Study on Solidification Behavior of Aluminium alloy (LM6) Castings by using Computer aided Simulation software

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Abstract
Method layout of a casting is an important aspect of tooling development. It involves decisions regarding part orientation in mould, parting line, cores, cavity layout, feeders, neck and gating system. An improper method layout leads either poor quality or low yield, which affects the productivity. Method design is mostly carried out manually, using 2D drawing of the cast part. Then tooling is fabricated the sample castings are produced to 3-4 trials which involves lot of production cost in the from of wastage of manpower, time and hamper the day to day schedule of the particular production. Computer simulation provides a clear insight regarding the location and extent of internal defects, ensuring casting are right as first time and every time.

In the present study plate castings were considered to study the solidification behavior of Aluminium Alloy (LM6) at different sizes of riser and riser neck. The VEM based casting simulation software is used to study the solidification behavior of above castings. The simulated results were compared with the experimental results. It is expected that this work will be of immense importance equally to the academicians as well as to the industrial methoding engineers.

Key Words: casting, LM6, solidification, shrinkage, simulation

Introduction:
In manufacturing process, casting is one of the most economical production processes, which involves considerable metallurgical and mechanical aspects. In casting process, the rate of solidification affects the microstructure of cast metal largely, which in turn controls the mechanical properties such as strength, hardness, machinability etc. of the cast metal. The proper design of riser /feeder required to achieve directional solidification is important because improperly designed riser results either defective casting with shrinkage cavity or lower yield . Hence, proper design of risering system and good control over the process parameters are necessary for quality castings. However, the experimental routes are always better for design and development of mould and for arriving at the optimum process parameters. But, it is costly, time consuming, and may be impossible in some cases. Therefore, casting simulation process is a convenient way of proper design of risering system and analyzing the effect of various parameters.

The application of casting simulation is increasing in Indian foundry as it essentially replaces or minimizes the shop-floor trials to achieve the desired internal quality at the highest possible time. A number of casting simulation softwares are available today, such as CastCAE, MAGMA, Novacast, ProCAST, and SolidCAST. The main inputs for the casing simulation are
- The geometry of the mould cavity (3D model of the casting, feeders, and gating channels),
- Thermo-physical properties (density, specific heat, and thermal conductivity of the cast metal as well as the mould material, as a function of temperature),

- Boundary conditions (i.e. the metal-mould heat transfer coefficient, for normal mould as well as feed-aids including chills, insulation and exothermic materials),
- Process parameters (such as pouring rate, time and temperature)

A lot of research work has been done on casting simulation by using different casting simulation methods. Such as **P. Prabhakara Rao** et.al. studied the simulation of mould filling solidification of casting of green sand ductile iron castings and concluded that the use of casting simulation software like working under Finite element method can be able to eliminate the defects like shrinkage, porosity etc. in the casting. It also improves yield of the casting, optimize the gating system design and the mould filling.**Dr. B. Ravi** Studied on optimization of mold cavities, feeders and gating system of an industrial component by using **Auto cast** casting simulation process. He has shown that the total time for method design and optimization of the casting reduced to about one hour. **Dr. B. Ravi** also studied the benefits and problems involving casting simulation and optimization. **Dr. B. Ravi et.al.** Studied 3D Junctions in Castings with the help of Simulation-based DFM Analysis and Guidelines. They have studied defects like shrinkage porosity of casting at 3D junctions such as L/V, T/Y and X/K. They predicted the location of shrinkage porosity by casting solidification simulation, and suggested by minor modification to part design. They also investigated the best values and ratios of junction parameters by using casting simulation software like AUTO CAST. In the present work an attempt has been made to carry out a comparative study of design parameters of riser and neck using a VEM based software with experimental observations.

Methodology:

A variety of methods have been devised to calculate the riser size and neck size needed to ensure that liquid feed metal will be available for as long as the solidify casting requires. Several most commonly used methods are Shape **factor method, Geometry method, Modulus method**. In this present work we have considered the **plate casting**(100mmx100mmx20mm thickness) of aluminum alloy (LM6) metal .The required diameter and the height of risers are calculated by modulus method and the castings are produced by green sand casting method. The same design calculation is done in simulation method also. The physical castings are cut in vertical section manually for observation

Patterns, risers and riser necks are made by CNC machines. The composition of green sand mould is given Table -1,

Table -1

Silica sand	Bentonite clay	Moisture	Coal dust
86%	8%	5%	1%

The mould box is used with the dimension of 330mm × 330mm (Fig 2).The aluminum–silicon alloy i.e.LM6, which is a well known alloy of aluminum, is used as the castings metal in the experiments. The chemical composition of the Al alloy (LM6) and molding sand have given in the **table-2 & table-3.** The aluminum alloy is melted in clay graphite crucible using an electric resistance furnace. The melt has poured at a temperature of 720 ^{0}C into a plate silica sand mould.

