CASTING SIMULATION TO IDENTIFY SHRINKAGE ZONES & REMEDIES FOR MANUFACTURING DEFECT FREE FLYWHEEL CASTINGS

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Abstract: **A flywheel is a rotating mechanical device that is used to store rotational energy. Flywheel has a significant moment of inertia, and thus resist changes in rotational speed .The amount of energy stored in a flywheel is proportional to the square of its rotational speed. Rejection rate is one of the major issues in Indian foundry. Foundries try to reduce rejection by experimenting with process parameters or modifying method and tooling design which reduces the quality of castings and increase cost of production. Shrinkage, blowhole, porosity, etc. are the main casting defects which is responsible to increase casting rejection rate. In present theories, good flywheel casting purposes we have to simulate the parameter which is helpful for defect free flywheel casting. For good casting purpose, first of all we have to identify casting defect & location of flywheel casting. After the defect identification & visualization we can simulate the responsible parameter & get good casting of flywheel.**

Keywords: **flywheel, Shrinkage, casting simulation, Actual trials.**

I. INTRODUCTION

A flywheel is a mechanical device successfully designed to efficiently store rotational energy .Flywheel resist changes in rotational speed by their rotational speed. The way to change a flywheels stored energy is by increasing or decreasing its rotational speed by applying a torque aligned with its axis of symmetry. Flywheel is useful in smoothing the power output of an energy source. For example, flywheels are used in reciprocating engines because the active torque from the individual piston is intermittent. In energy storage systems, delivering energy at rates beyond the ability of an energy source.[1] This is achieved by collecting energy in flywheel overtime & then releasing it quickly, at rates that exceed the abilities of the energy source. Flywheels store energy very efficiently (high turn-around efficiency) & have the potential for very high specific power compared with batteries. Flywheels have very high output potential & relative long life. Flywheels are relatively unaffected by ambient temperature extremes. For simulation purpose 3D simulation degree, Autocast, FLOW-3D CAST, PROCAST, Finite solutions casting simulation software,MAGMA5,Etc software's available in market which is provide number of options to get easy solutions.

Fig 1.1: Flywheel

2 DEFECTS: SHRINKAGE, POROSITY, BLOWHOLE, METALLURGICAL DEFECTS

A casting defect is an undesired irregularity in a metal casting process. Some defects can be tolerated while others can be repaired, otherwise they must be eliminated. They are broken down into five main categories: gas porosity, Shrinkage defects, mould material defects, pouring metal defects, and metallurgical defects.[2-3]

2.1 SHRINKAGE

Fig 2.1: Shrinkage

The most common causes of shrinkage are related to the casting sprue,which is the passage through which molten metal is poured into a mold.In some areas,such as the heavy sections of the mold, the metal takes longer to contract & solidify which reduces feed material availability & increses the likelihood of shrinkage,especially if the sprue is too small for the valume of flow.a properly sized sprue attached directly to the heavy section can feel the cavty & provide the feed material necessary to counteract shrinkage as cooling occeres. In addition, using a rounded,rather than a flat oe sprue can further reduce the risk of forming defects.Using a narrow or tapperedsprue can results in the molten metal being sprayed rather than poured into the cavity when this happens,certains section of the workpiece begin to solidify before the entire mould is filled.[4-8] Molten flow into the cavity should be as uniform as possible, & a larger central sprue or a multile sprue arrangement can help achieve the even supply of material.

3 Problem Identification & methodology

Identify & visualize defects, eliminate defects with the help of PROCAST software. In present theories we have to identify the defects & visualization of the zone area of shrinkage defect of flywheel. What is the main reasons & parameter behind the opening shrinkage defect during casting we have to analyse.

