirable result i.e. without shrinkage defect.

So the methoding of Turbine GB Carrier was done in systematic steps. Entire precautions were taken to make the casting right first time as it was a new casting. All the steps like, collection of plate sections for modulus calculation, identification of hot spots, design and location of risers and riser's necks, feeding distance verification, deciding number of risers and locating the 15 chills have been found to be satisfactory in simulation process.

The thermal analysis and solidification simulation per-formed by the MAGMASOFT software predicted no **Shrinkage** or any other kind of defect such as

Niyama, Tubulance in metal flow, Sand burn, Coldshut, Sand erosion etc.

At the end when the casting was actually made, no defects of any kind were found on the surface or inside the casting section at any location .So the various calculations of the methoding used predictions of soundness of casting by simulation was fully validated by production of the sound casting right first time.
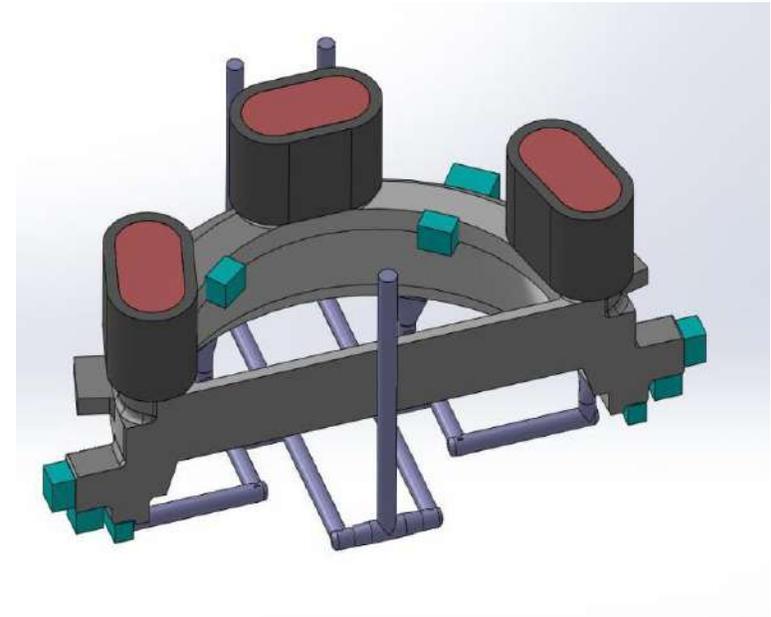
Figure-1.1. 3-D solid Model of **GB CARRIER** with **Chill, Riser, Sleeves, Neck & Runner**. In **SOLIDWORKS** Software.
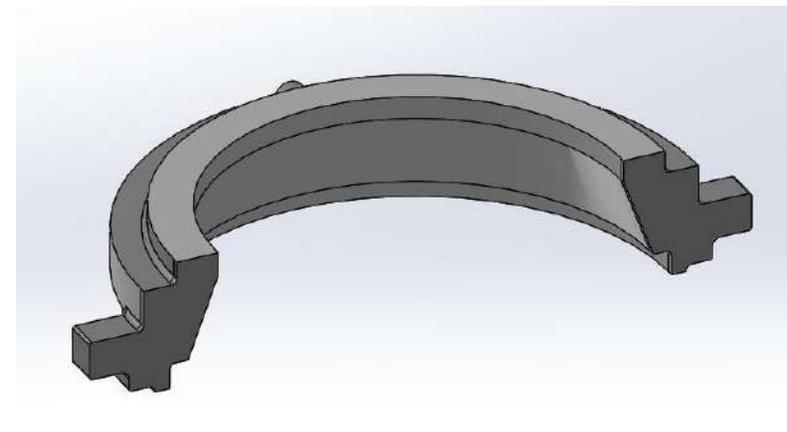
Figure-1.2 Casting Modell view of GB CARRIER

2. LITERATURE REVIEW:

2.1 FEEDER', 'FEEDER HEAD' OR A 'RISER'

During the cooling and solidification of most metals and alloys, there is a reduction in the metal volume known as shrinkage. To avoid shrinkage porosity, it is Necessary to ensure that there is a sufficient supply of additional molten metal, available as the casting is so-

Lidifying, to fill the cavities that would otherwise form. This is known as _feeding the casting' and the reser voir that supplies the feed metal is known as a **feeder', 'feeder head' or a 'riser'.**

Since liquid metal from the feeder cannot reach for an indefinite distance into the casting, it follows that one feeder may only be capable of feeding part of the Whole casting. The feeding distance must therefore be calculated to determine the number of feeders required to feed any given casting.

