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Optimization of Riser in Casting Using Genetic Algorithm

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ABSTRACT
India is the second largest casting component producer in the world after china. So, foundries represent important sector of the manufacturing industry. Yield percentage per component is main headeck for small and medium scale foundries. Weight of gating system and riser plays important role in improvement of yield per component. Gating system varies according to geometry of every component. So riser or feeder size plays very important role. Riser supplies liquid metal to compensate shrinkage that accompanies metal solidification. The risers should have sufficient capacity so that they provide required amount of molten metal and they freeze only after the casting has solidified completely. The classical approach of riser design is based on trial and error method and experience. But it takes too much time and man power. Now days commercial codes are used to simulate casting process but for that also initial riser design has to be fed manually. Simulation software only gives validation of results not initial design. Genetic algorithm (GA) with computer aided design generates an intelligent initial design that can go a long way in making intelligent manufacturing of casting component. Genetic algorithm gives optimized initial design of riser. In this paper the focus is sharpened in how to implement GA in riser design. At latter stage in paper case study is given on wheel flange with formation of genetic algorithm for wheel flange. Results of algorithm give number of alternative optimized riser design. Riser with 58 mm average diameter and 77 mm height is best optimized riser for wheel flange. For wheel flange Genetic Algorithm method gives more optimized results than the modulus method of riser design.

Keywords*- Artificial Intelligence Technique, Feeders, Genetic Algorithm, Modulus Method, Shrinkage in Casting*

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INTRODUCTION

The casting process offers the widest range of design of design and process parameters in terms of material weight, shape complexity, batch size and quality of product. 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 [1].

As the metal cools between the liquidus and solidus temperatures and changes state from liquid to solid, significant amounts of shrinkage tend to occur. Not all metals contract. Some expand, such as grey cast iron, in which low-density graphite flakes form as part of the solidification structure [2]. Risers are used to compensate such shrinkages in the casting. Riser size and shapes varies according to material, weight and shape of casting component.

Recently the use of casting simulation software is increasing day to day in Indian foundry as it essentially replaces or minimizes the shop-floor trials to achieve sound castings at the highest possible time. The main inputs for the casting simulation software are 3D geometry of the mould cavity with gating and risering system, thermo-physical properties of the mould and cast material. Riser design plays very important role in gating system design. In 3D geometry of mould cavity riser dimension has to give manually. Genetic algorithm can be used to design optimized riser.

Genetic Algorithm (GA)

Genetic Algorithms are a family of computational models inspired by evolution. These algorithms encode a potential solution to a specific problem on a simple chromosome-like data structure and apply recombination operators to these structures as to preserve critical information. Genetic algorithms are often viewed as function optimizer, although the ranges of problems to which genetic algorithms have been applied are quite broad [3].

An implementation of genetic algorithm begins with a population of (typically random) chromosomes. One then evaluates these structures and allocated reproductive opportunities in such a way that these chromosomes which represent a better solution to the target problem are given more chances to `reproduce' than those chromosomes which are poorer solutions. The 'goodness' of a solution is typically defined with respect to the current population [2].

Genetic algorithms are robust, effective optimization techniques inspired by the mechanism of evolution and natural genetics [4].

A GA has a number of advantages. It can quickly scan a vast solution set. Bad proposals do not affect the end solution negatively as they are simply discarded. The inductive nature of the GA means that it does not have to know any rules of the problem, it works by its own internal rules. This is very useful for complex or loosely defined problems.

GAs have drawbacks too, while the great advantage of GAs is the fact that they find a solution through evolution, this is also the biggest disadvantage. Evolution is inductive; in nature life does not evolve towards a good solution. It evolves away from bad circumstances. This can cause a species to evolve into an evolutionary dead end. Likewise, GAs risk finding a suboptimal solution.

Working Principle of Genetic Algorithm

Genetic algorithms are adaptive methods which can be used to solve search, optimization and complex problems. However the major disadvantage of genetic approaches is that the algorithm uses a tremendous amount of processing time [7]. Genetic algorithm begins with a set of solutions (represented by chromosomes) called the population.

i. Solution from one population are taken and used to form a new population. This is motivated by the possibility that the new population will be better than the old one.
ii. Solutions are selected according to their fitness to form new solutions (offspring); more suitable they are more chances they have to reproduce.
iii. This is repeated until some condition (e.g. number of populations or improvement of the best solution) is satisfied.

