Al-Khwarizmi Engineering Journal, Vol. 5, No. 2, PP 44 - 53 (2009)

Al-Khwarizmi Engineering Journal

# Automatic Optimization System of Cutting Condition for Different Types of Machining Processes

**Ali H. Kadhum*  and  Huda Hatem****

*Manufacturing Operation Department/ Al-Khawarizmi College of Engineering/ University of Baghdad*
**Email: kadhumali59@yahoo.com*
***Email: Hoda_Abode@yahoo.com*

(Received 10 November 2008; accepted 2 June 2009)

## Abstract

This research aims at calculating the optimum cutting condition for various types of machining methods, assisted by computers, (the computer program in this research is designed to solve linear programs; the program is written in v. basic language). The program obtains the results automatically, this occur through entering the preliminary information about the work piece and the operating condition, the program makes the calculation actually by solving a group of experimental relations, depending on the type of machining method (turning, milling, drilling). The program was transferred to package and group of windows to facilitate the use; it will automatically print the initial input and optimal solution, and thus reduce the effort and time required for the calculations, that helps to find the optimum values for the cutting system. Optimum values improved mechanical properties (wear, fatigue, strength …) and gave better productivity.

***Keywords:*** *Technical constraints, mathematical model, optimization, element of cutting condition, package, machining processes, factors, cutting parameters, date base.*

## 1. Introduction

The typical technological environment becomes more complex concerning types of parts, materials, machines, tools and job. It is obvious that the optimum of cutting conditions can be a very complex and time consuming job requiring a large a mount of data. This is further complicated by the fact that the cutting condition is a critical element in making the part correctly and economically [2, 8].

Modern industries need not only calculating the cutting systems by formulas, but also requiring the selection of the optimum cutting system for specific work piece, and then maintaining this system along the time of cutting. This requires that all factors with elements of a system known and fixed in advance [7].

To select the condition for the working tools, all the parameters of the process must be known, and this ensures greater efficiency, for the conditions of production, in the implementation of the requirements of the cutting conditions. It also must conform the technical parameters to the available cutting parameters [3,4,9].

To work the calculation of the optimum cutting condition, the difficult relations between the various factors that describes the operation must be taken into account. The parameters describing this processes are divided into inside and outside, and they also describe the difficult functional relationships between them. Total relations give a mathematical model for machining processes.

To find the optimum values in the calculation of the cutting conditions, acknowledgment of set of variables can guide in the cutting process (such as tool life, geometry of tool, the cutting thickness...). To select the criteria, it is necessary to include more influential working parameters. To build a flowchart, certain cases were analyzed after the selection of parameters, and the evaluation of the information is possible, and then using functional relationships among the inside and outside parameters at specific values (maximum rang) was put the aim in function.

The data base that must be developed contains specifics about available machines, tools, materials, stock removal, type of cuts that can be made by a particular machine, and tolerance information with regard to cutting conditions, machinability information [5]. A large data base and some complex calculations are required to accomplish this.

## 2. Technical Constraints of Cutting Condition

The expression of technical constraints [4, 6] of the inequality types ≤ or ≥, for cutting condition, could imagine the relationship between the variables and the elements of the cutting system (t, *n*, and *f*), which were constant as the operation was under one way. The technical constraints at the optimum calculation cutting system widely depended on the type of operation [7].

The choice of optimum values of feed and cutting speed is made more difficult by several constraints which must be satisfied along with the equations discussed in this paper. These are:-

### 2.1. Available Cutting Tool

Cutting speed has significant effect on the tool life, tool geometry, depth of cut, feed and surface finish. For turning machining processes the cutting speed can find with formula:

$$nf^{y_v} \leq \frac{318CvKv}{T^m D t^{x_v}} \quad \ldots (1)$$

### 2.2. Available Horse Power of Machine Tool

Effective machining forces and power are seldom classified as process boundaries. The power required during a cutting operation depends on the cutting speed and feed, and may be expressed for different types of machining as:

$$n^{n_z} f^{y_z} \leq \frac{N_n \eta K_{C_z}}{C_z t^{x_z} D^{z_z} \pi^{n_z} B_\phi^{y_z} Z^{u_z} K_z} \quad \ldots (2)$$

The maximum available power for cutting is a limited value which can be obtained by subtracting the transmission losses from the horsepower of motor provided on the machine.

