GENETIC ALGORITHM GA TO OPTIMIZEMACHINING PARAMETERS INTURNING OPERATION: A REVIEW

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ABSTRACT: The determination of optimal cutting parameters have significant importance for economic machining in minimizing of particularoperating mistakes like tool fraction,wear,and chatter. The evolutionary algorithm GA is used to improve many solutions of optimization complex problems in many applications. This paper reviewed the ideal selection of cutting parameters in turning operation using GA and its variants. This study deals with GA algorithm in different machining aspects in turning operation like surface roughness, production rate, tool life, production cost, machining time and cuttingtemperature. The survey showed that there aremany papers in the field of turning parameters optimization using GA, but there is a lack in studies in the field of cutting temperature optimization in turning operation which is very important problem in machining operation.In addition, there arerare papers that studied dry turning operations.

KEYWORDS: Computing Algorithms, Real Coded Genetic Algorithm,Sorting Benetic Algorithm, adaptive Neuro Fuzzy interface system.

1.0 INTRODUCTION

The evolutionary computing algorithms such as GA, PSO, and ABC etcetera are more robust and active approach for solving complex real-world problems compared with traditional optimization methods (Kao, Y., 2008). The difficulties in optimization operations made the determination of ideal cutting parameters an important and complex case (Yildiz, A., and Ozturk, F., 2006 and Chen, 2004), Also, the determination of optimum cutting parameters plays an important role in reducing machining problems as tool destroy and wear(Pinkey, Kusum, and Millie, 2011).Paper(Norfadzlan, *et.al.* 2007), studied many optimization algorithms such asGenetic Algorithm,Simulated Annealing, Particle Swarm Optimization, Artificial Bee Colonyand

Ant Colony Optimization. It posits that use of ABC algorithm beganat the latest years of this decade and concentrated on optimization the parameters of new cutting operations such aselectrical discharge andelectrochemical operations. However, no much papers in the field of using ACO optimization at the latest years. Also when use GA and PSO algorithms, the most machining operation that is usingit wasmultipass turning, while SA algorithm used in end milling and AJW. On the other hand, most machining performances usedsurface roughness, machining / production costs and material removal rate as shown in Fig.1which shows that the papers in the field of temperature measurement and dry turning are very rare.

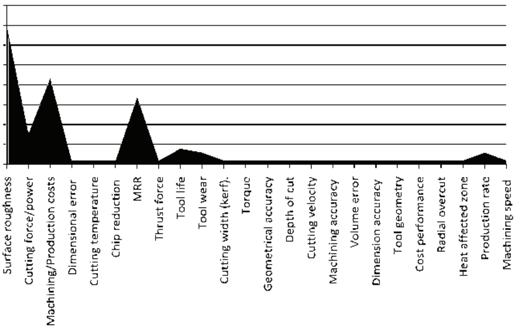

Fig. 1 Machining performance considered in GA, SA, PSO, ABC and ACO (Norfadzlan, *et.al.*, 2007)

Finally, we can say that the fineness of the parts, precise, and temperature estimationstill challenging because of the difficulties that accompany the cutting operation.So, this study aims to survey GA-based optimization for turning processes as below:-

2.0 USING GA IN TURNING PARAMETERS OPTIMIZATION

The optimal machining parameters can be finding using GA evolutionary techniqueswidely (Norfadzlan, *et.al.,* 2007). Three mainparts in GA can be used; reproduction, crossover and mutation. The binary encoding process used to encode the parameters as genes. Using of GA in turning operation improvement is studied as below:-