Based upon the above mentioned literature PROCAST software is used for meshing and casting simulation on the flywheel. The present CAD model is getting from as per customer requirement. The model of flywheel is shown below in fig3.1

3.1CAD:
In this phase, design is provided by customer as per their requirement now we have to do modelling of flywheel.
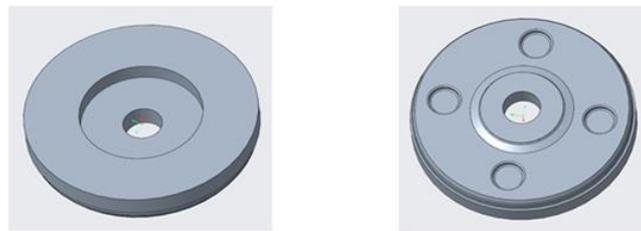

Fig 3.1: CAD Model of flywheel

3.2 GATING SYSTEM
The assembly of channel which facilitates the molten metal to enter into the mould cavity is known as Gating system. Alternatively, the gating system refers to all passage ways through which molten metal passes to enter into the mould cavity. To fill up the mould cavity is needed some arrangement in between this arrangement runner, riser, sprue cup, filter, etc. must be present with their proper specification. Total gating system arrangement is shown in fig3.2 as below.
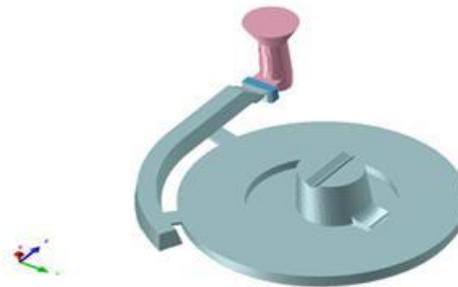
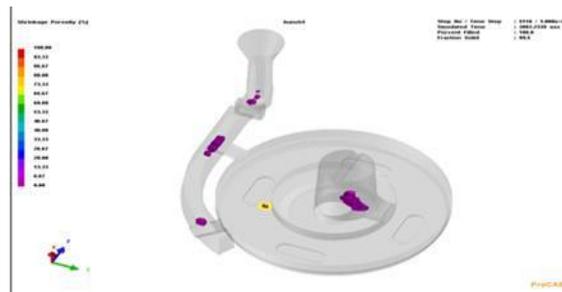

Fig 3.2: Gating system

3.3SAND RISER

Fig3.3: Centre pouring with sand riser

In general, casting procedure prefer centre pouring with centre riser. When we did it that's time it concludes that sand riser is with centre pouring is failed.

4 Simulations & Trials

4.1 Shrinkage Identification using PROCAST

When simulation is done & checks the results then we conclude that Shrinkage is opened in flywheel casting & caught the zone on shrinkage area. By using PROCAST simulation is done by as per general procedure. As per casting simulation process it could be denoted that shrinkage is opened in flywheel casting.It shows in below fig4.1
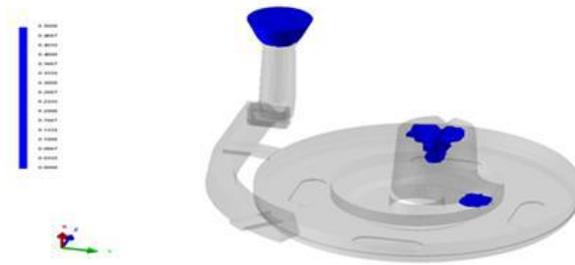

Fig 4.1: Shrinkage Identification

4.2Actual Physical Trial:

As per simulation data & results when we got it then it concludes that, shrinkage zone by using PROCAST & actual physical trial is remain same. When we check out the casting of flywheel that's time never any kind of roughness present but when we decided for confirmation then we cut the flywheel model perpendicularly & take cross section of casting then actual shrinkage is visualise.Actual physical trial, shrinkage is open in flywheel casting which shows below fig4.3.

Fig 4.2: Actual Physical trial

4.3 HIGH MODULUS

As per above mentioned data, Shrinkage defect is open in flywheel casting. When we studied in details then it could be visualise that solidification time & temperature cooling rate between casting & sand riser is low due to this parameter shrinkage defect is open in flywheel casting. It would be shown in below fig 4.3
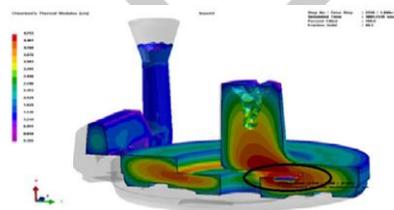

Fig 4.3: High modulus

As per above situation we conclude that simulation results & actual results must be remain same.