### 2.3. Machining Production Rate

In the cutting processes with an edged tool, the parameters which affect the machining rate are cutting speed and feed. The higher the values of these parameters, the less the machining time, the and the machine operation time. The following formula can express this:

$$nf \geq \frac{LR}{60K_l r_R - t_{B.H} R} \quad \ldots (3)$$

### 2.4. Available Cutting Speed and Feed on Machine Tool

Machine tools in general are equipped with only a limited rang (max, min) of cutting speed and feed and that too in step variations. Calculating the cutting speed and feed is consistent with the restrictions of the machine tools that range as:

$$n \geq n_{\min} \quad \ldots (4) \qquad f \geq f_{\min} \quad \ldots (6)$$

$$n \leq n_{\max} \quad \ldots (5) \qquad f \leq f_{\max} \quad \ldots (7)$$

### 2.5. Strength of Cutting Tool

This constraint clarifies the relationship between the calculated cutting speed with feed and the allowable strength of the cutting tool. The limit of strength of metal fixture under the effect of bending can be obtained by the following restrictions, when turning.

$$n^{n_z} f^{y_z} \leq \frac{4BH^2(10^3)^{n_z}}{C_z t^{x_z} D^{n_z} \pi^{n_z} L_{B.P} K_{S.F} K_z} \quad \ldots (8)$$

### 2.6. Cutting tool rigidity

The workpiece material, size and configuration determine the type of machining operation and the cutting tool to be used. Because of the cutting forces involved, the tool deflects causing a detrimental effect on the tool life, surface finish and dimensional accuracy; the deflection of the tool may assume undesirably high values, and the cutting forces and tool deflections must be kept within limits, and this can be expressed as:

$$n^{n_z} f^{y_z} \le \frac{(10^3)^{n+1} BH^3}{2C_z t^{x_z} D^{n_z} \pi^n L_{B.P}^3 K_z} \quad \dots (9)$$

## 2.7. Work piece Rigidity

Interested in these constraint terms, the amount of occupied deflection under the influence of the cutting force shall be less or equal to the allowed deviation, and we get a technical restriction for workpicece rigidity.

$$n^{n_y} f^{y_y} \le \frac{1.5\delta E \pi^{1-n_y} D_{n_p}^4 (10^3)^{n_y} L_{W.P}}{64 C_y t^{x_y} K_y D^{n_y} X_P^2 (L_{W.P} - X_P)^2} \quad \dots (10)$$

## 2.8. Strength of Feed Mechanism Unit

It is the relationship between the calculated cutting speed and feed. With the strength of feed mechanism, the following relationship holds:

$$n^{n_s} y^{y_s} \le \frac{(10^3) n_s P_{s-don}}{C_s t^{x_s} D^{n_s+z_s} \pi^{n_s} Z^{u_s} B^{\gamma_s} K_s} \quad \dots (11)$$

## 2.9. Requirements Surface Finish

For many machined components the surface roughness is an important criterion for their acceptance. A detailed discussion on surface roughness produced by various cutting processes, in turning is a function of a number of variables, tool material, tool geometry, cutting conditions and wear of tool. The parameters of tool geometry that affect the surface finish are the side, end cutting edge angles and the nose radius. The theoretical values of Ro (Ra, Rz, Rmax) are realized only at high cutting speed. The variation in feed directly affects the surface roughness because of the feed marks made by the cutting edge tool. For a particular cutting operation the surface finish restriction may be expressed as:

$$n^{K_2} f^{K_3} \le \frac{Ro}{K_1 t^{K_4} \varphi_1^{K_5} \varphi^{K_6} r^{K_7}} \quad \dots (12)$$

## 3. Mathematical Model to Calculate the Elements of Cutting Condition

Cutting condition should be optimum and the final part should be realized by a specified time and by allow production cost. All this leads to the need for computerized systems that will allow the cutting condition function to be performed by a computer, providing the user with optimum cutting condition in quick consistent fashion.

The calculations depending upon the different machining processes involved are:

- Turning and facing – cylinder.
- Drilling, reaming and boring – hole.
- End milling, slab milling, face milling, side milling, slot milling- *different surface*.

