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OPTIMIZATION OF MACHINING COST FOR TURNING OPERATION USING GENETIC ALGORITHM

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ABSTRACT

Determining the optimal cutting parameters is having vital importance in any machining process considering the economy of machining operation. In the optimization process, any possible variables will be evaluated based on requirements. In turning operation predicting the proper cutting speed and feed during turning is of great importance as it helps in setting the appropriate cutting parameters before machining starts in order to optimize the machining cost. The Genetic Algorithm (GA) is used for optimization of complex problems in many applications. The paper deals with the optimization of machining cost of turning operation by selecting the best possible cutting parameters in turning operation using Genetic Algorithm (GA) approach.

Keywords: *Optimization, Genetic Algorithm, Turning, Machining cost.*

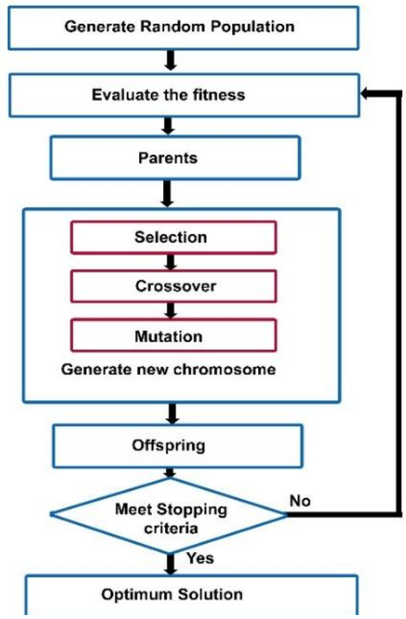
I. INTRODUCTION

In the modern metal cutting operations, the most emerging needs is to reduce the machining cost of the operation with better surface finish and high machining accuracy. These objective can be attained by finding out the best set of cutting parameters, before starting of actual machining operation. Selecting the optimal cutting parameters is important as the quality of machined products, machining costs and production rate strongly depends upon it.The cutting parameter optimization is also essential to avoid the adverse conditions related to tool life, power consumption, surface roughness, surface finish etc.

In the present work, the Genetic Algorithm is used for optimization of the cutting parameters for turning operation of EN10250 steel. The cutting speed and feed are considered as the key parameters, as improper selection of these parameters has a direct impact on tool life, time of machining and its cost.

II. GENETIC ALGORITHM

Genetic Algorithm (GA) works on the theory of Darwin's theory of evolution and the survival-of-the fittest. Genetic algorithms guide the search through the solution space by using natural selection and genetic operators, such as crossover, mutation and the selection. GA encodes the decision variables or input parameters of the problem in to solution strings of a finite length. While traditional optimization techniques work directly with the decision variables or input parameters, genetic algorithms usually work with the coding. Genetic algorithms start to search from a population of encoded solutions instead of from a single point in the solution space. The initial population of individuals is created at random. Genetic algorithms use genetic operators to create Global optimum solutions based on the solutions in the current population. The most popular genetic operators are (1) selection, (2) crossover and (3) mutation. The newly generated individuals replace the old population, and the evolution process proceeds until certain termination criteria are satisfied.



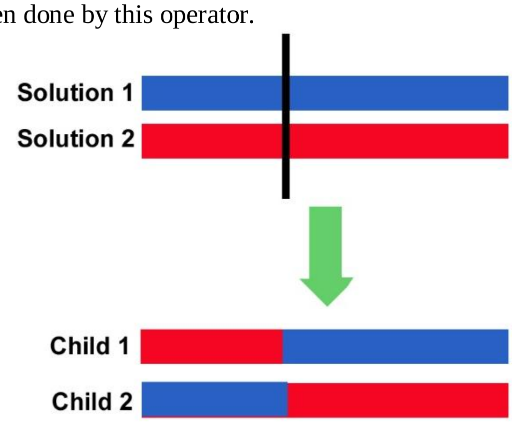
Flow chart of Genetic Algorithm

Selection

It is a procedure in which identification of good solutions is done from the population and bad solutions from the population are eliminated. The selection procedure implements the natural selection or the survival-of-the fittest principle. Individuals with higher fitness values have a higher probability of being selected for mating and then for genetic production. After selection, crossover and mutation recombine and alter parts of the individuals to generate new solutions.

Crossover

A new solutions from the existing solutions are created in this process. The new solutions thus created are made available in the mating pool after applying selection operator. The exchanges the gene information between the solutions in the mating pool is then done by this operator.



Example of crossover

Mutation

Mutation usually alters some pieces of individuals to form a solutions. Unlike crossover, which operates on two or more individuals, mutation operates on a single Individual. One of the most popular mutation operators is the bitwise mutation, in which each bit in a binary string is complemented with a mutation probability.