2.1 surface roughness optimization

Coarseness of the machined part is depending on several parameters such as feed rate, depth of cut, cutting speed, tool wear (Tamizharasan, T., 2002). Srikanth, T., and Kamala, V., (2008) studied the surface roughness optimization in turning operation by finding the optimum parameters (speed, feed and depth of cut) that minimize surface roughness. A real coded genetic algorithm (RCGA) also called floating-point representation is used as optimization method for this purpose. The conventional genetic algorithm uses binary code which needs more time to code and decode the values. In contrast, (RCGA) used real-parameters which enablethe use of large variablesto improve the operation of finding the optimal value, decrease the time and increasing the precision. The fitness function used to calculate the surface roughness is as:-

$$R_a = \frac{1.0632 \cdot f^{1.0198} \cdot d^{0.0119} \cdot H^{0.5234} \cdot r^{0.1388}}{V^{0.229}} \quad \text{Eq.......................................(1)}$$

Where as:-

Ra= Surface roughness (μm).
f = Feed rate (mm/rev).
d= Depth of cut (mm).
H= Material hardness.
r= Tool radius (mm).
V = Cutting speed (mm/min).

f, d , r , Vare taken as limitations of the operator and judgmentvariables. The authors observed that high speed, low feed,modestcutting depths and nose radius led to better surface quality. Savadamuthu *et.al.* (2012), using Taguchi-genetic algorithm for studying the quality improvement in turning operations. The objective function is to reduce the defect rate in a very short period of time. This method finds the idealdomination parameters for an adaptive Neuro Fuzzy interface system (ANFIS). It consists of predictor and fuzzy logic controller andable to keep a cutting force turning process at stable value under different conditions. Computer simulations to verify the effectiveness of this method was used.

Sanjeev *et.al*. (2012) showed the effect of cutting conditions on the surface qualityin CNC turning operations when turning poly tetra fluoro ethyleneusing genetic algorithm. The fitness function used to minimize the surface roughness is shown as:-

$$R_a = -0.309+0.675V+0.870f+0.175d-0.234V.f-0.002f.d-0.143V.d \quad \text{Eq.............. (2)}$$

Where as:-

Ra:- surface roughness.
V:- cutting speed.
F :- feed rate.
d:- depth of cut.

The constraints used are V, f, and d. The crossover type used is single point with probability of 0.08 andthe mutation probability type is 0.1 to prevent local convergence.

Raj *et.al.* (2010), developed a new type called improved genetic algorithm (IGA) to calculate the ideal parameters for estimating the surface quality.Cutting parameters used are nose radiusspeed, feed, and depth of cut. In this work, Taguchi's orthogonal array method is used to achieve the experiment of dry turning of SS 420 work piece. This method combinesstochastic crossover technique and an artificial initial population to provide faster search mechanism to avoid the local optimal trap. The author concluded thatthisalgorithm is more effective than conventional genetic algorithm (CGA).

Singh *et.al.*, (2007), used a genetic algorithm to estimate and optimize the work piece roughness values during operating the bearing steel by hard turning. Thecutting parameters were aimed to show the cutting tool rake angle and nose radius and cutting conditions (feed and speed) on the surface quality.Lower values of surface roughness and ideal conditions can be achieved by GA program.

Sahoo, (2011), studied the machining parameters optimization to improve the roughness characteristics of AISI 1040 mild steel in CNC turning using genetic algorithm. The cutting tool used is CVD carbide coated tools with titanium nitride. The mild steel mechanical properties used are hardness 201 BHN, density 7.85 g/cc and tensile strength 620 Mpa. The cutting parameters such as depth of cut, spindle speed and feed rate are used to study its effect on the surface quality aspects such as centre line average roughness, root mean square roughness and mean line peak spacing using response surface methodology. The author concluded that theincreasing cutting parameters lead to decrease the surface roughness parameters.

2.2 OPTIMIZATION OF PRODUCTION RATE AND TOOL LIFE

Quiza *et.al.* (2006) used two dissonant objective functions tofind the optimal value of depth, feed and speed simultaneously. Micro genetic algorithm is used for this purpose. The first fitness function is production rate (Z) which can be calculated as:-

$$Z = Z_s + \frac{V}{M}(1+\frac{ZTC}{C}) + Z_o \qquad \text{Eq……………………………..(3)}$$

Whereas:-

Z_s:-Set-up time.
ZTC:-Tool change time.
Z_o:-Time during which the tool does not cut.
V:-Volume of the removal metal.
M:-Material removal rate.

$$\varepsilon = \frac{V}{M \cdot T} 100\% \qquad \text{Eq………………..………….. (4)}$$

Whereas:-

V:-Volume of the removal metal.
T:- Tool life.
M:-Material removal rate.