5.Simulations & Actual Trials

5.1 Riser on one side pouring

As per above two trials it notice that centre riser location occurs due to open the shrinkage. Now we are changing the location of riser. First two trials are taken as centre pouring principle. In this trial we are using side riser pouring principle. In this trial we take simulation result that's time modulus exist but we are confident about modulus will be reduced. When take an actual physical trial that's time one side shrinkage is reduced. This was shown below.
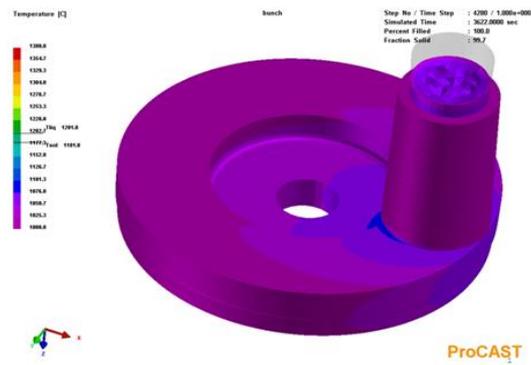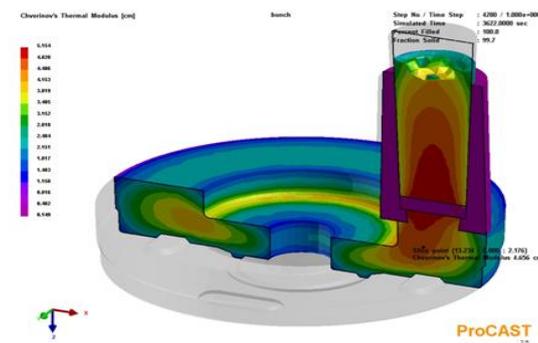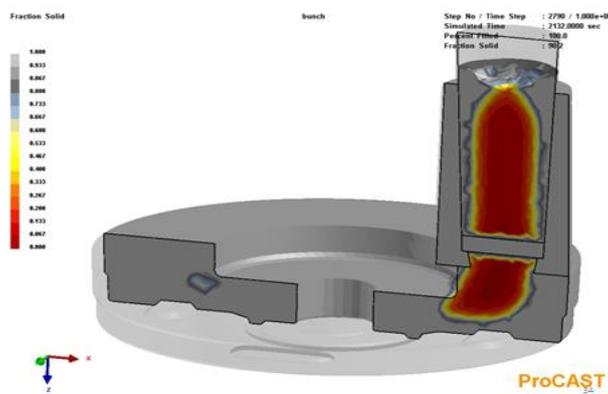
Fig.(5.1)Riser arrangement system

Fig.(5.1.1) Simulation result

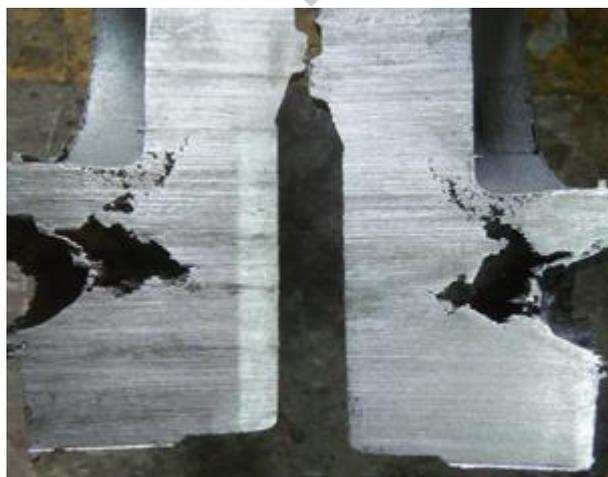Fig(5.1.2) Temp.distribusion during solidification

Fig.(5.1.3) Actual Physical Trial

5.2 Riser on core & hole at bottom

In this trial we are using riser on core & hole at bottom principle. Due to gravity pressure will be apply from upper side & due to core extra metal will be loaded from cope side to avoid shrinkage defect. In cope side riser is present with taking more advantage to extra load of molten metal. Strategy will be succeed in simulation trials also modulus rate also was reduced. When we check out the actual trials then shrinkage is present which shows the actual results.