RISER AND RISER DESIGN

Risers are added reservoirs designed to feed liquid metal to the solidifying casting as a means of compensating for solidification shrinkage. To perform this function, the risers must solidify after the casting. If the reverse were true, liquid metal would flow from the casting into the solidifying riser, and the casting shrinkage would be even greater. Hence, the casting should be designed to produce directional solidification, which sweeps from the extremities of the mould cavity to the riser. In this way, the riser can "Continuously feed molten metal and will compensate for the solidification shrinkage of the entire mould cavity. If such solidification is not possible then multiple risers may be necessary, with various sections of the casting solidifying toward their respective risers. Modulus method, Caines method etc. are some methods used for riser design.

Finally, risers should be designed to conserve metal. The yield of a casting is defined as the casting weight divided by the total weight of metal poured (sprue, gates, risers, and casting), it is clear that there is a motivation to make the risers as small as possible to still perform their task. Yield percentage is given by following equation [5],

$$Yield\% = \frac{Volume_{cast}}{Volume_{cast}+Volume_{gating+riser}} \quad ...(1)$$

According to this formula yield percentage per component is inversely proportional to the volume of the riser. So as the volume of riser decreases yield percentage per component automatically increases. Therefore in GA problem fitness function for this problem will be minimization of volume of the riser. This can often be done by proper consideration of riser size, shape, and location, and the nature of the connection between the riser and the casting.

There are different shapes of risers are used in foundries like cylindrical, spherical, rectangular bar, cube, plate, round bar etc. But the selection of the shape of riser depends upon the modulus of that particular shape. Generally spherical shape riser gives highest modulus than any other shape. But in spherical riser circumferential are solidified first, so molten metal present at the center of the spherical riser cannot supply liquid molten metal to casting cavity and it is very difficult to reproduce spherical shape on moulding plates. Therefore, though the spherical riser has higher modulus generally they are not preferred in foundries. Cylindrical riser overcome these two drawbacks very well and also gives higher modulus. So in the case study explained in this paper cylindrical riser is selected for providing molten metal to mould cavity. Modulus of cylindrical riser is given by equation 2.

$$Modulus = \frac{(DH)}{(4H+2D)} \qquad ...(2)$$

Where,
D = Average diameter of cylindrical riser,
H = Height of cylindrical riser.

A final aspect of riser design is the connection between the riser and the casting. Since it will ultimately be necessary to separate the riser from the casting, it is desirable that the connection area be as small as possible. On the other hand, the connection area should be large enough so that the link does not freeze before solidification of the casting is complete. Short-length connections are most desirable. The adjacent mould material will then receive heat from both the casting and the riser. Therefore, it will heat rapidly and remain hot throughout the cast, retarding solidification of the metal in the channel. The gating system in casting process is shown in figure 1.

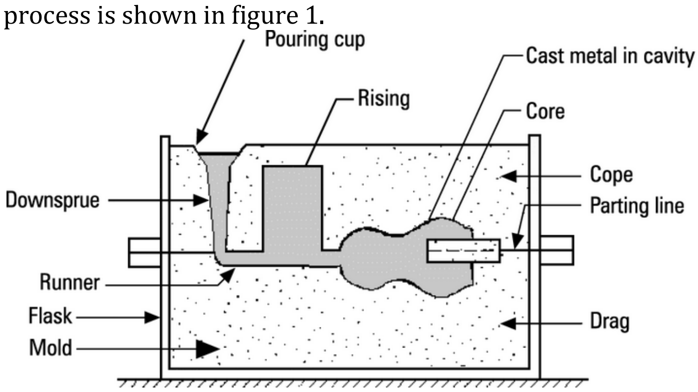

Fig.1. Gating and risering system in casting.

Formation of Genetic Algorithm Problem for Wheel Flange

It is made up of ductile iron using sand casting method.

A. Specifications of wheel flange
i. Material: Spheroidal Graphite CI (412 grade).
ii. Casting weight: 18.575 Kg.
iii. Vol. of Component: 2616197 mm3.
iv. Modulus of casting = (volume)/(surface area)
= 8.77
v. Shrinkage factor of material: 2.5% contraction to 2.5% expansion.

Surface area of component: 298176 mm^3 (Surface area of the component is calculated by creating the 3D image of the wheel flange in software CATIA and it is nearly equal to the actual surface area of component). Model of wheel flange in CATIA is shown in fig. 2.

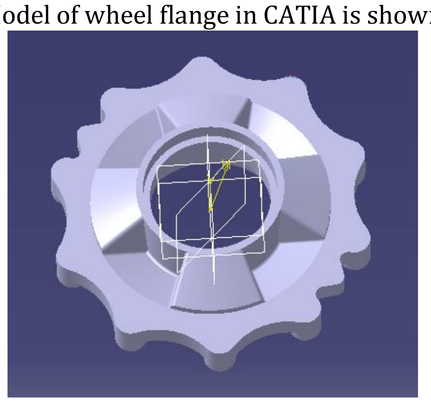

Fig.2. Model of Wheel Flange in CATIA.

