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Cracks in steel casting for volute casing of a pump

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Abstract— There is problem occurred in KSB Pump Vambori from last few months for casting process i.e. cracks occurs during casting & it is repeated one. Therefore that company gives opportunity to me to solve that problem. In case of steel casting there are mainly cracks & also blow holes induced due to foundry defects. There are many factors producing the foundry defect .The factor is uneven material feeding in casting, molding material & the core material. These cracks finally break directly the component of the casting i.e. in case of pump the casting component is like Impeller, Volute casing & casing cover.

At the time of feeding of steel material in to the casting the material is in liquidous form i.e. it is hot material & this material is feeding into casting at the time of feeding it develop different region of heat. At one side the temp is high & at other side the temp is low this also produce cracks. To simulate that we use the MAGMA SOFTWARE for simulation. We use some preventive action for that model crack.

Keywords—volute casing; core; NDT testing; Centrifugal casting, steel material, core box, runner, mould,

A) Introduction: The function of casting is to produce component as per the required design & from that design we produce mould as per the design of a casting & also the core can be made. For making the casting there are different terms are required one of that most important is the gating system .the gating system consist of component like runner, in gate, well, sprue, basin which is most important component of gating system. Gating system is used for pouring of hot metal i.e. liquidous metal in to the mould hence the gating system is most important component for casting. There are two types gating system first one is a horizontal & second one is a vertical gating system. The metal velocity & also gating system can causes the surface turbulence & minimize bulk turbulence with in the gating channels as well as the mould cavity this also causes casting defect .this mainly depends on the velocity of molten metal . This varies widely within the gating channel as well as inside the mould cavity. For a given location in the casting .the velocity also changes with time from start to end of filling. The most important event is that of molten metal emerging from the in gate. Just after the filling of gating channels & before the filling of mould cavity. The metal is both hot & fast at this location & instant & also can lead to considerable damage i.e. cracks if not controlled properly.(1)

There are many factors producing the foundry defect therefore the detection of defect is most important factor for analysis of foundry defect. In KSB pumps there is different NDT technique is used for detection of defect. Hence we have to use different condition monitoring technique for detection of cracks. These techniques are like a Radiography, liquid penetrant, magnetic particle & also acoustic emission. (2)

The demand for steels with higher strength, ductility and toughness is always increasing. Many alloy additions aim to improve these final product properties by Controlling grain size and precipitate formation during rolling operations. Large grain size decreases ductility and toughness, by allowing strain to concentrate at the grain boundaries to form cracks.
The amount, composition, morphology and size distribution of precipitates evolving from the molten steels to the final products are important for determining the mechanical properties of modern commercial steels throughout processing. Precipitation and grain size are both influenced greatly by the steel composition and cooling history. There is a critical balance for precipitates to form and function.(3)

The investigation of aluminum alloy die casting die failures was done with the emphasis on thermal cracks. The aim of the study was to prolog the in-service die life by cladding with maraging steels, which would be economically beneficial. (4)

The thermal aging embrittlement of cast stainless steels (CASSs) is one of the key material property degradation that would limit the long-term operation nuclear power plants. In this study, we investigated the recovery behaviors of thermal aging embrittlement of cast stainless steels (CASSs) by the reversion heat treatment. Two heats of CF8M with different ferrite contents were used and the degree of aging embrittlement was measured by the micro-hardness of ferrite phases. (5)

B) Literature review: The function of casting is to produce component as per the required design & from that design we produce mold as per the design of a casting & also the core can be make. For making the casting there are different terms are required one of that most important is the gating system .the gating system consist of component like runner, in gate, well, sprue, basin which is most important component of gating system.

Acoustic emission (AE) can be described as a shock wave inside a material, which is under stress. The shock wave causes the surface of the material to move, and this movement is measured with a very sensitive sensor. The transient elastic wave is generated by a rapid release of energy from a local source within the material.

