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# Cost Minimization Of Turning Machining Process Using Cuckoo Search, Pattern Search, Firefly And Flower Pollnation

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**Abstract**
Modern non-traditional optimization algorithms are used to find the global optimum values for any problem. Optimization methods of machining process are the tools to improve the product quality and reduce the cost and time. Optimal parameters of machining which are the cutting speed and feed were determined using all the methods. Also, minimal cost for the turning process was achieved using cuckoo search, Pattern search, flower pollination and firefly algorithms.

**Key words**: machining process, turning, pattern search, cuckoo search, flower pollination, firefly.

## 1. Introduction
Optimization of parameters in one of the standard problem in machining process. The turning process requires finding the cutting sped and feed and then do the turning process, which requires more time and the cost is too high because only by trial and error we can fine the value of the cutting speed and feed. The optimization is divided into two parts. a) Design optimization b) process optimization. The problem that we have considered here is process optimization which will be difficult but is of great help to reduce the cost of turning machining process. In this paper, we use four different optimization methods for cutting parameters for turning of mild steel. The key parameters are cutting speed and feed.

## 2. Optimization methods
### 2.1. Cuckoo search
Cuckoo search (CS) is a new metaheuristic search algorithm. This algorithm is based on the obligate brood parasitic behavior of some cuckoo species in combination with the Le´vy flight behavior of some birds and fruit flies (Daoud, 2013). It is developed by Yang and Deb(2009, 2010) and the preliminary studies show that it is very promising and could outperform existing algorithms such as GA and PSO (Shadkam & Bijari, 2014). The CS algorithm has been proven to deliver excellent performance in function optimization, engineering design, neural network training, and other continuous target optimization problems and has solved the knapsack and nurse-scheduling problems (Ehsan Valian, 2011). (Yang & Alavi, 2013)

### 2.2. Pattern search
A direct search algorithm for numerical search optimization depends on the objective function only through ranking a countable set of function values. It does not involve the partial derivatives of the function and hence it is also called non-gradient or zeroth order method. This methodology involves setting up of grids in the decision space and evaluating the values of the objective function at each grid point and thereby incrementing and decrementing the grid space to get the optimum point (Ajay.A, 2013). The point which corresponds to the best value of the objective function is considered to be the optimum solution

### 2.3. Firefly algorithms
Firefly Algorithm (FA) was first developed by Xin-She Yang in late 2007 and 2008 at Cambridge University, which was based on the flashing patterns and behaviour of fireflies (Pal, Rai, & Singh, 2012).

#### 2.3.1. Behaviour of Fear Fly in Nature:-
There are near to two thousand firefly species, and most of them produce short and rhythmic flashes. The pattern observed for these flashes is unique for most of the times for a specific species (He, 2013). The rhythm of the flashes, rate of flashing and the amount of time for which the flashes are observed are together forming a kind of a pattern that attracts both the males and females to each other. Females of a species respond to individual pattern of the male of the same species (Arora & Singh, 2013).

### 2.4. Flower pollination
The flower pollination algorithm (FPA) was developed by Xin-She Yang in 2012, inspired by the flower pollination process of flowering plants. FPA has been extended to multi-objective optimization with promising results (Sakib, Kabir, Subbir, & Alam, 2014). Flower pollination is typically associated with the transfer of pollen, and such transfer is often linked with pollinators such as insects, birds, bats and other animals (Prathiba, Moses, & Sakthivel, 2014). In fact, some flowers and insects have co-evolved into a very specialized flower-pollinator partnership (X. S. Yang, 2014) (Yang X.-S., 2012).

## 3. Common difficulties with most of the traditional direct and gradient methods
1. Convergence to an optimal solution depends on the chosen initial solution
2. Most algorithms are prone to get stuck to a suboptimal solution
3. An algorithm efficient in solving one problem may not be efficient in solving a different Problem.

4. Algorithms are not efficient in handling problems having discrete variables or highly nonlinear and many constraints
5. Algorithms cannot be efficiently used on a parallel computer

## 4. Process optimization

### 4.1. Machining Process

Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process.