Risers are to be designed, one for each feeding section for which the dimensions have to be determined. The search space has infinite possibilities for feeder dimensions. GAs gives a methodology for parallel search in the domain of all possible solutions such that the fitness function, which in this case is yield maximization. Inputs are volume and the modulus of a riser section. The other inputs required are the shrinkage factor, efficiency and a multiplication factor of safety and upper and lower bounds

within which each of the design variables (the riser dimensions) can vary. The bounds reduce the search space. One or more of these variables can also be fixed [4].
To encode a solution of the problem, instead of the commonly used bit string encoding, a real number representation is used as the parameters to be determined are al real. A chromosome vector is coded as a vector of real numbers of the same length as the solution vector. The initial population is selected by a random number generator so that the variables lie within the specified bounds.
Yield percentage per component is calculated by using volume of casting, volume of gating system and volume of risers. So to maximize yield percentage per component volume of riser must as minimum as possible and it must satisfy all design requirements of riser.

Objective function, it is also known as Fitness Equation, which is given in equation (3),

Minimize,

$f(x) = V_{riser} = \frac{\pi}{4} D^2 H$ ...(3)

Constraints:

1. $V_{max} > V_{riser}$ ...(4)
2. $V_{riser} > V_{min}$ ...(5)
3. $M_r > 1.2 \times M_c$ ...(6)

For Wheel flange,

1. $254340 > V_{riser}$ ...(7)
2. $V_{riser} > 65405$ ...(8)
3. $M_r > 1.2 \times 8.77$ ...(8)

Where, V_{max}= maximum volume of riser;

V_{min} = (minimum volume required for riser)
= (contraction factor of material × volume of Casting);

M_r = Modulus of riser = $\frac{V_{riser}}{SA_{riser}}$;

M_c = Modulus of casting = $\frac{V_{casting}}{SA_{casting}}$

Where,

V_{riser} = Volume of riser,

SA_{riser} = Surface area of riser.

Here V_{min} and V_{max} values can be obtained. So by providing these boundary conditions in the Genetic Algorithm we can obtain the Optimized volume of the riser, which will fulfill all the design requirements of riser.

Steps Used in Genetic Algorithm for Preparing Program

To solve the above problem using Genetic Algorithm C++ programming language is used and code is generated to solve above problem. It is based on the following steps,

```
Basic Steps in GA
    formulate initial population
    randomly initialize population
    repeat
    evaluate objective function
    find fitness function
    apply genetic operators
    reproduction
    crossover
    mutation
       until stopping criteria
```

A. Reproduction

Reproduction is usually the first operator applied on population. Chromosomes are selected from the population to be parents to cross over and produce offspring. According to Darwin's evolution theory of survival of the fittest, the best ones should survive and create new offspring. That is why reproduction operator is sometimes known as the selection operator [3].

B. Cross Over

After the reproduction phase is over, the population is enriched with better individuals. Reproduction makes clones of good strings, but does not create new ones. Cross over operator is applied to the mating pool with a hope that it would create a better string. The aim of the cross over operator is to search the parameter space. In addition, search is to be made in a way that the information stored in the present string is maximally preserved because these parent strings are instances of good strings selected during reproduction [3]. Cross over operation is shown in table 1.

Table 1: Cross over operation.

String 1	011|01100	String 1	011|11001
String 2	110|11001	String 2	110|01100
Before Crossover		After Crossover	

C. Mutation

Mutation of a bit involves flipping string, changing 0 to 1 and vice versa with a small mutation probability. Sometimes it is not possible to get the optimum solution by only crossover at that time mutation is necessary. Output remains constant after few iterations at that time mutation operator is used for further optimization of problem. Mutation operation is shown in table 2.

Table 2: Mutation operation.

	Third point is mutation point	Fitness function (x^2)
Initial String	0101	25
Mutated String	0111	49

Input variables for the program/code are volume of casting and surface area of casting. By just entering volume of casting and surface area of casting program gives the optimised design of cylindrical riser for wheel flange.

The GA optimization algorithm can be summarized as follows:

i. Generate a random initial population of N individuals.
ii. Compute the fitness values of the N individuals.
iii. Select individuals to reproduction.
iv. Apply crossover and mutation operator.
v. Compute the fitness values of the N individuals.
vi. Select the N best individuals to compose the new population.
vii. Repeat steps 3-6 until it reaches a predefined stopping criteria

RESULTS AND DISCUSSIONS

Genetic algorithm code gives number of alternative and optimized designs of riser sizes. These riser sizes satisfy all the technical requirements of the riser. From the results riser number 1 (as shown in table 3), gives minimum volume of riser (that is 203336 mm^3) and having average diameter 58 mm and height 77 mm. Modulus of this riser is 10.53 which is sufficient for wheel flange casting. Also designer can go with riser number 2 having volume 226991 mm^3, with diameter 57 mm and height 89 mm. But to increase yield percentage per component riser 1 will be best for wheel flange casting. Riser number 4 also satisfies all three technical conditions for design of riser but give less yield per component. But the volume of riser 4 is more than volume of riser 1. So yield percentage per component with riser 1 is better than riser 4. But if there is any constraint due to mould size then designer can choose any suitable combination of average diameter and height. Results obtained from the genetic algorithm are shown in table 3.