The last region to solidify in such a casting section is termed a **hot spot**. Once the hot spots in a casting are identified, a riser must be placed adjacent to each hot spot. This ensures that feed metal will be available to feed each hot spot until solidification is complete.

The riser also serves as a **heat reservoir**, creating a temperature gradient that induces **directional solidification.** Without directional solidification, liquid metal in the casting may be cut off from the riser, resulting in the development of internal porosity. Two criteria determine whether or not a riser is adequate: 1) the solidification time of the riser relative to that of the casting, and 2) the feeding distance of the riser.

The **feeding distance (FD)** is the maximum distance over which a riser can supply feed metal free of internal porosity. When multiple risers are present , the feeding between the risers is called lateral feeding , **the lateral feeding distance (LFD)**

There are two terms that are important to understand when considering feeding distances: *riser zone* and *end zone*. Since the riser remains hotter than the casting section to be fed, it provides a temperature gradient.

that facilitates feeding. The length over which this *riser effect* acts to prevent shrinkage porosity is called the *riser zone length* (RZL). This is illustrated for a top riser in Figure 6. The cooling effect of the mold at the end of a casting section also provides a temperature gradient along the length of the casting section to be fed. This is called the *end effect*, and it produces a sound casting over the so-called *end zone length* (EZL). This is depicted in Figure 7. The feeding distances are functions of RZL and EZL.

2.2 Chills:

Chill blocks are inserted into the mold to enhance the feeding distance by creating a steeper temperature Gradient. The chill surface in contact with the casting must be clean   and dry. Surface roughness has little effect on heat   transfer characteristics. Chills can be used with a thin refractory coating or carbon black. Cast iron or steel chills, for all practical purposes, are equally effective. Water-cooled copper chills are more effective than uncooled cast iron or graphite. However, the effectiveness of these external chills is greatly reduced by the formation of a gap at the casting/chill interface as the casting shrinks away from the chill. may deteriorate with use. Chills are used at the end of castings sections and as drag chills between two risers.

2.3 Gating System Design:

The liquid metal that runs through various channels in the mould obeys the Bernoulli theorem states that the total energy constant at any section. The same stated in the equation from ignoring frictional losses is

$$H+P/W+V^2/2g = \text{constant}$$

Where, H = potential head, m

P = pressure

V = liquid velocity, m/s

g = gravitational constant on earth, 9.8 m/s^2

Quantitavely Bernoulli's theorem may not be applied, it helps to understand quantitavely, the metal flow in the sand mould. As the metal enters in the pouring basin it has the highest potential energy with no kinetic or pressure energies. But as the metal moves through the gating system , a loss of energy occurs because of the friction between the molten metal and the mould walls. Also heat is continuously lost through the mould material through it is not represented in the Bernoulli's equation[29]. This lets the casting solidify.

Another law of fluid mechanics, which is useful in understanding the gating behaviour, is the law of continuity, which says the volume of metal flowing at any section in the mould is constant. The same in the equation form can be

$$Q = A1V1 = A2V2$$

Where, Q = rate of flow, m^3/s

A = area of cross-section, m^2

V = velocity of metal flow, m/s

It was suggested earlier that the sprues are tapered to reduce the aspiration of air due to increases velocity as the metal enters or flows down the sprue. This conclusion was drawn by applying the above equation of continuity along with the Bernoulli's equation.

Sprue: The Sprue should be tapered down to take into the ac-count the gain in velocity of the metal as it flows down reducing the air aspiration. The exact tapering can be calculated by the equation of continuity. Denoting the top and chock section of the sprue by the sub-script t and c respectively, we get

$$A1V1 = A2V2$$

Gating Ratio:

The gating ratio refers to the proportion of the cross sectional areas between the sprue, runner, and ingates and is generally denoted as sprue area runner area ingate area. Depending on the choke area there can be two types of gating system :

1. Non-pressurized
2. pressurized

A Non-pressurized gating system having choke at the bottom of the sprue base, having total runner area and ingates then the sprue area. In this system there is no pressure existing in the metal flow system and thus it helps reduce turbulence. This is particularly useful for the casting drossy alloys such as aluminum and magnesium alloys. There have tapered sprue, sprue base well and pouring basins. When the metal is to enter the mould cavity through multiple ingates, the cross-section of the runner should accordingly be reduced at each of a runner break up to allow for equal distribution of metal through all ingates.