The parameters (T) and (M) depend upon variables feed, speed and depth of cut. Many constraints affecton the optimal cutting conditions taken in account like (cutting force, cutting power and surface roughness). This system gives greatest amount of information to select cutting parameters in turning with low computational cost. The future workis include another constraints such as work piece surface temperature. Wang *et.al*. (2007),studied the single and multi-pass turning operations using two ways; with and without the effects of tool wear. A hybrid models such as nonlinear programming methodsand a genetic algorithms for four machining performance are considered. Cutting force, tool wear, tool life, chip form, chip breakability, and surface roughness are used as machining aspects. This method enables to obtain the ideal cutting conditions and select suitable tools for turning operations.

Yusoff *et.al.* (2011), showed the application of non dominated sorting genetic algorithm (NSGA-II) for optimizing machining parameters such asfeed rate, cutting speed and rotational speed. This method is used forquick classification of multi objective optimization problems. This system optimizes each objective without control of any other solution simultaneously. It can finda group of optimal solutions based on combination of suitable variables.

2.3 Optimization of production cost

In recent machining operations, the aims areforgetting high quality products with as possible as minimum cost (Xie,S., and Guo, Y., 2011). Xieand Guo, (2011), minimized the production cost in multi-pass turnings using GA combines with a pass repeating method. This operation is very complicated because many constraints should be considered. Cutting speed, feed rate and depth of cut for both rough and finish machining are used for this purpose. The fitness function used computed as:-

$U_C = C_M+C_I+C_R+C$ Eq……………………..……….(5)

Whereas:-

UC:- production cost for multi-pass turning.
CM:-cutting cost by actual time in cut.
CI:-machine idle cost for loading and unloading operations and idling tool motion.
CR:- tool replacement cost.
CT:-tool cost.

The constraints used are tool-life, surface quality, force, power, roughing and finishing parameters relations, chip-tool interface temperature and fixed cutting area.The numbers of possible value of rough cuts are calculated as:-

$m = (n_u - n_l + 1)$ Eq……………..…………….. (6)

Whereas:-

m:- number of rough cuts.
n_u:- upper limit
n_l:- lower limit.

The authors proposed bound adjustment of optimized variants (BAOV) method to minimize the number of impractical individuals in the iteration process and eliminate surface finish constraint. Yildiz *et.al.* (2006), proposed GA algorithm for solving the turning optimization problems. The machining cost used related with machining variables (speed, feed and depth of cut) as shown below:-

$C_i = c_i v^{a_{i1}} f^{a_{i2}} d^{a_{i3}}$ Eq………………..……………..(7)

Whereas:-

C_i:- machining cost.
c_i:- cost component coefficients.
v:-the speed.
f:-the feed.
d:-depth of cut.
i=1… n and ai1, ai2, ai3: are machining variable exponents.

The constraints B_n in this research can be expressed as:-

$B_n = b_n v_n^{a_{m1}} f_n^{a_{m2}} d_n^{a_{m3}}$ Eq………………………………(8)

Whereas:-

b_n:- term coefficient of constraints.
n=1… N.
m=1… M.

Han *et.al.* (2010),studied the cost minimization operation in multi-pass turning operations. The boundaries used are maximum and minimum allowable cutting speeds, feed rates depths of cut, tool life, surface roughness, cutting force and cutting power consumption. The ideal values of cutting parameters using three ways: integer programming, nonlinear programming, and genetic algorithms. The author concluded that the system generates minimum production costs in comparison with the results obtained from the previous and data collected from the handbooks.