### 4.2. Turning

Turning is the process of machining external, or internal cylindrical and conical surfaces in which the part is rotated as the tool is held against it on a machine called LATHE. Mathematically each surface machined on a lathe is a surface of revolution. A revolution part with different types of surfaces and most A revolution part with different types of surfaces and most appropriate tools (Gilbert & W., 1950). The work piece is rotated while the tool is fed at some feed rate (mm per revolution).The desired cutting speed determines the rpm of the work piece (Saravanam.R, Ashokan.P, & Sachithanandam.M, 2001).

### 4.3. Cutting Tools

The tool used in a lathe is known as a single point cutting tool. It has one cutting edge or point whereas a drill has two cutting edges and a file has numerous points or teeth. The lathe tool shears the metal rather than cuts and it can only do so if there is relative motion between the tool and the work piece. For example, the work is rotating and the tool is moved into its path such that it forms an obstruction and shearing takes place. Of course the amount of movement is of paramount importance-too much at once could for instance result in breakage of the tool (Neelesh.K.J, Jain.V.K, & Kalyanmony.D, 2007).

### 4.4. Tool Life

As a general rule the relationship between the tool life and cutting speed is V Tn = C
Where; V = cutting speed in m/min;T = tool life in min;C = a constant

### 4.5. Cutting Speed & Feed

As you proceed to the process of metal cutting, the relative `speed' of work piece rotation and `feed' rates of the cutting tool coupled to the material to be cut must be given your serious attention. This relationship is of paramount importance if items are to be manufactured in a cost-effective way in the minimum time, in accordance with the laid down specifications for quality of surface finish and accuracy. You, as a potential supervisory / management level engineer, must take particular note of these important parameters and ensure that you gain a fundamental understanding of factors involved.

#### 4.5.1. Cutting Speed

All materials have an optimum Cutting Speed and it is defined as the speed at which a point on the surface of the work passes the cutting edge or point of the tool and is normally given in meters/min. To calculate the spindle Speed required,

$$N = \frac{CS \times 1000}{\pi d}$$

Where:
N = Spindle Speed (RPM)
CS = Cutting Speed of Metal (m/min)
d = Diameter of Work piece

#### 4.5.2. Feed

The term `feed' is used to describe the distance the tool moves per revolution of the work piece and depends largely on the surface finish required. For roughing out a soft material a feed of up to 0.25 mm per revolution may be used. With tougher materials this should be reduced to a maximum of 0.10 mm/rev. Finishing requires a finer feed then what is recommended.

## 5. MATHEMATICAL MODELLING OF MACHINIG COST.

Machining optimization provides optimal or near optima solution in actual metal cutting process. The optimization has two parts. The first one is to mathematically formulate the problem and in the second part a global optimum should be reached with all the limitations. (Onwubolu.G & Kumalo.T, 2001) (Petkovic & Radovanovic,, 2013)

C-Cost of Machining; $C_r$-Labor plus overhead cost ;$t_L$-Non-productive time; $t_m$-Machining time; T-Tool life ;$t_d$-tool changing time; $C_a$-tool cost per cutting edge;D-Work piece diameter;

L-Length of turning;$V_c$-cuting speed;f-feed;
$a_p$-depth of a cut; $C_T$, p, q, r-empirical constants

Cost of Machining: $C = C_r t_L + C_r t_m + \frac{t_m}{T}\left(C_r \cdot t_d + C_a\right)$

Machining time in turning process

$$t_m = \frac{\pi \cdot D \cdot L}{1000 \cdot v_c \cdot f}$$

Tool life

$$T = \frac{C_r}{v_c^p \cdot f^q \cdot a_p^r}$$

Cost of Machining:

$$C = C_1 + C_2 \cdot v_c^{-1} \cdot f^{-1} + C_3 \cdot v_c^{p-1} \cdot f^{q-1}$$

Where:

$$C_1 = C_r \cdot t_L$$

$$C_2 = \frac{\pi \cdot D \cdot L \cdot C_r}{1000}$$

$$C_3 = \frac{\pi \cdot D \cdot L \cdot a_p^r (C_r \cdot t_d + C_a)}{1000 \cdot C_r}$$