A pressurized gating system normally having the ingate area smaller, thus maintaining the back pressure throughout the gating system. Because of this back pressure in this gating system, there is more turbulence and generally flows full and there by can minimize the air aspiration even when a straight sprue is used (after the initial stages of pouring).These system s generally provide a higher casting yield since the volume of metal use up in the runners and ingates is reduced. Because of the turbulence and the associated dross formation, this type of gating is not used for light alloys but can be advantageously used for ferrous casting.

For steel a Non-pressurized gating system used

 Nozzle : sprue : Runner : Ingate

 1 :1.4-1.7 : 2.5-4 : 4-7

3. Experimental Procedures

3.1 Problem Visualization

The work is based on the fact of utilizing maximum feeding distance of riser in the sand mould for large size casting without defect in Bowl casting, which is simulated using the solstar software.

Table 3.1 Chemical analysis of GB Carrier casting

METAL GRADE	COMPOSITION SPECIFIED	C MAX	S MAX	P MAX	Si MAX	Mn MAX	Ni MAX	Cr MAX	Mo MAX	V MAX	Cu MAX
G17CrMo 9-10		0.2	0.02	0.02	0.6	0.9	0.4	2.5	1.2	0.05	0.3

3.2 Methoding of "Bowl" or Technology Preparation of "bowl"

1. Drawing no. – 0-38200-4013399-12 Rev.A

2. Material grade – G17CrMo9-10

3. As cast weight - 2300 kg

3.3 Steps for Technology Preparation-

1. Study of component drawing:

See the different view of component, Machining allowances and tolerances are carefully observed. And take double allowances 15 to 20 mm as mention in the component drawing for machining.

2. Selection of parting line:

Correct selection of parting plane is very important for saving of material, cost and time.

3. Modulus calculation of piece:

Draw the 2-D drawing of component on Auto-Cad and calculate the area. A = 111648.6 mm² = 11.16dm²
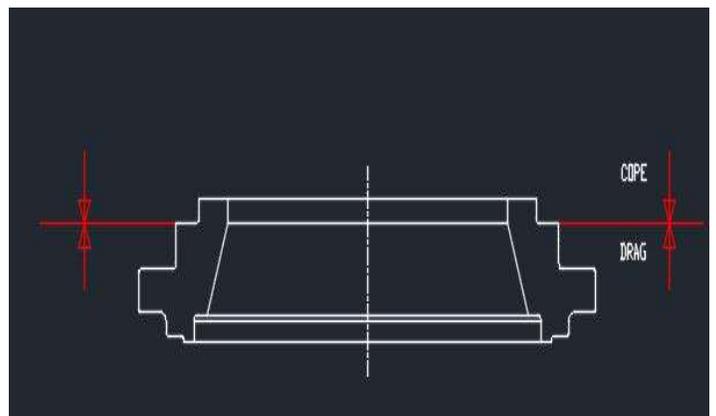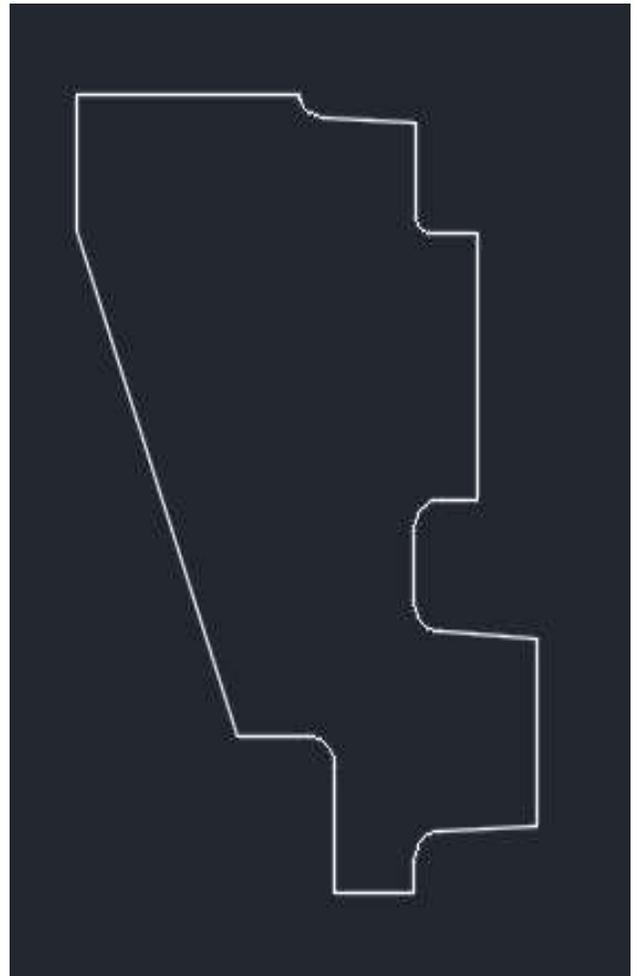
2-D drawing of component on Auto-Cad