Al-Aomarand Al-Okaily, (2006), developed a simple genetic algorithm (SGA) to a CNC turning machine for determinationthe optimal machining and production parameters so as minimizethe production cost. This method has active convergence with minimum number of search generations. The systemproducesbest productivity but needs to higher cost. The effectiveness of system research show by results obtained full factorial designs.

2.4 Optimization of machining time

Ahmad, and Anwarul, (2001), studied the optimization process planning parameters for machining rotational component using a genetic algorithm optimization Matlabtoolbox. The objective function used to decrease the operating time Tmwhich is calculated as:

$$T_m = \frac{L_f n_{pass}}{f N_w} \qquad \text{Eq………..…………………..(9)}$$

Whereas:-

T_m:- machining time.
L_f:- length of surface.
npass:-number of passes.
f:- feed rate.
N_w:- rotational speed of work piece.

The constraints used are cutting velocity, feed rate, depth of cut, rotational velocity of spindle and the power of machine. The results showed that at the low the depths of cut and cutting speed and high feed rate, the optimum total machining time can be obtained.Car *et.al.* (2009), proposed a hybrid genetic algorithm and linear programming optimization for turning process optimization. The objective function used to minimize production time (t_1) is expressed as:

$$t_1 = t_g + t_a + t_p \qquad \text{Eq……………..…………..(10)}$$

Whereas:-

t_g:- main machining time.
t_a:- time for tool changing.
t_p:- time during which the tool do not cut.

The author concluded that this system is efficacious and proper to optimize machine parameters. Chauhan *et.al.*(2011), suggested a newmethods, the first is "LXPM" and second is Differential Evolution(DE)for determination of optimal machining conditions for turning process on CNC machines. The author showed that these methods used as real coded genetic algorithm. The fitness function is based on total production time that affects the production rate as shown below:-

$$Tu = tm + tcs + (tm / T) + tr + thz \qquad \text{Eq……………………………(11)}$$

Whereas:-

Tu = Total production time.
tcs = Tool changing time (min/edge).
tr = Quick return time(min/pass).

thz = Loading and unloading time (min/pass).
T = Tool life.

The parameters to be optimized are cutting speed, feed rate and depth of cut while the nonlinear constraints such as cutting force, power, tool-chip interface temperature and surface are considered. The results of this method were satisfactory, reliable and computational. Saravananand Janakiraman, 2007), studied the optimization the turning operation using facing and undercutting operationsbygenetic algorithm. The objective function to reduce the time of machining with many restrictionssuch as power, force, tool life, surfacequality of the final part and the range of the operating parameters is used. The optimization problem was solved very efficiently using the above methodology.

2.5 Optimization of cutting temperature

2.5.1 Cutting temperature measurement in turning

Determinationoftheultimatecuttingtemperatureanditsallocationvalues along the rake face of the cutting tool is veryimportantdue to its influence on cutting tool properties. The measuring temperature in the cutting zone and theassessmentof heat distribution in cutting operations and determination of internal temperatures on the cutting tool is very difficult action due to a straiten shear limit, chip formation, and the touch phenomena where the movement between the tool and chip are continuous with respect to each other. The temperature in the primary and secondary shear zones are usually very high, therefore it affects the shear deformation and tool wear. During the cutting operation, the total energy of the yielding distortion at the primary shear plane and at the chip–tool interface is converted into heat. Maximum heat occurs on chip-tool interface temperature is one of the critical factors during machining because itseffectonthe formation of chip , cutting forces, tool life, surface quality, total tool wear rate and crater wear on the rake face and product surface quality. (Sekeri, U., 2003, Abhang, L., and Hameedullah, M., 2010, Carvalho, S., 2006, and Jurković, Z., 2011)

Abhangand Hameedullah, M, (2010), studied the turning operation of EN-31 steel alloy with tungsten carbide inserts. A tool-chip interface temperature is measured using a tool-work thermocouple technique and response surface methodology. The cutting parameters considered are cutting speed, feed rate, depth of cut and tool nose radius. The increment in cutting speed, feed rate and depth of cut leads to increase the cutting temperature, on the other hand increasing nose radius leads to reduce the cutting temperature.