Constraint functions:-

a. Constraint on the cutting tool ability:

$$v_c \cdot f^y \leq \frac{C_v \cdot k_v}{T^m \cdot a_p^x}$$

b. Machine tool power force constraint:

$$v_c \cdot f^{y_1} \leq \frac{6120 \cdot P_M \cdot \eta}{C_{k1} \cdot k_F \cdot a_p^{x_1}}$$

c. Strength tool constraint:

$$f^{y_1} \leq \frac{R_{sd}}{C_{k1} \cdot C_0 \cdot k_F \cdot a_p^{x_1}}$$

d. Stiffness work piece constraint:

$$f^{y_1} \leq \frac{\delta_2 \cdot E \cdot I}{0.8 \cdot C_{k1} \cdot \ell_1^3 \cdot k_F \cdot a_p^{x_1}}$$

e. Constraint on the minimal spindle speed:

$$v_c \geq \frac{\pi \cdot D \cdot n_{\min}}{1000}$$

f. Constraint on the maximal spindle speed:

$$v_c \leq \frac{\pi \cdot D \cdot n_{\max}}{1000}$$

g. Constraint on the minimal feed:

$$f \geq f_{\min}$$

h. Constraint on the maximal feed:

$$f \leq f_{\max}$$

**The Mathematical model of the objective function is represented as:-**

**Objective function:-**

$$\min\ C = 0.30 + \frac{4.60}{v_c \cdot f} + 1.72 \cdot 10^{-11} \cdot v_c^{4.55} f^{0.67}$$

Constraint functions:

a. $v_c f^{0.30} \leq 91.57$

b. $v_c f^{0.75} \leq 74.80$

c. $f^{0.75} \leq 6.48$

d. $v_c \geq 5.03$

e. $v_c \leq 502.65$

f. $f \geq 0.04$

g. $f \leq 9$

The above problem is solved using all the four non-traditional optimization methods. And each method is run for 20 trials and the average values are taken for $V_c$, f and the cost.

**6. OPTIMIZING THE TURNING MACHINING PROCESS USING ALGORITHMS.**

As we mentioned earlier, the second part is to solve the mathematical model to obtain the global minimum of the objective function. When the optimization is terminated, the minimal value of the cost of machining is found and tabulated for different algorithms. All the algorithms have to be run for 20 trails and the average is taken so as to get the global optimization (Ebeltagi.E, 2005,. We have run the program 20 times and the average values are tabulated.

**Table 1.Comparison table of all algorithms**

| Algorithm | Vc m/min | F mm/rev | Cost (RS) | Time (secs) |
|---|---|---|---|---|
| PATTERN SEARCH | 14.39525 | 9 | 0.33552 | 1.572269 |
| CUCKOO SEARCH | 14.39527 | 9 | 0.335519 | 11.57563 |
| FLOWER POLLINATION | 14.39527 | 9 | 0.335519 | 3.515813 |
| FIRE FLY | 19.99888 | 6.125872 | 0.339522 | 5.151057 |

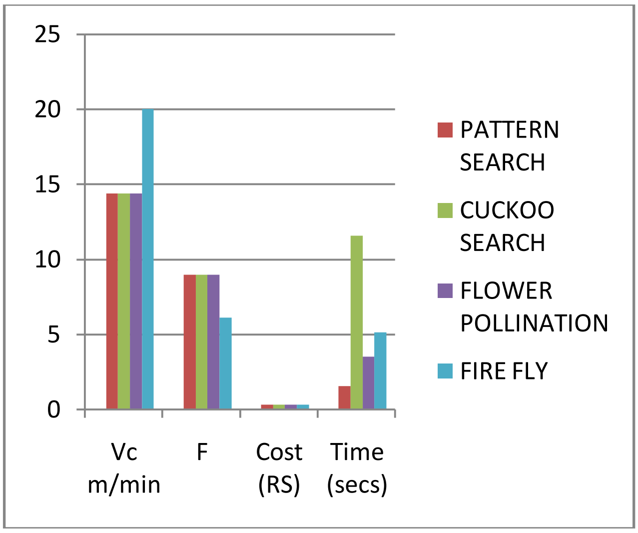


**Fig.1. Bar diagram explaining the variables for different algorithms**

From the above graph we can see that the pattern search algorithm is best compare to the other three methods.