The demand for steels with higher strength, ductility and toughness is always increasing. Many alloy additions aim to improve these dispersion of very fine precipitate particles, and/or by inhibiting grain growth through these second-phase particles.

The thermal aging embrittlement of cast stainless steels (CASSs) is one of the key material property degradation that would limit the long-term operation nuclear power plants. Liquid penetrant testing is one of the oldest and simplest NDT methods where its

Earliest versions (using kerosene and oil mixture) dates back to the 19th century. This method is used to reveal surface discontinuities by bleed out of a colored or fluorescent dye from the flaw. The technique is based on the ability of a liquid to be drawn into a "clean" surface discontinuity by capillary action. After a period of time called the "dwell time", excess surface penetrant is removed and a developer applied. This acts as a blotter that draws the penetrant from the discontinuity to reveal its presence.

For moulding us use of two types of sand that is fresh sand & reclaim sand. Fresh sand means pure silica sand &reclaim sand means that sand follows all process up to metal pouring & knockout the actual component(casting) is free from mould. The sand remains after all process in mould is called as reclaim sand. The % of sand use for that mould is 30% silica sand & 70 % reclaim sand. The reclaim sand quantity is higher than silica sand. The silica sand is use only for outer to the reclaim sand & it cover the casting.

Sand casting carried by medium and large scale industries typically uses commercial silica sand. Natural disaster on Mount Kelud eruption has introduced a new breakthrough in the form of ideas to use volcanic sand foundry sand as a base material for aluminum silica based products. This study, meanwhile, used the experimental method in which, prior to be given the treatment, the specimens were analyzed on the strength of molding sand, disability and ability to cast the metal flow (fluidity), and the quality of Al-Si as casting product. In addition, to observe the defects, tests on surface hardness and microstructure of Al-Si using Optical Microscope and Scanning Electron Microscope (SEM) were conducted.

This study reports an in house experience of the rapid development of export items in a foundry by simulation techniques along with some industrial case studies. This is also a detailed &step by step process of developing export casting right from tooling development to method & process standardization by using 3D modeling software & casting simulation.

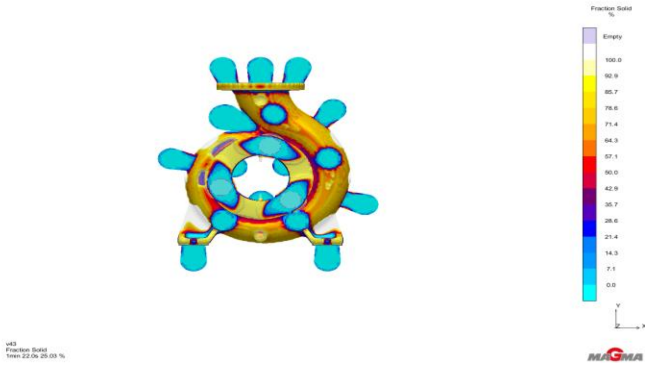
C) Objectives:

1) The objective of project is to carry out the Foundry defect analysis (cracks)

2) By Using Foundry defect analysis we are going to find actual parameters by which cracks are induced in the casting and then taking the suitable preventive action on that cracks.

D) Analytic method:

1) Simulation: In case of simulation the KSB Pumps uses simulation software as MAGMA. We made 3D model in UG/Catia/Pro-e & then import that model in to that



FigD.1.1Actual volute casting showing the fraction solid percentages in different region [8]

Then we add the geometry perspective for assigning axis & then assign the material for the object for each part that is use for casting i.e. casting material, chill, sleeve & finally for runner. After that we did the meshing perspective for that objects that distribute the casting into different material as like an ANSYS.