▢   Once area is calculated , then calculate volume.

V = 1251618545.8 mm³ = 1251.6 dm³

3-D drawing of component on Auto-Cad

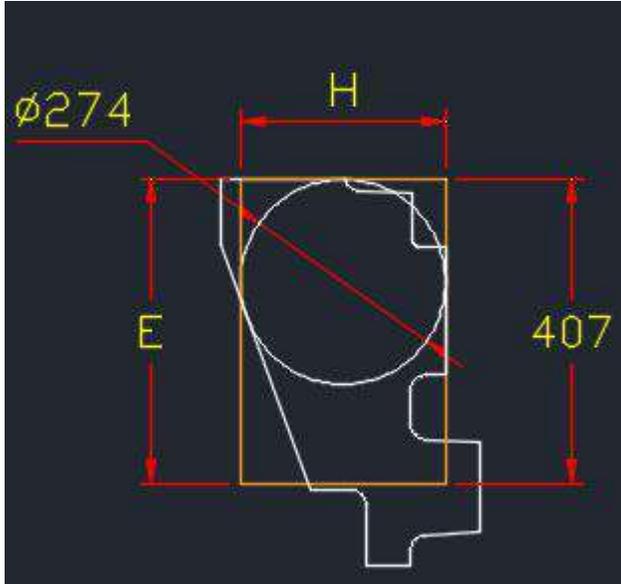▢   Calculate the hot spot thickness (maxi-mum inscribed diameter)

Figure shows location of hot-spot in the 2-D of GB Carrier on Auto-Cad

We know H = 274 mm = D = 2.74 dm

    Area=E/H
    E=AREA/H
     =11.16/H
     =11.16/2.74
     = 4.07dm

MODULUS= VOLUME/COOLING SURFACE ARE OR AREA/PEREMETER

      =11.16/2(4.07+2.74)
      =0.82dm OR 8.2 cm

4. Feeding distance and extremity effect calculation:

Feeding distance or —feeding area —Al

Directional solidification occurs from the low tem perature areas toward s the high temperature areas around hot-top The parts of the piece located between hot - top , which will be free from shrinkage ,
are referred to as —feeding areas.

Calculation of —feeding area :

Al = n x H with n function of ɼ and H ; ɼ = E/ H

Note – numerator is always m ore than that of denominator.

Al = n x H with n function of ɼ and H ; ɼ = E/H

Note – numerator is always more than that of denominator.

r = E/H = 4.07/2.74 = 1.48 dm

For ɼ = 1.48 , value of n from graph is 1.6.

Feeding distance (Al) = n x H = 1.6 x 2.74 = 4.384 dm

Extremity effect or —extremity areas —Ex

The free end s of the piece diffuse rapidly heat through the

sand of the mould , thus generating a directional solid-

ification process and the sound part is called —extremity area.

5. Calculation of hot-top diameter:

Modulus of hot-top (Mm) = 1.2 x Mp

D hot-top ($\emptyset$) = Yx Mp

D hot-top ($\emptyset$) = 6 x Mp   (for Ring type hot-top)

          = 4.8 x Mp(for spot type hot-top)

We have taken spot hot-top –

D hot-top($\emptyset$) = 4.8 x Mp

          = 4.8 x 0.82

          = 3.936 dm

7.   Neck calculation:

Diameter of the neck Dc = 4.2 to 4.4 Mp
Height of the neck Hc = 0.15 Dc with a minimum of 25 mm
to allow flame cutting.

6. Calculation of number of hot-tops:

n‖ is the number of hot-top required for a proper feeding of
the piece.

Its value is dependent on :

☐

The feeding distance
TH E extremity effect
The diameter of hot-top

After the feeding distance , the extremity effect , the
approximate diameter of the hot-top , It is simple to
determine the number of hot-tops to suit the part to be fed.