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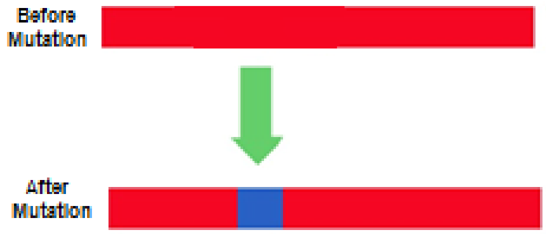

Example of Mutation

III. OPTIMIZATION OF MACHINING COST

An optimization problem consists of two phases; first one is to forming the objective functions while satisfying several constraints and the second phase is optimizing the objective function by using the algorithm. These objectives may be conflicting and unequaled, just as the increase in feed rate increases the production rate but at the same time it also increases the operational cost because of higher tool wear and low surface finish quality.

Mathematical Modeling

Mathematical modeling is the first phase of optimization process. In this phase the objective function is defined along with all the constraints and bounds using equalities and/or inequalities.

While optimizing the turning process, the objective function is usually the machining cost. In the present work, minimum machining cost is taken as objective function and is defined [1] by the equation;

$$C = C_r\, t_L + C_r\, t_m + \frac{t_m}{T}(C_r\, t_d + C_a) \quad (1)$$

Where: C (Rs.) – cost of machining, Cr (Rs.) – labor plus overhead cost, tL (min) – nonproductive time, tm (min) – machining time, T (min) – tool life, td (min) – tool changing time, Ca (Rs.) – tool cost per cutting edge.

In turning process, Machining time can be expressed as:

$$t_m = \frac{\pi DL}{1000\, vf} \quad (2)$$

Whereas the relationship between the cutting speed and the tool life, feed and depth of cut is given as;

$$T = \frac{C_T}{v^p . f^q . d^r} \quad (3)$$

where: L – length of turning (mm), D – work piece diameter (mm), v– cutting speed (m/min), f– feed (mm/rev). T– Tool life (min), d– depth of cut (mm), CT, p, q and r – empirical constants.

According to the equation (1), (2) and (3), cost of machining can be expressed as:

$$C = C_1 + C_2 v^{-1} f^{-1} + C_3 v^{p-1} f^{q-1} \quad (4)$$

Where: $C_1 = C_r\, t_L$

$$C_2 = \frac{\pi DLC_r}{1000}$$

$$C_3 = \frac{\pi DLd^r (C_r t_d + C_a)}{1000.\, C_T}$$

The process can be said as optimized when the machining cost is minimum or near to it, respecting all the constraints on variables v and f.

The constraint functions are as follows;

1) Constraints on cutting ability of tool:
   $v^p . f^q \leq \frac{C_T}{T.d^r}$ (5)
2) Constraints on machine tool power:
   $v.f \leq \frac{6000.P.\eta}{d.F}$ (6)
3) Constraints on minimum cutting speed:
   $v \geq \frac{\pi D n_{min}}{1000}$ (7)
4) Constraints on maximum cutting speed:
   $v \leq \frac{\pi D n_{max}}{1000}$ (8)
5) Constraints on minimum feed:
   $f \geq f_{min}$ (9)
6) Constraints on minimum feed:
   $f \leq f_{max}$ (10)

The selected work piece for turning is a bar of 100 mm diameter made from Hardened 42CrMo4 (EN10250) Steel having Hardness 35 HRC, and the tool is commercially available Tungsten based cemented carbide, Inserts type SNMM120404,Tool holder ISO PCBNR/L 2020K12.

For determining the optimum feed and cutting speed for turning operation, the following data is necessary; D= 100mm, L= 150mm, d=2mm, Cr = 2 Rs., tL = 2 min, T = 60 min, td = 2 min, Ca = 10 Rs., d = 2mm, ,η=0.8, P=11Kw, F= 280 kg/mm2. The empiric constants CT = 1821.634, p=0.825, q=0.769, r=0.248 [6], minimum spindle speed= 20rpm, maximum spindle speed= 1500 rpm, minimum depth of cut=0.04mm, maximum depth of cut=9mm.

Mathematical model of optimization:
By putting the above values of various selected parameters are substituted in the equations (4),(5),(6),(7),(8),(9) and (10), we get the following objective function and all the constraints functions.
Objective function:

$C = 4 + \frac{94.24}{v.f} + 0.43\, v^{-0.178} . f^{-0.231}$ (11)

Constraint Functions:

1) $v^{0.825} . f^{0.769} \leq 25.56$ (12)
2) $v.f \leq 94.28$ (13)
3) $v \geq 12.57$ (14)
4) $v \leq 471.24$ (15)
5) $f \geq 0.04$ (16)
6) $f \leq 9$ (17)

Use of genetic algorithm
The above mathematical model has been programmed in MATLAB. For the implementation of GA, Matlab's GA toolbox is used. For optimizing process of machining cost, the optimal parameters have been given. GA continues until the stopping criteria are met.