Fig.(5.2.1) Systematic arrangement
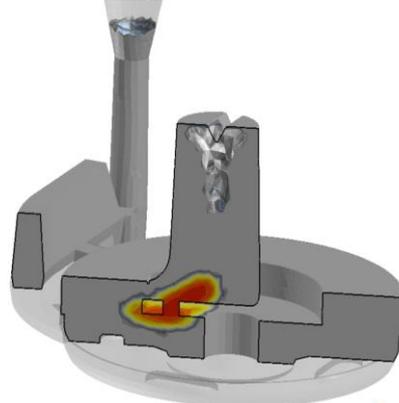
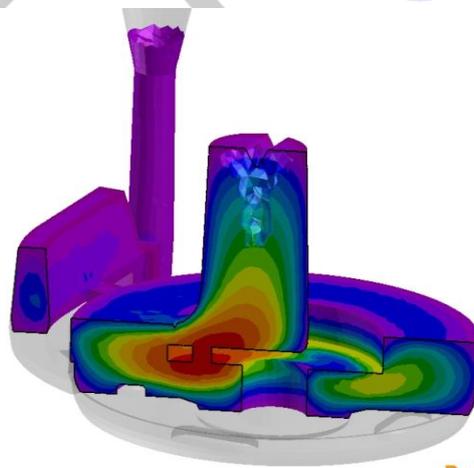Fig.(5.2.2) Temp.distribusion during solidification
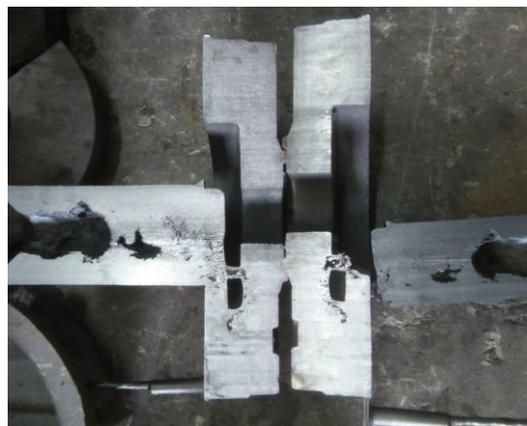
fig.(5.2.3) Temperature distribution

Fig.(5.2.4) Holes At Botton of core

As per above Situation we conclude that shrinkage is available in cross section of flywheel casting which is identify when we take cut section of flywheel casting.

5.3 Without Riser Feed From Runner, Ingates

From above Four trials riser & location of riser are the main parameter to open the defect in flywheel casting. Let we avoid the riser. By using ingates we can pour the molten metal & fill the mould box. By using simulation metal flow rate is important parameter which could be avoid defects. So we change the dimension of ingates & runner increases respectively. When we got simulation results at that time no shrinkage is available in cut section of flywheel casting. When we take an actual trial then surface of flywheel casting is in depression stage as shown in below.
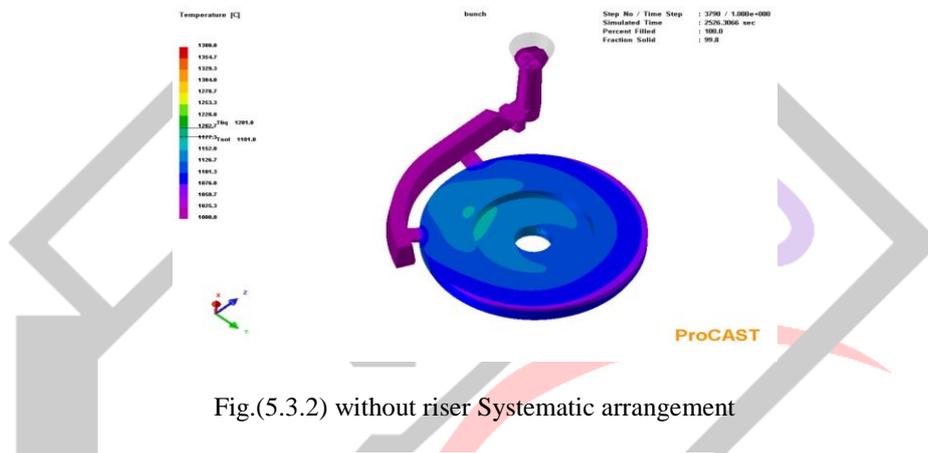