TABLE-2
Chemical Composition (LM6)

Elements	Si	Cu	Mg	Fe	Mn	Ni	Zn	Pb	Sb	Ti	Al
Percentage(%)	10-13	0.1	0.6	0.5	0.1	0.1	0.1	0.05	0.2	0.1	Rest

TABLE-3
Thermo physical properties of sand

TABLE-4
The list of risers and necks used in the present work is given below

Riser Dimensions	Neck Dimensions

Properties	Sand
Density(gm/cm^3)	1.6
Thermal conductivity(W/m/K)	0.52
Specific heat (j/Kg/K)	1170

Ø40mm × 80mm Height	Ø20mm × 5mm Height
	Ø15mm × 5mm Height
	Ø12mm × 5mm Height
	Ø10mm × 5mm Height
Ø38mm × 76mm Height	Ø20mm × 5mm Height
	Ø15mm × 5mm Height
	Ø12mm × 5mm Height
	Ø10mm × 5mm Height
Ø36mm × 72mm Height	Ø20mm × 5mm Height
	Ø15mm × 5mm Height
	Ø12mm × 5mm Height
	Ø10mm × 5mm Height
Ø34mm × 68mm Height	Ø20mm × 5mm Height
	Ø15mm × 5mm Height
	Ø12mm × 5mm Height
	Ø10mm × 5mm Height

The castings are cut at the mid section and the observations are taken away. Fig 3 shows the aluminium alloy cast products.
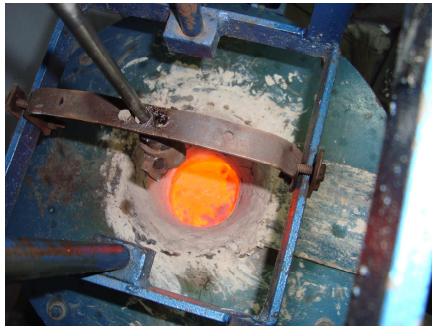
Fig.1
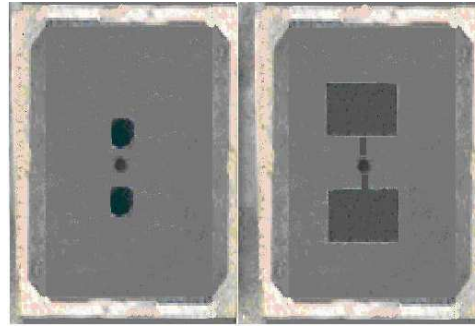
Fig.2.

Optimization of Riser neck:
Again castings were produced using the following risers along with the necks to optimize the riser neck sizes.

Table-5

Riser Dimensions(mm)	Neck Dimensions(mm)
Ø 38mmx76mm height	Ø 14mmx5mm height
	Ø 13.5mmx5mm height
	Ø 13mmx5mm height
Ø 40mmx80mm height	Ø 14.5mmx5mm height
	Ø 14mmx5mm height
	Ø 13.5mmx5mm height

Result and discussion:

The castings were sectioned approximately down the middle to see if the macro-porosity is visible. It is observed that in some castings shrinkages are present and in some cases no shrinkage are found. No shrinkages are available in the following cases,

Table-6

Riser Dimension	Neck Dimension
Ø40mm × 80mm Height	Ø20mm × 5mm Height
	Ø15mm × 5mm Height
Ø38mm × 76mm Height	Ø20mm × 5mm Height
	Ø15mm × 5mm Height
Ø36mm × 72mm Height	Ø15mm × 5mm Height

Table-7
The shrinkage defects present are listed

Riser Dimension	Neck Dimension
Ø38mm × 76mm Height	Ø12mm × 5mm Height
	Ø10mm × 5mm Height
Ø36mm × 72mm Height	Ø20mm × 5mm Height
	Ø12mm × 5mm Height
	Ø10mm × 5mm Height
Ø34m × 68mm Height	Ø20mm × 5mm Height
	Ø15mm × 5mm Height
	Ø12mm × 5mm Height
	Ø10mm × 5mm Height

Fig3(a) Sample with Riser Ø 34mmx68mm Height with Neck Ø 12mmx5mmHeight.