The first problem to be solved is bringing all the technical constraints and evaluation function to a linear form. For example, consider bringing to linear form the first line of technical limitations in equation (12) using a logarithm method [1, 7].

$$K_z \ln n + K_3 \ln f \le \ln\left(\frac{Ro}{K_l t^{K_4} \varphi^{K_5} \varphi^{K_6} r^{K_7}}\right) \quad \dots (13)$$

Entering symbols

$$\ln n = X_1 \ , \qquad \ln(100f) = X_2$$

$$\ln\left(\frac{Ro}{K_6 t^{K_4} \varphi^{K_5} \varphi^{K_6} r^{K_7}}\right) = b_{12}$$

and the bases of their constraints [12], we get

$$K_2 X_1 + K_3 X_2 \le b_{12} \quad \dots (14)$$

Similarly, it can be obtained from the linear equation which depends on other technical constraints.

Analysis of earlier criteria for best value shows that optimizing the two elements of the cutting system ***n*** and ***f*** without changing:

$$f_o = (X_1 + X_2) \to \max \quad \dots (15)$$

The transformation of technical limitations to the linear forming and presenting them in the form of inequalities in conjunction with evaluation function gives a mathematical model of the process of cutting metal [7].

$$\left.\begin{array}{l} z_1 X_1 + y_1 X_2 \le b_1 \\ z_2 X_1 + y_2 X_2 \le b_2 \\ . \\ . \\ z_n X_1 + y_n X_2 \le b_n \end{array}\right] \quad \ldots (16)$$

With regard to the mathematical model (15) to determine the optimal cutting system is to find among all kinds of non-negative values of *x*1 and *x*2 systems the optimum values *X1opt, X20Pt* where the linear function takes the maximum value of *f*0 **max**. [6].

The theory of linear programming shows that the extreme importance of the evaluation function is provided for *X*1 and *X*2, are at a point lying on a boundary straight lines or intersections . The task of finding the best values *X*1opt and *X*2opt is the consistent consequence calculation of the coordinates for all possible intersection points of the boundary and then to find the maximum summation .

$f0=(X1+X2) \rightarrow \max$

After positioning *x*1opt and *x*20Pt calculate the optimal values of the elements of the cutting condition in the formula :

*n*opt = exp (*x*1opt); ***f***opt = exp (*x*20Pt) / 100.

To determine the optimal solution of the problem, for linear equations system and inequalities, simplex method is commonly used. Determine a pair of points intersecting the straight lines and putting this points in inequalities system. A point, which coordinates satisfy everyone without exception. Any straight line (check the compatibility of the system of equations) at the same time of the summation of the coordinates (*X*1+*X*2), will be a maximum and an optimum point [6].

## 4. Flow Chart to Find the Optimum Condition

The flow chart in (Fig.1) starts by selecting the type of machining process; then introducing all the necessary information about the workpice (diameters, lengths, allowance, roughness, production rate and the depth of cut). Then the user makes a selection for different types of working materials, added to the program as a data base; after that select the type of turning machine. [5]

Starting the operation of program, the first window is shown (Fig.2), then put the information about the workpiece and select the work materials; then select the type of machine, after that click (Next) to translate to the second window (Fig.3) which contains types of tool materials that must be selected, according to the type of working material, then select the dimensions of the tool and type of machine work, from these many conditions the program will find all the factors according to the data base. These factors are used with requirements of the inequalities equations, and then the program will calculate and solve all the inequalities equations to find the optimum values. The third window (Fig4) and fourth window (Fig.5) shows the result of the calculation, the optimum value for cutting speed and cutting feed and all the information about the cutting condition.

