CHAPTER 7

SELECTION OF OPTIMAL PARAMETERIC COMBINATION
BY USING GENITIC ALGORITHM

7.1 INTRODUCTION

Genetic algorithms have been widely studied, experimented, analyzed and applied in many fields of engineering studies. Genetic algorithm is a stochastic search procedure for understanding combinatorial optimization problems, based on the mechanism of natural selection and natural genetics. The elements and mechanisms of genetic algorithm are representation, population, evaluation, selection, operator and parameter. The algorithm starts with a randomly generated initial set of population called chromosomes that represent the solution of the problem. These are evaluated for the fitness function and then selected according to their fitness value. Many selection procedures are currently in use to generate next generation. Most of the selection procedures are based on the fitness value of the individuals of the current generation.

7.2 CHROMOSOME/STRING REPRESENTATION

The value of each parameter in the process is referred to as a gene. The numerical value assigned to each gene is dependent on the
range defined to the respective gene. All the parameters that influence
the casting rejection rate are referred to as a string or chromosome. The
chromosome is a collection of genes. The length of the chromosome is
obviously the total number of parameters that influence the casting
rejection rate. In this research work, the length of the chromosome is
assumed to be nine which represents the process parameters that
influence the casting defects.

7.3 INITIALIZATION

Number of chromosomes is referred to as population size. Initially, the population is generated randomly and the initial population
size is assumed as 10.

7.4 FITNESS FUNCTION EVALUATION

The objective function provides appropriate mechanism for
evaluating each string. The objective of the casting parameter
optimization problem is to minimize the percentage of rejection rate. To
transfer the objective function value into a convenient range, it is
necessary to map out the underlying natural objective function to a
fitness function through mapping, scaling and normalization. In this
research work, fitness function value $F(x)$ of each chromosome is
evaluated using the following equation 7.1:

$$F(x) = \frac{1}{1 + f(x)} \quad (7.1)$$

where, $f(x)$ is the objective function value.
7.5 REPRODUCTION

Reproduction is a biased selection process to choose “mates” for the offspring generation. The selection policy is ultimately responsible for assuring survival of the best-fitted individuals. Moreover, proportionate selection schemes like roulette wheel selection scheme, rank based selection scheme and tournament selection scheme, have been developed to improve the performance of Genetic Algorithms. In this research work, roulette wheel selection scheme is used to carry out the reproduction process.

7.6 CROSSOVER

The crossover operation takes two chromosomes and exchanges a part of their genetic information to produce a new chromosome. The exchange is accomplished by sharing the genetic information between two selected chromosomes. Here, single point, multipoint and uniform crossovers are the commonly used techniques. In this research work, single point crossover technique is used in the process.

7.7 MUTATION

Mutation is the process of randomly selecting some genes in a chromosome and changing them within the respective acceptable range. The mutation operator is used to introduce new genetic structure in the population by randomly modifying some of its genetic structures and can assist in the search process escape from local optimum trap. Accordingly, by assigning a new value to the selected gene within its interval does the modification occurs.
7.8 GENETIC ALGORITHM - CONTROL PARAMETERS FOR GREEN SAND CASTING

Population size = 10
Reproduction = Roulette wheel method
Crossover = Single point crossover
Crossover probability (Pc) = 0.55
Mutation = Single point mutation
Mutation probability (Pm) = 0.03
Termination criterion = Number of Generations 500

7.9 GENETIC ALGORITHM - CONTROL PARAMETERS FOR CO₂ CASTING

Population size = 10
Reproduction = Roulette wheel method
Crossover = Single point crossover
Crossover probability (Pc) = 0.60
Mutation = Single point mutation
Mutation probability (Pm) = 0.04
Termination criterion = Number of Generations 500

7.10 FLOW CHART FOR GENETIC ALGORITHM

In this research work, Genetic algorithm based optimal parametric combination selection is employed for optimizing the process parameter and the percentage of rejection rate for green sand and CO₂ castings are minimized. The schematic flow chart shown in Figure 7.1 clearly explains the various processes involved in Genetic algorithm.
Figure 7.1 Flow chart for genetic algorithm
7.11 RESULTS AND DISCUSSIONS