Fig3(b) Sample with Riser Ø 36mmx72mm Height with Neck Ø 20mmx5mmHeight

T Nandi, R.Behera, S kayal, A Chanda, G.Sutradhar / International Journal of Engineering Research and Applications (IJERA)   ISSN: 2248-9622   www.ijera.com

Vol. 1, Issue 2, pp.157-164
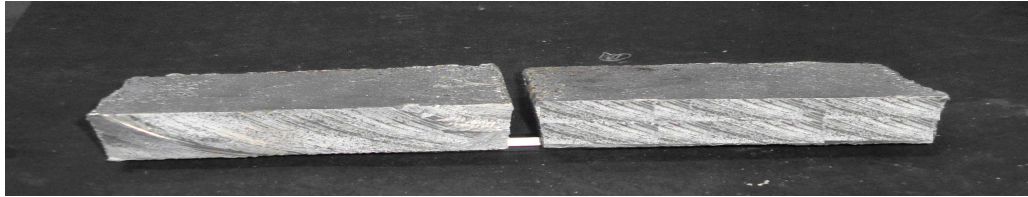
Fig3(c) Sample with Riser Ø 38mx76mm Height with Neck Ø 15mmx5mmHeight

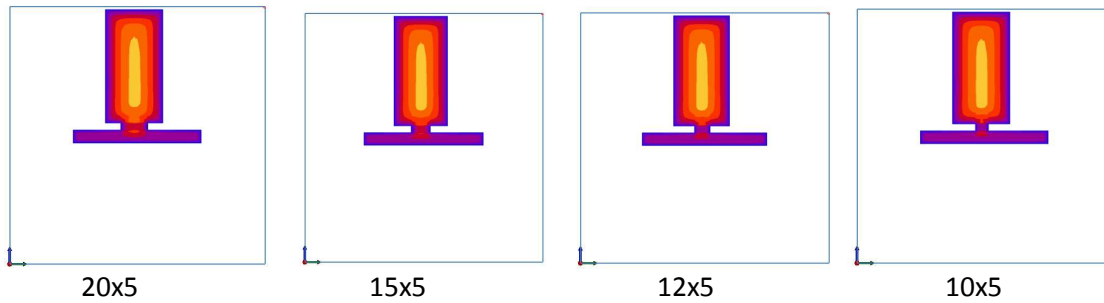Fig.4(a) The simulated results for the dimension of riser 40mmx80mm Height at different sizes of riser neck.

| 20x5 | 15x5 | 12x5 | 10x5 |

Fig.4(b) The simulated results for the dimension of riser 38mmx76mm Height at different sizes of riser neck.

| 20X5 | 15x5 | 12X5 | 10x5 |
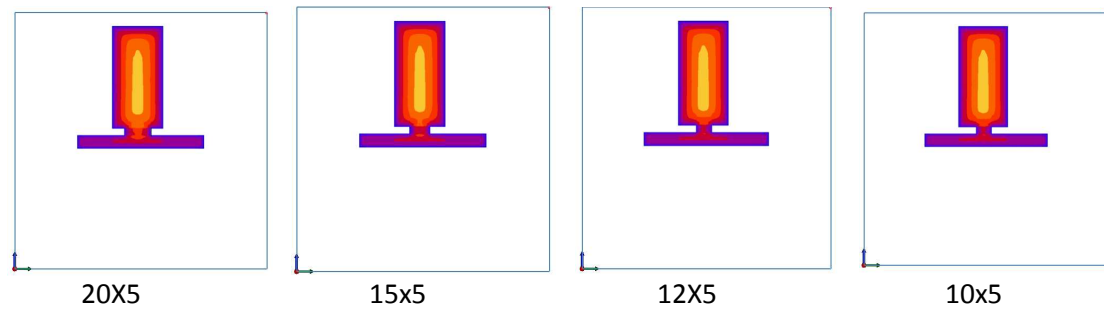
Fig.4(c) The simulated results for the dimension of riser 36mmx72mm Height at different sizes of riser neck.