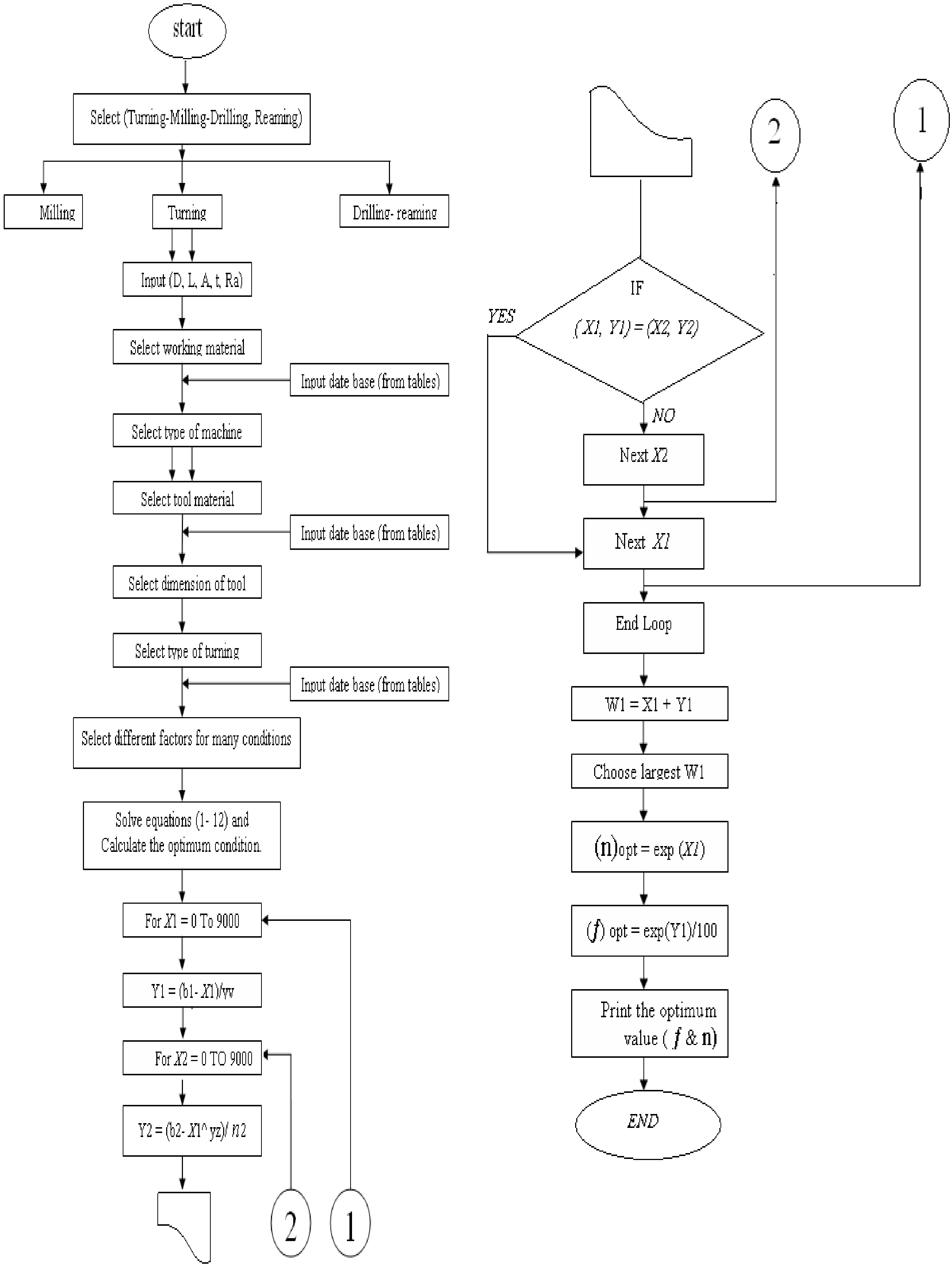


**Fig. 1. General Flow Chart to Calculate the Optimum Cutting Condition**

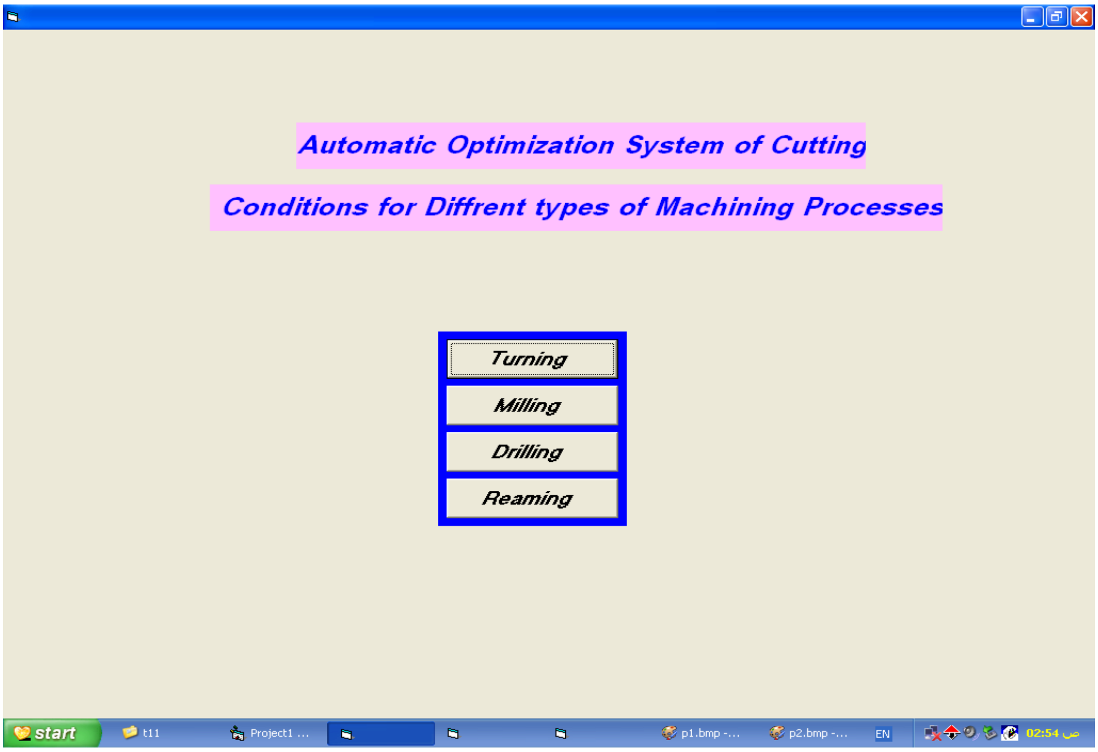