**7.RESULT VALIDATION.**

The work piece is a bar 80mm in diameter and 165mm in length, made from mild steel C45E(EN). Machine tool is the Kistler Dynamometer and Turn master-35.Cutting tool is holder PSBNR 2525M-12 with insert SNMG 120408 model VPISTF.

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**Fig.2.OriginalRod**

**Fig.3**

**Fig.4 Rod after Turning Insert SNMG120408**

### 7.1. Roughness of the bar

Roughness average of the surface
$R_a$ =0.931 micron
Mean Roughness depth of the surface $R_z$=13.533 micron
Root mean square roughness
$R_q$=3.203 micron
The machine used to check the roughness of the rod is Surface Tester model 210J made in Japan.

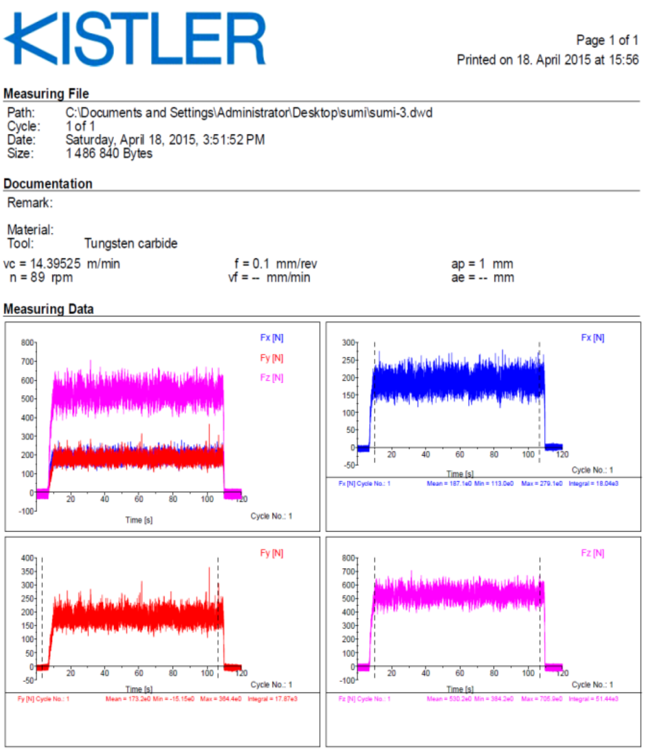


**Fig.5. Graph explaining the roughness of the bar**

### 7.2. Explanation of the Graph

$F_x$-The force acting opposite to the feed
Fy-The force acting opposite to the tool
$F_z$-The force acting downward to the tool
The software used for the graph is Dynoware Software. In the graph we took reading for 120 seconds. From the graph we can observe where the force is maximum and where the force is minimum and where the force is steady. At the origin we had Initial force and at the ending we had Terminal force.

## 8. CONCLUSION

Modern methods of optimization are powerful and popular for solving complex engineering problems; this paper shows the possibilities of solving such problems using four different nontraditional algorithms. Cost of machining in turning process, depending on the cutting speed and feed was minimized under certain conditions. The results obtained through the four methods are checked with the original work done using GA.In this case all the methods shows the same result in cutting speed, feed and cost but the run time taken in pattern search method is 1.57 secs which is too low than the other methods. Of all the algorithms we have taken the **Pattern Search** algorithm is the most simplest. The consistency table gives the parameters that remain constant for all the trails

Thus it is seen that the Pattern Search solver satisfies all the criteria and scores 100% for its practicality in giving result according to the standards. So the appropriate algorithm, for turning machining process is suggested as **direct search algorithm** & the solver is **pattern search**

**Table.2. Optimum values of the variables and cost**

| | |
|---|---|
| Cost of Machining | 0.33552 Rs |
| Cutting Speed | 14.39525 m/min |
| Feed | 9.0 mm/rev |

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