Once the parameter satisfies all the constraint functions, it gives the optimal value of objective function.
In this case, at first the machining cost is defined in the Matlab environment and then the nonlinear constraints are defined. This function is then minimized using GA toolbox. When the optimization process is terminated, then the optimized value of the objective function which satisfies all the constraints. Figure 4 shows the Matlab GA toolbox.

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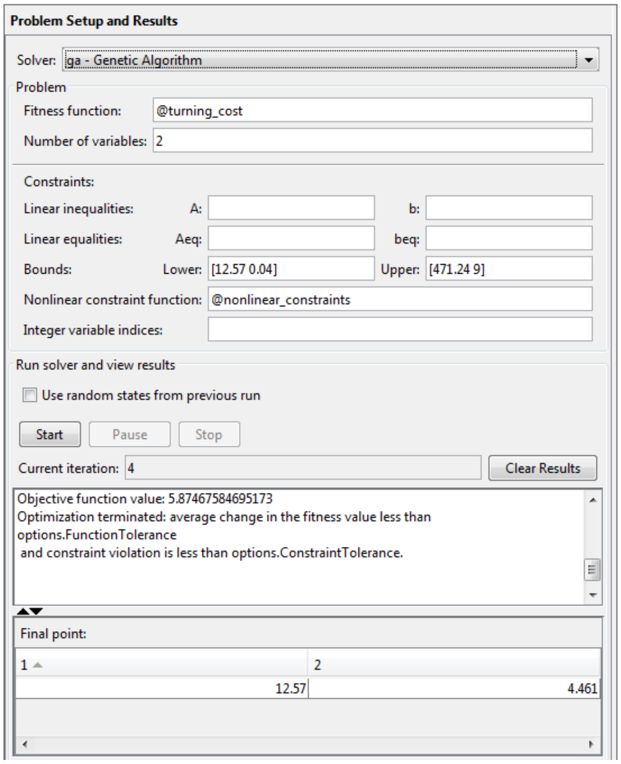

Genetic Algorithm Toolbox in Matlab environment

IV. RESULT & DISCUSSION

The optimum results were obtained after 4 iterations using [12.47 0.04] as lower bound and [471.24 9] as upper bound for the two variables; cutting speed and the feed respectively.
The optimized value of machining cost function and both the variables are as shown in table 1. And the Figure below shows the graphical representation of the optimization process with Matlab GA toolbox.

Table 1. Optimized values of machining cost, cutting speed and feed

Machining cost- C_{min}	**Cutting speed v**	**feed f**
5.874 Rs	12.57 m/min	4.46 mm/rev

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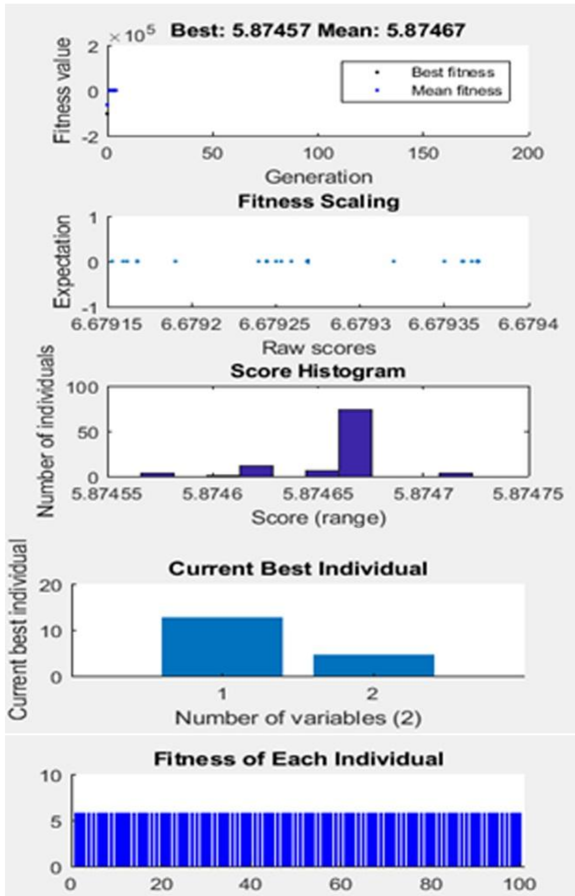

Graphical representation of simulation process

V. CONCLUSION

Obtaining the minimum Machining cost with respect to various constraints is of key importance and the research topic in the field of machining. The recent methods of optimization has make it easier to optimize the complex machining optimization problem. The optimum cost of machining in turning process, depending on cutting speed and feed was obtained effectively under some nonlinear constraints in very less time. As by using the GA approach, the minimal value of machining cost is obtained, it can be used for obtaining machining parameters for more complex machining operations having many variables and more constraints.

The results obtained from the optimization process has presented a quick and suitable solution for the selection of machining parameters.

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