| 20x5 | 15x5 | 12x5 | 10x5 |
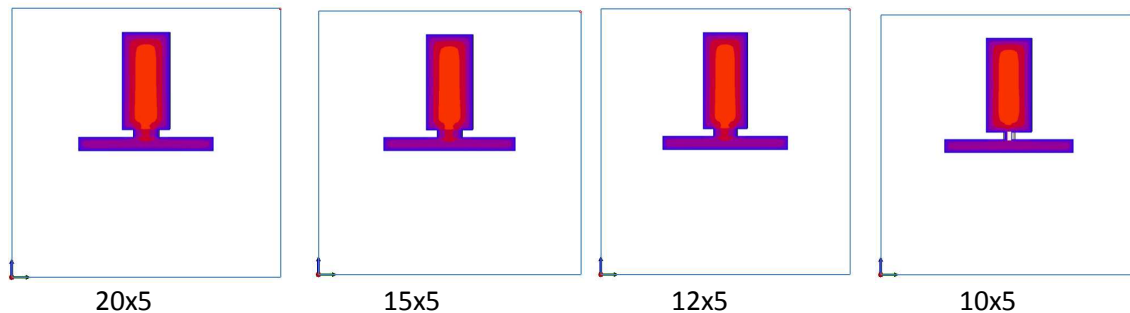
Fig.4(d) The simulated results for the dimension of riser 34mmx68mm Height at different sizes of riser neck.

| 20x5 | 15x5 | 12x5 | 10x5 |
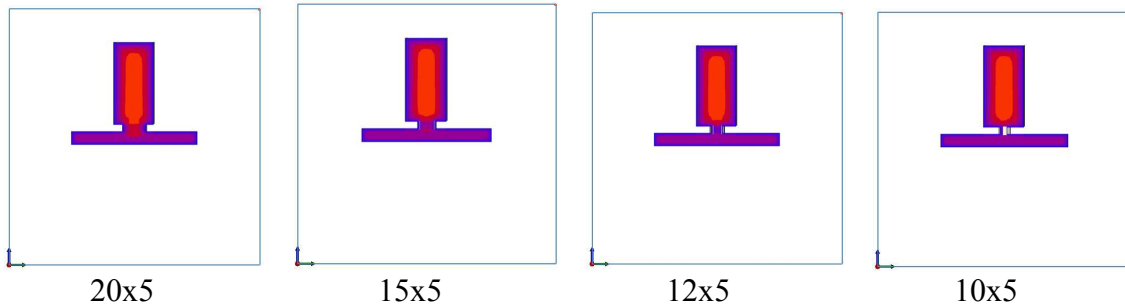
From the above calculation carried out by Modulus method, it is observed that for the riser, Ø 34mmX68mm height is not suitable with any neck for casting (as pre steel casting the neck diameter is generally considered 40 to 50 percentage of the riser diameter). In case of riser size Ø 40mmX80mm height, the neck size should be within Ø 16mm to Ø 20mm.So less than this is not acceptable. Similarly, for riser Ø38mmX76mm height it is found that shrinkage is present with neck Ø 12mmX5mm height & Ø 10mmX5mm height. For riser Ø 36mmX 72mm height with Ø 20mmX 5mm height, Ø 12mmX5mm height, Ø 10mmX5mm height are not suitable for the above castings . The simulated results are obtained using the above riser sizes and neck sizes. The simulated results of riser Ø 34mmX68mm height with all necks are shown in Fig 4(d).Other simulated results also given in Fig 4(a),(b),(c) Here we find all the cases shrinkage are present. Fig 3(a) and Fig3(b) show the experimental results with riser Ø 34mmX68mm along with the neck Ø12mmX5mm height ,and riser Ø 36mmx72mm height along with the neck Ø 15mmX5mm height respectively where shrinkage defects are also possible. Fig3(c) shows a section of experimented product of the riser Ø38mX76mm height with the neck Ø15mmX5mm height. Here we find no shrinkage defect.

Optimization: It has been observed that no shrinkages are found the following riser along with the necks.

Table8

Riser Dimensions	Neck Dimension
Ø38mmx76mm Height	Ø14mmx5mm Height
	Ø13.5mmx5mm Height
Ø40mmx80mm Height	Ø14.5mmx5mm Height
	Ø14mmx5mm Height

Shrinkages are available in the following cases

Table9

Riser Dimensions	Neck Dimension
Ø38mmx76mm Height	Ø13mmx5mm Height
Ø38mmx76mm Height	Ø13.5mmx5mm Height