Table 3: Results obtained from genetic algorithm.

Sr. No.	*Average Diameter (mm)*	*Height (mm)*	*Volume (mm^3)*	*Modulus*
1	58	77	203336	10.53
2	57	89	226991	10.79
3	75	60	264937	11.54
4	64	84	270090	11.59
5	75	62	273768	11.68
6	80	57	286368	11.75

This generated code can be used to design cylindrical riser for each and every component. Code will give number of alternative designs of riser. According to manufacturing limitations designer can choose any of the riser which is optimized. GA program asks user only the volume of component, surface area of component, contraction factor of material and number of iterations only. By feeding these values to program designer will automatically get the design of riser (size of riser) as a output of the program/code.

Comparison of results

Generally riser is designed using modulus method. The modulus of wheel flange is 8.77 mm, so required modulus of riser will be 1.2 times modulus of casting. So the designed modulus must have modulus greater than or equal to 10.528 mm. In modulus method of riser design H/D ratio is assumed as 1.5. With this data modulus method give the riser with average diameter 57 mm and height 85 mm. Volume of the riser is 216790 mm^3. Presently used riser has average diameter 60 and height 90 mm and having volume 254340 mm^3.

Table 4: Comparison of results.

Sr. No.	Method	Avg. Diameter	Height	Volume	Modulus
1	Modulus	57	85	216789	10.53
2	GA	58	77	203336	10.53

The riser design by the Genetic Algorithm method is efficient than modulus method. It gives 6.2% less volume than the modulus method for same riser modulus. One another advantage of Genetic Algorithm method over modulus method is GA gives number of alternative solutions. While modulus method give only one particular solution.

CONCLUSIONS

The code/program generated by using Genetic Algorithm technique can be used to obtain optimized riser size for every type of casting component. The Genetic Algorithm method can be applied to any standard feeder shape as the volume and area can be calculated by geometrical formulae. As the algorithm is computationally fast and easy to implement, many alternate feeder dimensions can be evaluated quickly. The artificial intelligence technique of GAs can generates an intelligent initial design that can go a long way in making intelligent manufacturing of cast components. As GA is a random selection process it does not require more analytical information. The optimization tool (Genetic Algorithm) can be used in foundry process to increase the yield of foundry. For wheel flange component optimized riser size have 58 mm diameter and 77 mm height with 203336 mm^3 volume. Genetic Algorithm method gives 6.2% optimized riser, than the modulus method.

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REFERENCES

1. T. Nandi, R. Behera and G. Sutradhar, "Optimization of Riser Size of Aluminium Alloy (LM6) Castings by Using Conventional Method and Computer Simulation Technique," International Journal of Scientific and Engineering Research, Volume 2, Issue 11, November-2011, pp. 1-6.
2. http://faculty.ksu.edu.sa/melrayes/Course%2OME355%20Processing%20of%20Engineering%20Materials1/prediction%20of%20solidification%20time.pdf (Cited on 4-10-2012, time-03:15 pm).
3. T. V. Mathew, "Introduction to Genetic Algorithm", Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai.G.
4. E. Jacob, R. Sasikumar, B. Praveen, and V. Gopalkrishna, "Intelligent Design of Feeders for Castings by Augmenting CAD with Gentic Algorithm", Journal of Intelligent Manufacturing, pp. 299-305,2004.
5. Jean Kor, Xiang Chen, Zhizhong Sun, and Henry Hu, "Casting Design Through Multi-Objective Optimization", Preprints of the 18th IFAC World Congress Milano (Italy),pp. 11642-11647,Sup. 2004.
6. S. Rajasekaran, and G. Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic and Genetic Algorithm", Prentice-Hall of India, Eastern Economy Edition, 2008.
7. H. Htofuji, M. Tamura, and H. Ito, "Production of the 7-ton Nonmagnetic Ductile Iron Casting for Largest Class Power Generator", Material Transactions, vol. 51, pp. 103-109,2010.
8. Zhou, "Analysis of Reasons Causing Riser Feeding Failure in Nodular Iron Casting Production", 7th FOSECO Cup excellent foundry papers of FICMES, Vol. 2, No. 4, Nov. 2005, pp. 231-238.

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