Fig.5.3.1 Systematic Arrangement

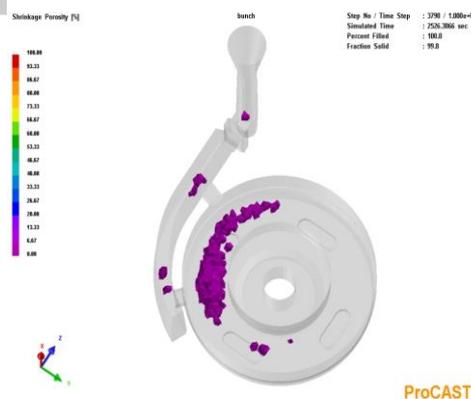Fig.(5.3.2) without riser Systematic arrangement
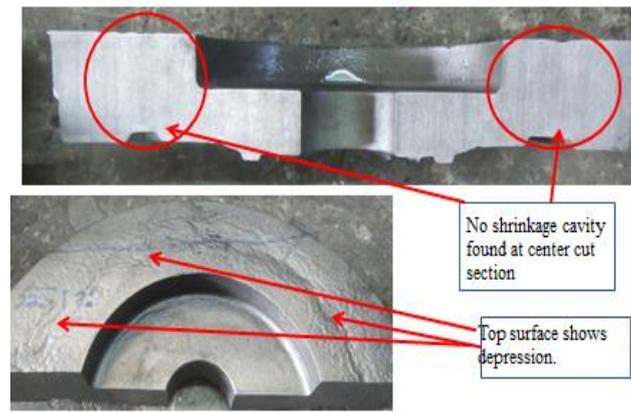

Fig.(5.3.3) Shrinkage Identification

Fig.(5.3.4) Depression Occurs in actual trials

From above trials it conclude that shrinkage occurs open in cross section flywheel casting also surface of flywheel casting.

6 Results & Discussion
6.1 Mesh
1st step of flywheel casting is doing meshing. 2D mesh is done in first step in PROCAST software. It includes flywheel casting sprue cup & over mounted & attaching mechanism was mesh under first step. Meshing is having different types two-dimensional, triangle, quadrilateral, three dimensional, tetrahedron, pyramid, Triangular prism and hexahedron as per complicated shape choose mesh as per requirement.
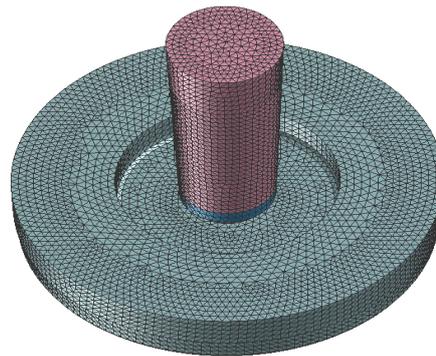

Fig.(6.1.1) 2D Mesh

Here we are meshing mould box , casting, filter, sleeve ,vent, runner, riser, ingates, etc. parts we have to mesh separately in this step which was done by using PROCAST.
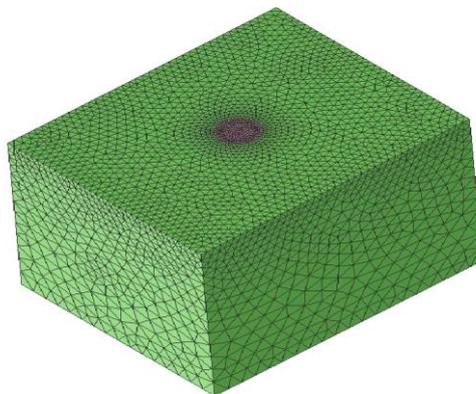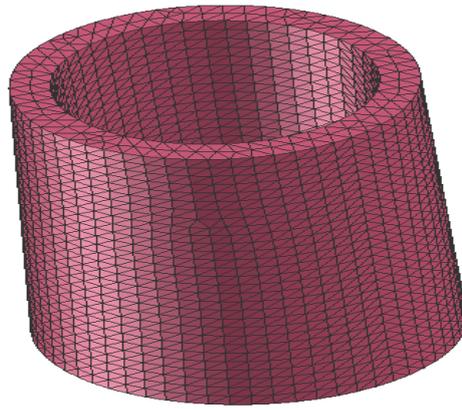