The optimal green sand casting and CO₂ casting process parameters and the corresponding minimum percentage casting rejection obtained by using genetic algorithm are given in Tables 7.1 and 7.2. The least percentage of casting rejection rate for the optimal values of green sand casting and CO₂ casting process parameters is found to be 7.0814 and 6.2489. The Genetic algorithm convergence curves obtained for various crossover, mutation probabilities and various runs for green sand casting are shown in Figure 7.2 to Figure 7.7 and for CO₂ casting are shown in Figure 7.8 to Figure 7.13. The result confirms the crossover probability and mutation probability as 0.55 and 0.03 for green sand casting, whereas it is 0.6 and 0.04 for CO₂ casting. The genetic algorithm results clearly give the minimized percentage rejection for green sand casting is 1.72 and CO₂ casting is 1.15. The process control parameters and their relative importance on quality of the casting process employed to produce the casting components.
Table 7.1  GA result of optimal green sand casting process parameters and the corresponding minimum casting rejection

<table>
<thead>
<tr>
<th>Parameter designation</th>
<th>Process Parameters</th>
<th>Optimal value of process parameter</th>
<th>Objective function value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Moisture content (%)</td>
<td>2.99</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Green strength (gm/cm²)</td>
<td>925.63</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Ramming pressure (N/m²)</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Mould hardness (No.)</td>
<td>88.79</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Permeability (No.)</td>
<td>269.63</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Sand particle size (No.)</td>
<td>75.88</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Pouring temperature (°C)</td>
<td>1600</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Pouring height (cm)</td>
<td>21.79</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Cooling time of poured metal (min)</td>
<td>19.61</td>
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</table>

Table 7.2  GA result of optimal CO₂ casting process parameters and the corresponding minimum casting rejection

<table>
<thead>
<tr>
<th>Parameter designation</th>
<th>Process Parameters</th>
<th>Optimal value of process parameter</th>
<th>Objective function value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Weight of CO₂ gas (kg)</td>
<td>0.73</td>
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</tr>
<tr>
<td>B</td>
<td>Mould Hardness (No.)</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Sand particle size (No.)</td>
<td>50</td>
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</tr>
<tr>
<td>D</td>
<td>Percentage of Sodium silicate (%)</td>
<td>4</td>
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</tr>
<tr>
<td>E</td>
<td>Sand mixing time (min)</td>
<td>4.66</td>
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</tr>
<tr>
<td>F</td>
<td>Pouring time (sec)</td>
<td>16.51</td>
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</tr>
<tr>
<td>G</td>
<td>Pouring height (cm)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Pouring temperature (°C)</td>
<td>1550</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Cooling time of poured metal (min)</td>
<td>58.13</td>
<td></td>
</tr>
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</table>
Figure 7.2  Comparison of GA convergence curves for various cross over probabilities for green sand casting (Pm=0.03)

Figure 7.3  Comparison of GA convergence curves for various cross over probabilities for green sand casting (Pm=0.04)

Figure 7.4  Comparison of GA convergence curves for various cross over probabilities for green sand casting (Pm=0.05)
Figure 7.5  Comparison of GA convergence curves for various mutation probabilities for green sand casting (Pc=0.55)

Figure 7.6  Convergence of objective function for GA based green sand casting for various runs

Figure 7.7  Convergence of objective function for GA based green sand casting for single run
Figure 7.8  Comparison of convergence curves for various cross over probabilities for CO₂ casting (Pm=0.03)

Figure 7.9 Comparison of convergence curves for various cross over probabilities for CO₂ casting (Pm=0.04)

Figure 7.10 Comparison of convergence curves for various cross over probabilities for CO₂ casting (Pm=0.05)
Figure 7.11  Comparison of convergence curves for various mutation probabilities for CO\textsubscript{2} casting (Pc=0.6)

Figure 7.12  Convergence of objective function for GA based CO\textsubscript{2} casting for various runs

Figure 7.13  Convergence of objective function for GA based CO\textsubscript{2} casting for single run