Carvalho *et.al.* (2006), posits the complexity of the immediate temperature measurements at the chip–tool interface.The authors proposed the valuation of the temperature from heat flow at the chip–tool interface. The inverse heat conduction problem technique was used. Many cutting tests using cemented carbide tools were performed for examination the model and to confirm the influence of the cutting parameters on the temperature field.

Jurković, Z., (2011), used Taguchi's method for minimizing the tool-chip interface temperature when cutting Č1730 (EN C60) steel work piece by cemented carbide inserts in turning process using a tool-work thermocouple technique. The author concluded that the main cause affects on the cutting tool and work piece properties is the cutting temperature.Also the cutting speed is the most worthy parameter on cutting temperature.

Salihu *et.al.* (2011), measured the temperature using the thermocouple method during the CNC turning on steel C45 work piece and ceramic cutting plates MC2 cutting tool. The cutting parameters used: cutting velocity (v), feed (s), depth of cut (a) and nose radius (r). There are three zones of cutting temperature: primary shear zone, secondary shear zone (chip-tool interface) and shear zone due to scrub between the tool and work piece. The authors concluded that cutting speed and feed have a great influence on temperature , on the other hand, when the cutting angle increases, the cutting forces also increase and then the temperature increase.

Zuperland Cus, (2000),used the feed forward and radial basis neural networks to study a complex optimization of cutting parameters. The method produces accurate andreliable results, but require more time for training and testing alsothe precision of results is worse. The authors suggested application of this method to experimental problems and stretchingit to adaptive control of machining operations or on-line adjustment of cutting parameters based on information from sensors.

Dolinšek, S (2006), posists that the tool wear is generally considered to be a result of mechanical thermo dynamic wear such as abrasion and chemical thermo chemical wear such as diffusion interactions between the cutting tool and work piece. At high temperature reaches to 1000C° or more , the appearance of the chemical wear becomes visibleand clear which enhances the diffusion and oxidation processes.

Ueda *et.al.*, (2008) proposed a new type of pyrometer, in which two optical fibers are used to accept and transmit the infrared energy. The two fibers are connected using a non-contact fiber coupler. In turning, the incidence face of one optical fiber which is embedded in a rotating workpiece accepts the infrared rays radiated from the cutting tool and emits it at the other face. The infrared energy is accepted by the other optical fiber which is fixed at the pyrometer and led to the two-color detectors.

2.5.2 Cutting temperature optimization in turning using GA

Dry and high speed machining produce significant heat dissipation in the chip formation zone.Hence, thermal phenomenon plays a key role in tool wear and machinability of the materials. The increasing in the temperature of the work piece material in the primary deformation zone softens the material,on the other hand, minimumcutting forces and energy values is desired.

Sultana *et.al.*(2010), studied the optimization of cutting speed (Vc), feed rate (f), pressure (P) and flow rate (Q) of high pressure coolant to improved machining performances in turning AISI-4320 steel by uncoated carbide insert. An experimental study has been carried out using response surface methodology. The predictive models of cutting temperature (θ), chip reduction co-efficient (ξ) and surface roughness (Ra) were considered.Multi-objective optimization has been carried out based on genetic algorithm (GA) usingtwo conflicting objectives, minimizing cutting temperature and cutting force simultaneously.The constraint of surface roughness less than 3 μm is considered. The results showed that θ, ξ and Ra can be well estimated through the models.

3.0 DISCUSSIONS AND CONCLUSIONS

Optimization operation is one of the important goals of manufacturing systems, also it simple to use and are increasingly used to solve inherently intractable problems quickly.From previous studies and papers,it is clearly that the genetic algorithm is one of the best population searches and its variants have been extensively used. However,many studies are concentrated on optimization of surface roughness , machining / production costs and material removal rate , but only a few donein other fields like cutting temperature, torque, geometrical accuracy, heat affected zone tool geometry.

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