Fig.(6.1.2) Bunch Mesh

Fig.(6.1.3) Sleeve pin Mesh

6.2 3D meshing

Now, here bunch of casting & mould box we have to mesh. Each & every part has already meshed & we have to give interface between them. Assemble the all parts like runner, riser, sprue cup, ingates, sleeve, core, etc. parts must be included which is necessary to get exact simulation.
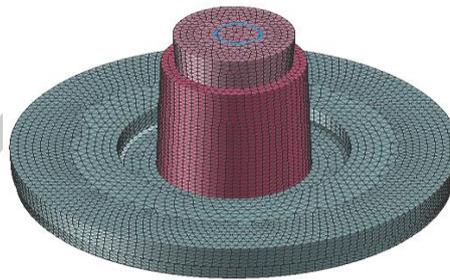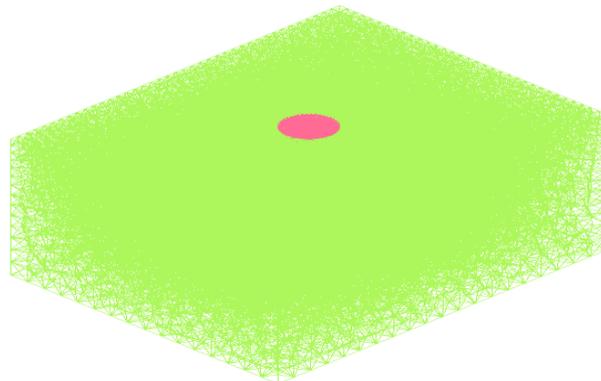

Fig.(6.2.3) 3D Cast Mesh

Fig.(6.2.4) 3D Bunch Mesh

In second stage we have to gives the boundary condition at each part & give the access with respect to casting. Standard interfacing condition we have to include during simulation. Interfacing system is the system which is gives the value of heat transfer coefficient with respect to cast to filter, cast to sleeve & cast to mould.
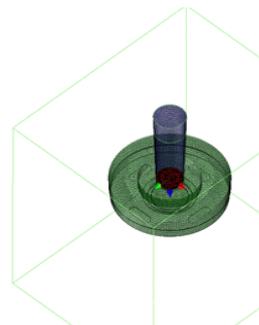
6.3 Interfacing

Fig.(6.3.1) boundary condition for interface condition

Here, we are giving the material properties as per standard data to simulation software. At the same time we have to submit the initial temperature with respect to cast, mould, sleeve & filter. As per customer requirement all properties are filling up with respect to material properties.
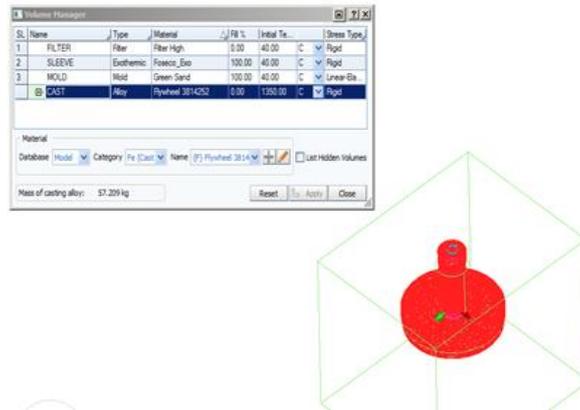
6.4 Boundary Condition

Fig.(6.4.1) Apply Boundary Condition

When metal will be pour in the mould box then how temperature will be distributed through the mould box is shown as below fig 6.5
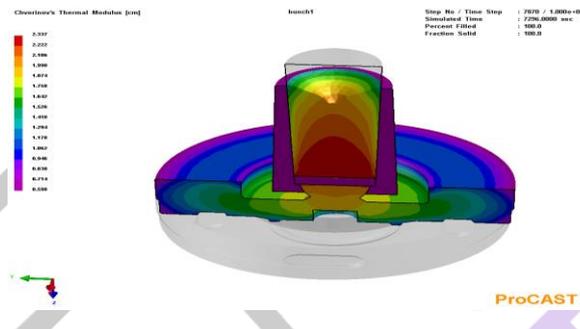
Fig.6.5 Cross section area for thermal modulus

When metal will be pour in the mould box then how material will solidify with respect to time is noticed that as shown in fig.6.6

Fig.6.6 temperature distribution with respect to time

When we check the simulation results then it could be notice that shrinkage is available in sleeve pin. But sleeve pin is not a part of actual casting .So if shrinkage is available in sleeve pin it could be separate in final inspection.