From the above observation it is found that in case of aluminium we can consider the minimum neck diameter is 35% of the riser diameter where as in steel it 40% to 50% of the riser diameter. The simulated results(fig) are also conforms the above observations. Fig5(a) The simulated results for the dimension of riser 38mmx76mm Height at different sizes of riser neck.
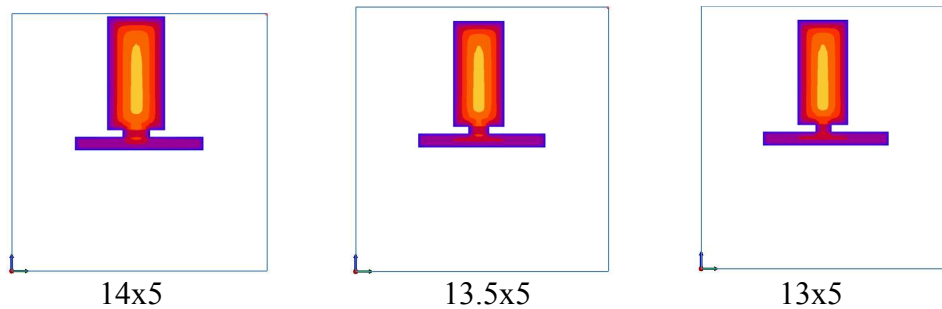
| 14x5 | 13.5x5 | 13x5 |

Fig.5(b) The simulated results for the dimension of riser 40mmx80mm Height at different sizes of riser neck.
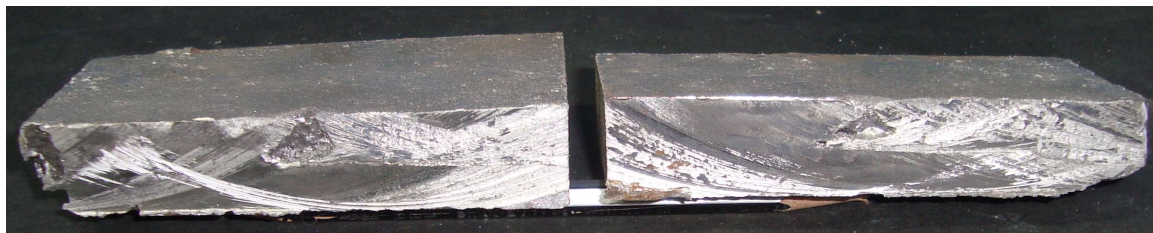

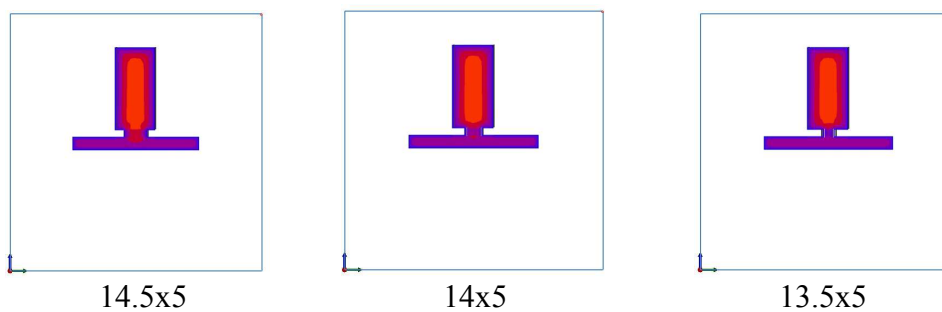| 14.5x5 | 14x5 | 13.5x5 |

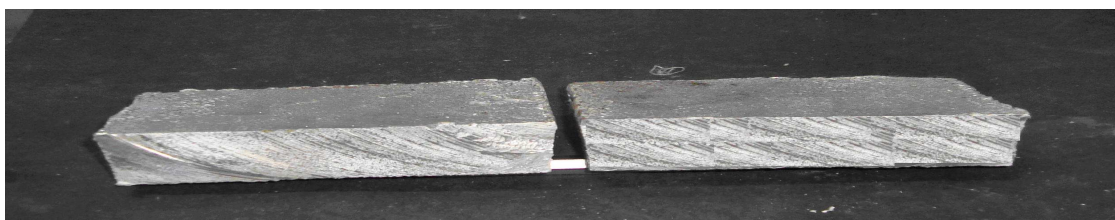Fig6(a) Sample with Riser Ø 38mmx76mm Height with Neck Ø 13 mmx5 mm Height

Fig.6(b) Sample with Riser Ø 38mmx76mm Height with Neck Ø 13.5mmx5mmHeight

Conclusion:

In case of steel the neck diameter is generally 40% to 50% of riser diameter but from the above experiments it is found that for LM6 Aluminium alloy the minimum neck diameter is 35% of riser diameter. Moreover the application of casting simulation softwares in the foundries not only minimizes the wastages of resources required for final castings, but also improves/ enhances the quality and yield of castings, which implies higher value addition and lower production cost. The experimental study represents the effect of sizes

of risers and necks on the solidification behaviour of the aluminium alloy castings. The simulated results are more or less similar with experimental results.

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