8. Padding calculation

9. Chills calculation

Let E be the casting thickness and e the thickness of the
chill , the maximum effect of surface chill is

e = E/2 i.e equal to the casting modulus.

If the chills is placed on vertical side of the casting the
module of the chill is equal to 0.7 times the module , e=
0.7 E.

In —GB Carrier, at outer surface E=300, e = 0.7 x
          300
               = 0.7 x 300 = 210 Ξ 200 mm

Use 1 chills Between two riser.

W = 1 x e = 200 mm

L = 2 x e = 2 x 200 = 400 mm H =

1 x e = 2 00 mm

1 chill used at four places so total 2 chills used of 200 x 400
x 200.

Second type of chills used of following dimensions. E =0.7 x

165

=   0.7 x 165

=   115 Ξ 100 mm Use

2 chills together . W = 1

x e = 100 mm L = 1 x e =

100 mm H = 1 x e = 100

mm

2 chills used at 2 places so 4 chills of 100 x 100 x 100.

Note: In similar way we used 6 types of Chill & total no of chills are 15 in this casting.
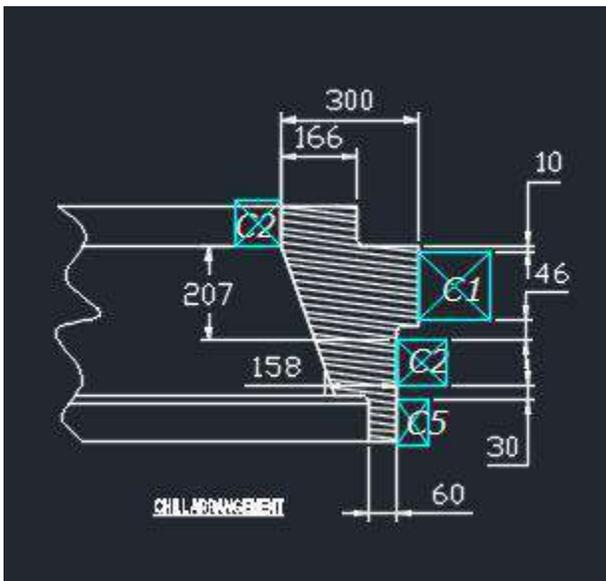
10. Gating system calculation:

For steel a Non-pressurized gating system used

Nozzle : sprue : Runner : Ingate

1 : 1.4-1.7 : 2.5-4 : 4-7

NOZZLE SIZE

For 2.3 Ton nozzle of Dia 60 – 1No.

Sprue size calculation

Nozzle : sprue = 1: 1.4

1.4 x area of nozzle = area of sprue

$1.4 \times (D^2 nz /4) = (D^2 sp /4)$

D sp = 1.4 x 60x60

Dsp = 71 Ξ 80 mm

Runner size calculation

Nozzle : runner = 1: 2.5

2.5 x area of nozzle = area of runner

$2.5 \times (D^2 nz /4) = (D^2 runner /4) \times 2$

(e take two side opening of runner)

D runner = 64.8 Ξ 70 mm

Ingate size calculation

We require 4 nos. of ingate according to the

GB carrier shape.

Nozzle : ingate = 1: 4

1.4 x area of nozzle = area of ingate x $(D^2 nz /4) = (D^2$

ingate /4) x 4

D $_{ingate}$ Ξ 60 mm

Exothermic/Insulating powder calculation
Take 10-25% of riser height

Thus 10% of 550 = 55mm

11 –AS CAST LIQUID METAL REQUIREMENT

Liquid metal required for casting before machining =

total volume of casting x density of steel

Volume of the casting without tie bar = 294.872 dm^3 or 0.295 m^3

Density of steel = 7.8 kg/dm^3 or 7.8 g/cc or 7800 kg/m^3

    ▢   Liquid metal required for casting before machining = 0.295 x 7800 = 2300 Kgs

Approximately 2.3 TONNE

    ▢   FEEDER WEIGHT- 1021 KG

    ▢   RUNNER WEIGHT-300 KG

    ▢   PADDING+RISER NECK+TEST BAR- 460KG

TOTAL LIQUID METAL= 2300+1021+300+460

= 4081KG (APPROX. 4.1 TONNE)

4. Result & Discussion, Observations

Casting process is an ideal technique for modelling. If the process of filling a mould with liquid metal and its subsequent solidification could be accurately and quickly modelled by computer, shrinkage cavities and other potential defects could be predicted. The effect of changing the gating system, the position and size of feeders and even the casting design could be simulated. Casting method could then be optimised before the design and method are finalised, so avoiding expensive and time consuming foundry trials.