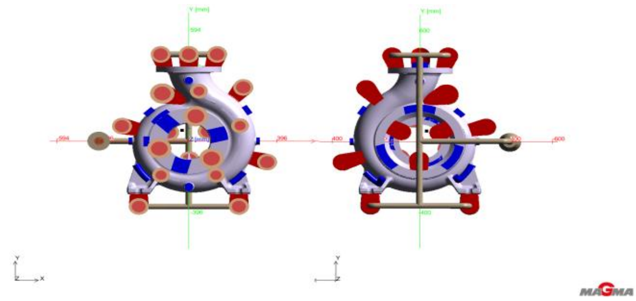


Fig D.1.2 Actual volute casting showing Runner, Riser, Gating system & Pouring Basin

Then we use the definition prospective for assigning material properties, define temperature, define a heat transfer data & pouring time then we use the simulation command . After that we click on result tool bar then we get the temp vs. time graph for fraction solid for fraction liquid, porosity & for hot spot.

FigD.1.3 Actual volute casing showing the temperature distribution with runner, riser &feeder.[8]

Pyrometers for the surface temperature measurement and they reported a substantial fluctuation of measured temperatures, which makes the measurement inapplicable. Magma the design of volute casing &impeller are unchanged. It shows the different region of temperature distribution.

Fig D.1.4 Actual volute casing showing the porosity percentage in different region[8]

E) Experimental method:

Experiments for UG1118294-0000 Part

1) Experiment 1:

a) Core Making:

In core making process we use the binder, hardener &silica sand. In case of core we check the core material properties in that we check:

Sand (Fenotec), binder (Fenotec 5519) & Hardener (H-720 %H-740% H-200%) percentage is proper or not if not then we maintain it by adding & reducing it.

For sand & binder percentage:

For Silica sand = 100 kg

Fenotec 5519 binder(X) = 1.4 to 2.2[7]

Hardener H-720% H740% H-200%(Y) =0.280kg to 0.500kg

Then for 87.7kg silica sand the binder is

$X=\frac{1.4+2.2}{2}=1.8kg$

For 100kg of silica sand =binder is 1.8kg

For87.7kg of silica sand=binder is X

$X=\frac{87.7\times1.8}{100}=1.5786$ kg

Similarly by calculating amount of hardness we get Y=0.34203kg

(87.7kg of sand + 1.5786 kg binder + 0.34203kg Hardener)

Hardness of core is=55 BHN

b) Moulding:

Total sand required for part UG1118294-0000=775.1KG (It is specification of that part) Calculate the fresh sand &reclaim sand required: 1) fresh sand=30% of Total sand required for part UG1118294-0000= 0.3X775.1=232.53KG=232.5kg 2) Reclaim sand=70% of Total sand required for part UG1118294-0000=0.7X775.1=542.57KG=542.6KG

SAND FOR MOULD=Fresh sand (30%) 232.5KG + reclaim sand (70%) 542.6KG

Hardness for mould=56 BHN

The colour is painted on mould to avoid sand fusion on casting the name of that colour is isomal 380 Foseco [7]

c) Heat number: This all data is required when cracks or any other defect is produced to find actual parameter which produced the defect (analysis).

For this part i.e. UG1118294-0000 we use heat number as a **C756.**

d) Metal chemistry: In case of this casting we use the CF8M as grade for that steel material. For checking of metal chemistry we take sample of metal (CF8M) from each furnace for particular heat number. Punting that sample on machine name as a spectrometric analysis machine to check the % of different contain like c, Mn, si, Cr, Mo, Ni, P, S. That machine work on AMITEC software there is a land connection between machine & computer in that computer the AMITEC software is

C	Si	Mn	Cr	Mo	Ni	P	S
0.07	0.700	1.180	18.999	2.430	9.440	0.036	0.011

installed

Fig E. 1. d (i) Setup used to checked the metal chemistry

Following table shows the specification of CF8M grade:

C	Si	Mn	Cr	Mo	Ni	P	S
0.08 Max	1.50 max	1.50 max	18-21	2-3	9-11	0.04 Max	0.04 max

i) Chemical composition in%:

Table E.1.d (ii) specification of CF8M grade for Chemical composition in %

ii) Mechanical properties at room temperature:

Table E.1.d (iii) specification of CF8M grade for Mechanical properties at room temperature

BHN	Yield stress (MPa)	Tensile strength (MPa)	Elongation in %
130-200	205Min	485Min	30Min

Following are the Actual chemical composition & physical properties:

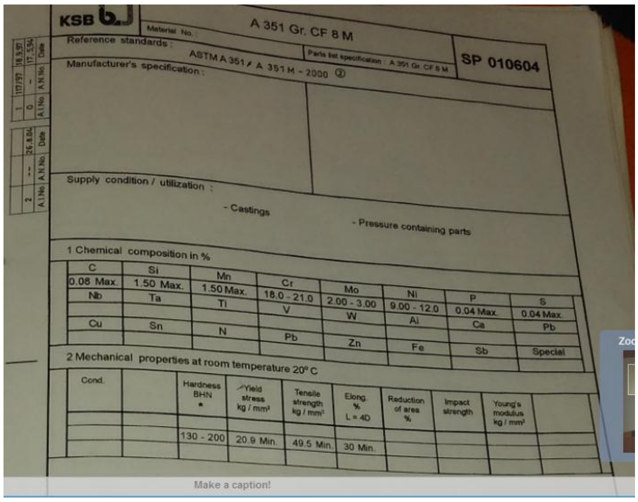
i) Chemical composition in%:

Table E.1.d (iv) Actual CF8M grade Chemical composition in%

ii) Mechanical properties at room temperature:

Table E.1.d (v) Actual CF8M grade Mechanical properties at room temperature

BHN	Yield stress (Mpa)	Tensile strength (Mpa)	Elongation in %
148	338.449	536.531	52.000



KSB

A 351 Gr. CF 8 M

Reference standards : ASTM A 351 / A 351 M - 2000

Manufacturer's specification :

SP 010604

Supply condition / utilization : - Castings - Pressure containing parts

1 Chemical composition in %

C	Si	Mn	Cr	Mo	Ni	P	S
0.08 Max.	1.50 Max.	1.50 Max.	18.0 - 21.0	2.00 - 3.00	9.00 - 12.0	0.04 Max.	0.04 Max.

2 Mechanical properties at room temperature 20° C

Hardness BHN	Yield stress kg / mm²	Tensile strength kg / mm²	Elong. % L = 4D
130 - 200	20.9 Min.	49.5 Min.	30 Min.

Make a caption!

Fig E. 1. d (vi) Actual proof to check the metal chemistry

e) Temperature: Temperature of the hot metal in the furnace is 1630°c. the rang of temperature is between1600 °c to 1700 °c is safe point of temperature.

Item	Pattern number	Heat No.	Temperature	Tested date
VSC	UG1118294-0000	C756	1630°c	5-3-2016

Table E.1.e (i) shows the pouring temperature record

Fig E.1.e (ii) shows the actual pouring temperature record

After this process I follow all process that is required for manufacturing of volute casing like Knock out, Power cutting, Heat treatment, Cooling, Shot blasting, and Fettling

f) NDT: i) Liquid penetrates & Dye penetrates NDT Testing:

The defect is found. Liquid penetrant testing is one of the oldest and simplest NDT methods where its earliest versions date back to the 19th century.[6]

Table E.1.l f(i) shows the NDT Testing record

Item	Pattern number	Heat No.	Remark	Tested date
VSC	UG1118294-0000	C756	Defect is present	28-2-2016

Fig E.1 .f(ii) shows the actual cracks in a casting

This method is used to reveal surface discontinuities by bleed out of a colored or fluorescent dye from the flaw. The technique is based on the ability of a liquid to be drawn into a "clean" surface discontinuity by capillary action.