Fig.6.7 Shrinkage identification in centre

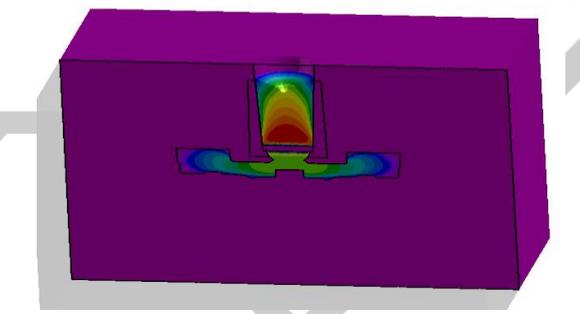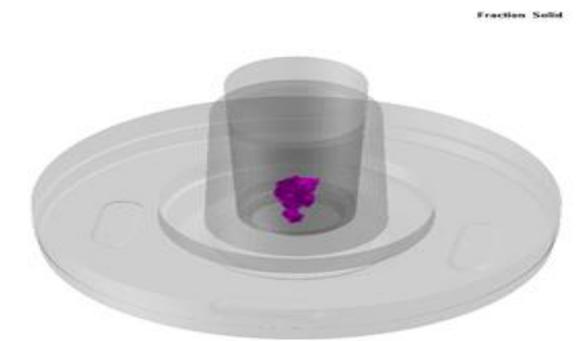When we check the simulation report then it would be noticed that shrinkage is present up to end of sleeve pin which is shown as below in fig.6.8
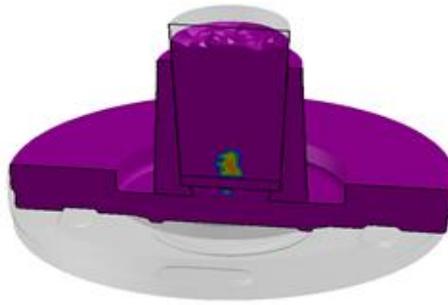

Fig.6.8 Cross section area & identifying shrinkage zone

In actual physical trial we can observed that sleeves & vents are available during the flywheel casting. Vent is the medium which can passes the gas from inside mould box to outside of mould box. Due to this principle porosity defects avoids.

Simulation result & actual physical result is must be same. From last 6 trials shrinkage is open in cross section area but by using centre pouring with sleeve flywheel casting will became defect free or zero defect.

7. CONCLUSION

Proper design of gating system has immensely helped in achieving the directional solidification leading towards the runner, thereby solving the problems of premature failure due to junction solidification and incomplete fill due to sudden variations in modulus. Feeder was placed at last solidifying region using PROCAST software. This approach has helped in minimizing the solidification related defects, thereby providing a defect free casting.

1. In this study, it was observed result shown by the PROCAST for gating yield and casting yield is 76.68 % .
2. Quality, Feeding yield obtained from software were 100%, 76.68% and respectively and solidification simulation enables visualization of the progress of freezing inside a casting and identification of the last freezing regions or hot spots.
3. To overcome the problems of current gating and risering system, a method based on CAD and simulation technology is implemented.
4. By moving the trial and error process into the virtual world and determine the cost of different design and process options by minimizing real world trial and error making casting right the first time.
5. Difference between first trial casting weight & final weight of casting is reduced by 2.5kg .
6. Neglecting trial & error method & get exact solution.
7. By using simulation we can reduce manufacturing cost, reduce development time and reduce trial cost, manufacture & optimized simulation of flywheel casting.
8. Casting rejection is reduce up to 5% to 6%, casting rejection is reduces then simultaneously profit cost will be increases.
9. By using this simulation we are identifying the defect & reduce this defect & increase the productivity of flywheel which was the main task of my project title.

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