Due to numerous availability of commercial software packages process improving all the time. The model-ling of heat flow and solidification of castings is now well advanced. Modelling the filling of castings is more difficult since both turbulent and quiescent flow in complex shaped cavities may be involved. The effects of surface oxide films and bubble entrainment are further complications and it is not easy to check the predictions experimentally in complex moulds.

4.1 Solidification modeling

Purpose of solidification modeling

1. Predict the pattern of solidification, indicating where shrinkage cavities and associated defects may arise.

2. Simulate solidification with the casting in various positions, so that the optimum position may be selected.

3. Calculate the volumes and weights of all the different materials in the solid model. Provide a choice of quality levels, allowing for example the highlighting or ignoring of micro-porosity.

4.2 Mould filling simulation

MAGMA soft have developed such programs which allow the visualization and animation of the movement of the melt surface during filling.

4.3 The MAGMASOFT solidification program:

(1) Using the casting drawing, determine model scale and element size.

(2) Create the solid model of the casting.

(3) Create the solid model of the proposed production method (feeders, chills, insulators etc.). Use the pro-gram's own feeder-size calculator if required.

(4) Perform thermal analysis to establish the order of solidification.

(5) Perform solidification simulation to a set quality standard, for the selected alloy incorporating shrink-age percentage, in gate effects etc. This results in the model being changed to the predicted final shape (internal and external) of the casting showing size, shape and location of shrinkage cavities in casting and feeders.

(6) Investigate with the help non-destructive testing assumed shrinkage by viewing and plotting of 3D 'X-rays' and sections of the model in 2D slices or 3D sections and relating predicted defects to solidification contours and required quality standards.

(7) If assumed defects do not meet the required quality standard, develop an improved production method and repeat the procedures.

4.4 Solid modeling

Create a three-dimensional model of the component with its associated method. This will often take the greatest proportion of time, as much as 70%. The MAGMASOFT programme has its own solid modeller/mesh generator capable of modelling the most complex casting shapes. Depending on the computer hardware specification, models can contain up to 256 million elements but most models use between 2 and 64 million elements. Figure 1.1 shows a solid model

of a 2300 kg steel GB Carrier casting containing 20 million elements produced in less than 3 hours.

It is possible to transfer 3D models from any other CAD system using Stereolithography STL files created by them. These models can then be manipulated within the solidification software so that the method can be added.

4.5 Thermal analysis

Calculates the simulated heat flow b/w the elements of the solid model which gives a 'thermal picture' of the conditions prevailing at a specific point in time. MAGMASOFT thermal analysis simulates 'heat flow' in 26 directions, with each cuboid element of metal, mould, chill etc. being the equivalent of the centre block of a 'Rubik' cube (27 cubes).
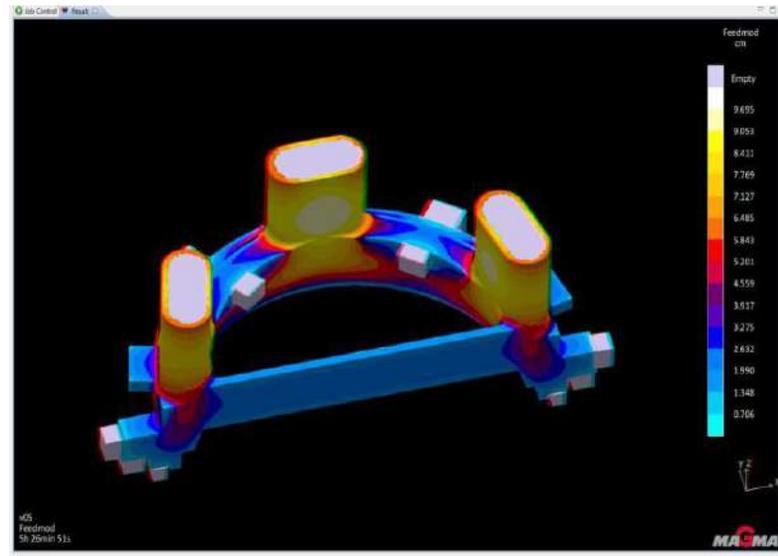