2) Experiment 2: By trial &error method

By varying the binder %let's see what is the effect on hardness [9]

. If we take binder as 1.4 for 100kg of silica sand & Hardener as a 0.290kg

Then for 87.7kg of silica sand

1) Binder is

$$x = \frac{87.7 * 1.4}{100} = 1.2\text{kg}$$

2) Hardener is:

$$x = \frac{87.7 * 0.290}{100} = 0.25kg$$

For87.7kf of silica sand

Binder is 1.2kg& Hardener is 0.25kg

By using scratched hardness tester we get the hardness as a 36BHN

But the life span of that core is very less about 1-2hr due to low hardness & the core friable is occurred.

Hence that core is not suitable for production.

3) Experiment 3: By trial &error method

If we take binder as 1.6 for 100kg of silica sand & Hardener as a 0.3 kg

Then for 87.7kg of silica sand [7]

1) Binder is

$$x = \frac{87.7 * 1.6}{100} = 1.40kg$$

2) Hardener is:

$$x = \frac{87.7 * 0.3}{100} = 0.26kg$$

For87.7kf of silica sand
Binder is 1.4kg& Hardener is 0.26kg
By using scratched hardness tester we get the hardness as a **43BHN**
The life span of that core is large but the core is failed at the time of assembly due to medium hardness.
Hence that core is suitable for production but not for casting

4) Experiment 4
Preventive action for the cracks
By providing the core saver inside the core: For providing the core saver inside the core the procedure is follows as per above procedure with a heat number as a **C1693**.
a. Core Making: In core making process we use the binder, hardener &silica sand.
In case of core we check the core material properties in that we check:

Sand (Fenotec), binder (Fenotec 5519) & Hardener (H-720 %H-740% H-200%) percentage is proper or not if not then we maintain it by adding & reducing it.

For sand & binder percentage:

For
Silica sand = 100 kg
Fenotec 5519 binder(X)= 1.4 to 2.2

Hardener H-720% H740% H-200%(Y)=0.280kg to 0.500kg[7]

Then for 85.7kg silica sand the binder is
$X=\frac{1.4+2.2}{2}=1.8kg$
For 100kg of silica sand =binder is 1.8kg
For85.7kg of silica sand=binder is X
$X=\frac{85.7\times1.8}{100}=1.5426kg$
Then for 85.7kg silica sand the hardener is
$y=\frac{0.280+0.500}{2}=0.390kg$
For100kg of sand=hardener is 0.390 kg
For 85.7 kg of silica sand= hardener is Y
Then
$Y=\frac{0.390\times85.7}{100}=0.33423kg$
For 85.7 kg of silica sand we use 0.33423kg Hardener
Mixing (85.7kg of sand + 1.5426kg binder + 0.33423kg Hardener) &placing this in core box &make core after that check the hardness.

Fig E.4.a (i) core with core saver for UG1118294-0000
Hardness of core is=55BHN
b. Moulding: In case of moulding we can't change any of parameter in case of mould it follows same content as per the above content.

Total sand required for part UG1118294-0000=775.1KG (It is specification of that part)
Calculate the fresh sand &reclaim sand required: 1) fresh sand=30% of Total sand required for part UG1118294-0000= 0.3X775.1=232.53KG=232.5kg
2) Reclaim sand=70% of Total sand required for part UG1118294-0000=0.7X775.1=542.57KG=542.6KG
SAND FOR MOULD=Fresh sand (30%) 232.5+ reclaim sand (70%) 542.6
Hardness for mould=56 BHN
c. Heat number: Heat number means number which is use for particular furnace number heat, time at which this achieves some temperature. This all data is required when cracks or any other defect is produced to find actual parameter which produced the defect For applying corrective action we again produce the volute casing of part Number UG1118294-0000 we use heat number as a **C1693.** C means company follows all alphabetical for heat number.
d. Metal chemistry: In case of this casting we use the CF8M as grade for that steel material. For checking of metal chemistry we take sample of metal (CF8M) from each furnace for particular heat number. Punting that sample on machine name as a spectrometric analysis machine to check the % of different contain like c, Mn, si, Cr, Mo, Ni, P, S. That machine work on AMITEC software there is a land connection between machine & computer in that computer the AMITEC software is installed.
Following are the Actual chemical composition & physical properties:
Table E.4.d (i) Actual CF8M grade Chemical composition in %:

Table E.4.d (ii) Actual CF8M grade Mechanical properties at room temperature

BHN	Yield stress (Mpa)	Tensile strength (Mpa)	Elongation in %
150	339.567	565.913	49.200

e. Temperature: temperature of the hot metal in the furnace is 1630 ^{0}c. This record is kept in

Fig E.4.e (i) shows the pouring temperature record

All the remaining middle process is follow a per process 1

f. NDT:

1. Liquid penetrates& Dye penetrates NDT Testing: By conducting the liquid penetrant test on UG11182940000-00 part. It says that the given part with heat number as **C1693** does not produce the cracks by providing the core saver.(6)

Table E.4.f (i) shows the NDT testing record

F) Results:

In this we follow 4 processes each has different hardness

1) Experiment 1: without core saver

Core Hardness: 55BHN

Mould hardness: 56BHN

It produces cracks.

2) Experiment 2:

Core Hardness: 36BHN

The life span of core is 1-2hr

Not suitable for production

3) Experiment 3:

Core Hardness: 43 BHN

Failed at the time of assembly

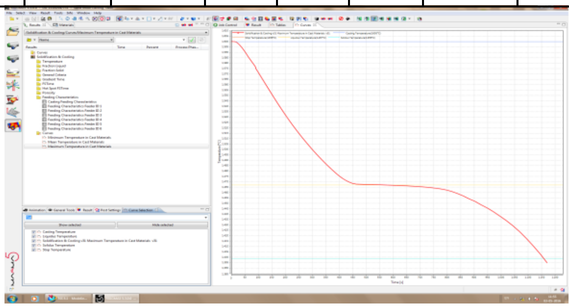
4) Experiment 4: with core saver inside the core

Core Hardness: 55BHN

Mould hardness: 56BHN

Suitable for production .not produces the cracks

C	Si	Mn	Cr	Mo	Ni	P	S
0.072	0.690	1.180	18.900	2.530	9.650	0.038	0.009

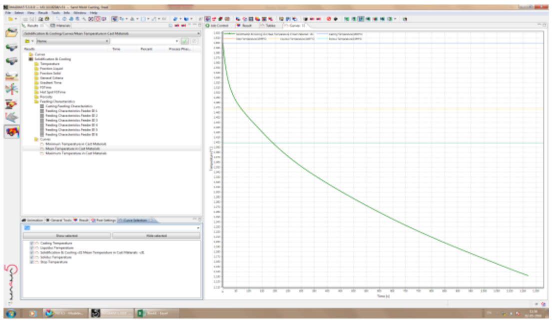


Item	Pattern number	Heat No.	Temperature	Tested date
VSC	UG1118294-0000	C756	1630^{0}c	7-4-2016

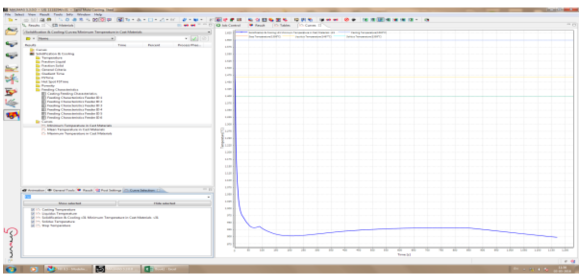
Graph F.1TempVS Time(Max.Temprature in cast

Item	Pattern number	Heat No.	Remark	Tested date
VSC	UG1118294-0000	C1641	No defect found	18-4-2016

material)



Graph F. 2 TempVS Time(Mean Temprature in cast material)



Graph F.3 TempVS Time(Min.Temprature in cast material)

G) Conclusions:

1) By trial & error method as the binder % is changes the hardness of the core is also changes.
2) The core is most important parameter to produce the cracks in steel casting.
3) By providing the core saver the cracks is also reduce.

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