Figure 4.1 & 4.2 Thermal analysis of GB Carrier casting in MAGMASOFT.
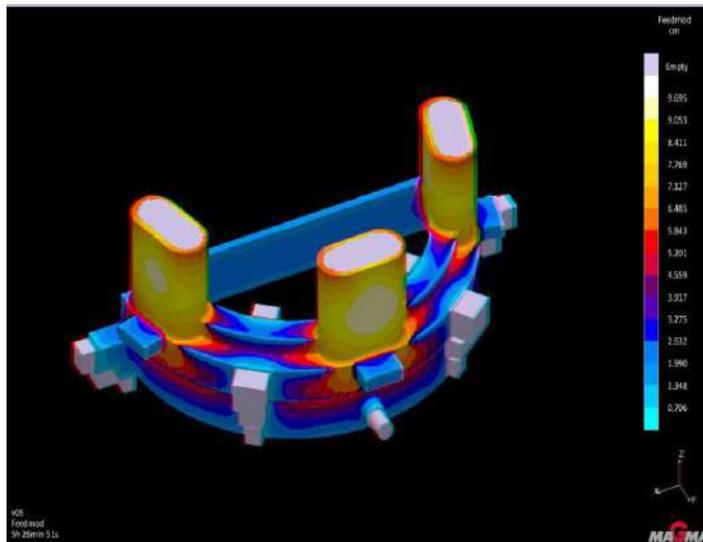
4.6 Solidification simulation

Allocated an order of solidification . MAGMASOFT then carries out a solidification simulation of the metal elements, by solidifying.

(1) The solidified elements are assumed to have in-creased in density, accompanied by a loss of volume.

(2) This loss (liquid shrinkage) is calculated by multi-plying the number of solidifying elements by the input shrinkage factor for the alloy.

(3) The software calculates (according to the alloy and the required quality standard) whether this shrinkage will manifest itself in the form of a cavity and, if so, how big the cavity will be.

(4) The resultant cavity is placed in the remaining liquid of the section of which it is a part. Where it resides in this remaining liquid depends on the type of alloy.
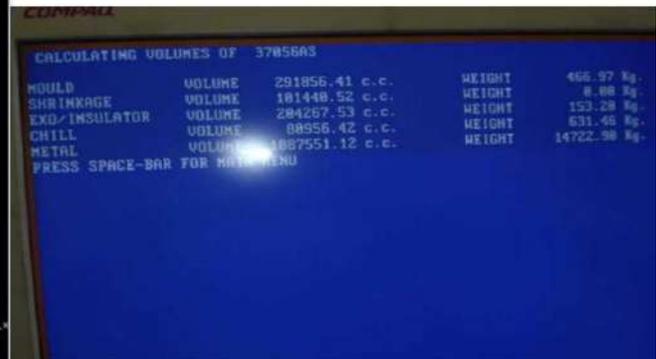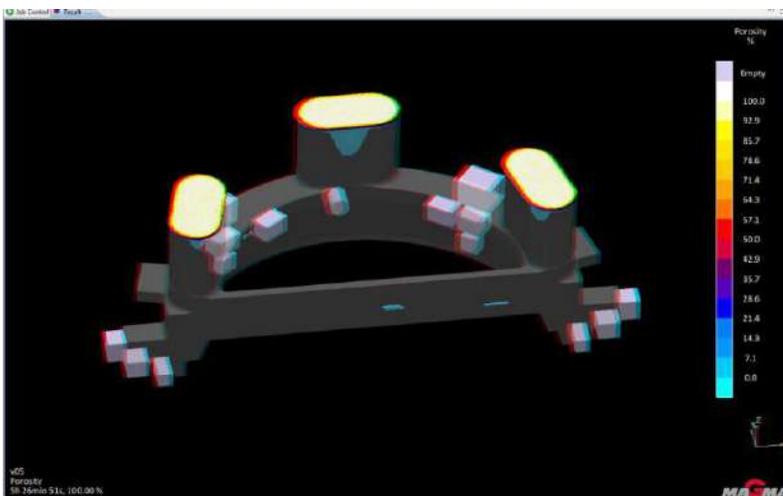
4.7 Feeder size and weight calculation
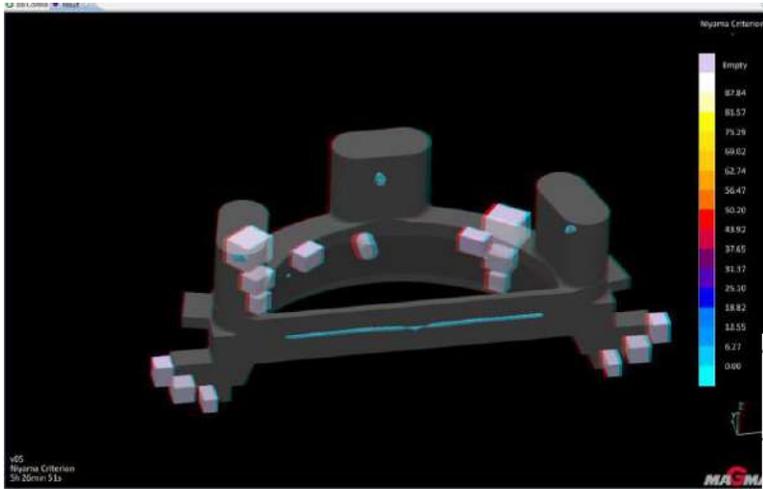

Figure 4.5 Calculations of Volumes of GB Carrier

Figure 4.3 **Porosity** Defect analysis Pic of GB Carrier in **Magma soft.**

Figure 4.3 **Niyama** Defect analysis Pic

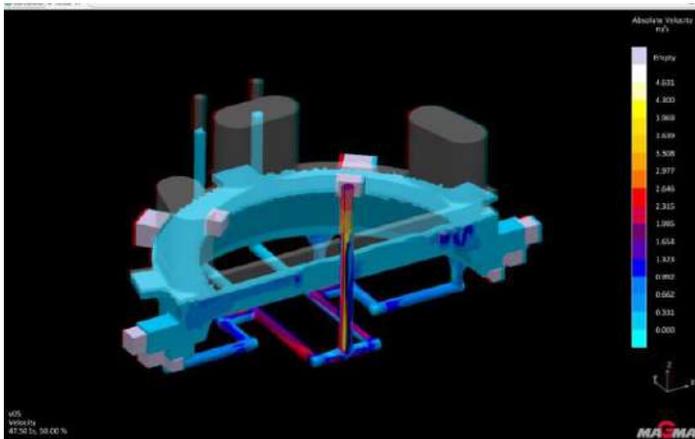of GB Carrier in **Magma soft.**

Figure 4.3 **Velocity of Metal flow** analysis Pic of GB

Carrier in **Magmasoft.**

4.8 Cost benefits of solidification simulation

Table Shows a simplified trialing process for making a cast component, the cycle may need repeating sever-al times before product of acceptable quality is made. Solidification simulation software such as MAGMASOFT can be used to electronically sample the method and cut down on the
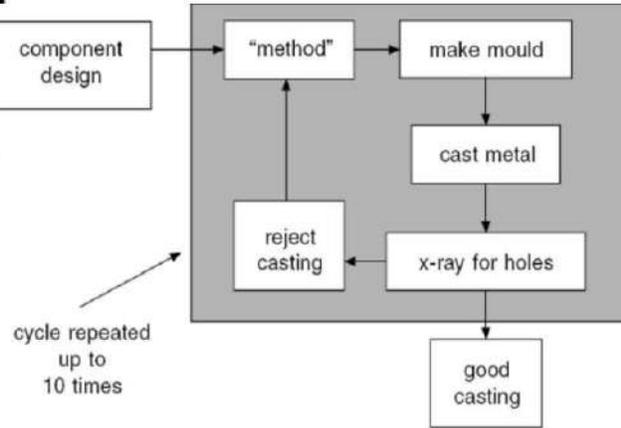

Figure **4.6** Trailing process for making a cast component of acceptableable quality

Table-4.1. Pre & post MAGMASOFT methoding accuracy in

Steel Foundry.

Trial methods	Before MAGMASOFT	Using MAGMASOFT
Right first time	50%	99%
Two attempts	85%	100%
Three attempts	98%	100%

Table-4.2. Probability of right first time reported by

MAGMASOFT user

Steel	99%
Iron	90-99%
Non-Ferrous (short freezing range alloys)	99%
Non-Ferrous (long freezing range alloys)	85-95%

4. Conclusions

 Based on the present work following conclusions have been drawn:

1. Riser and gating system were designed applying empirical rules and technological prudence. From the simulation of solidification it was found that the design of risers and gating sys-tem are working well. The actual manufacturing of the GB Carrier casting was found to be successful and no defects were found in the casting.

2. The design of the riser and gating system found alright on verification by simulation saved valuable time and any trial production.

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