**Fig.2. Select One of the Different Types of Machining Processes**

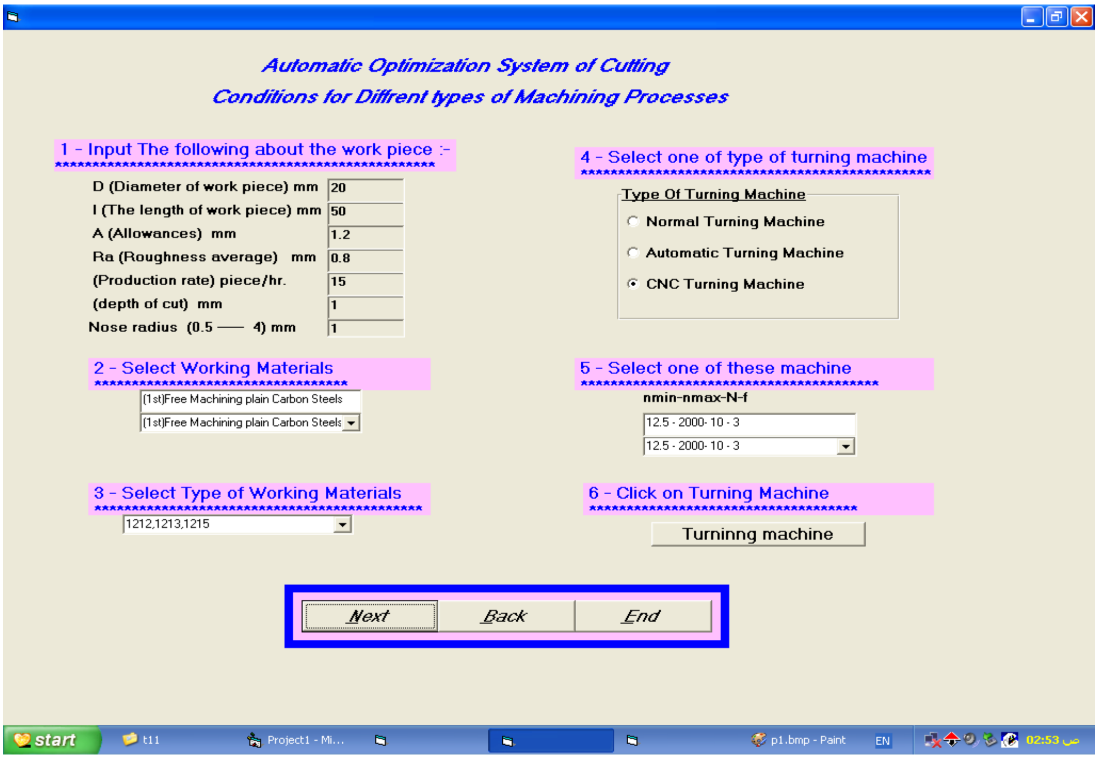


**Fig.3. Input the Data and Select the Parameters of Machining Process**

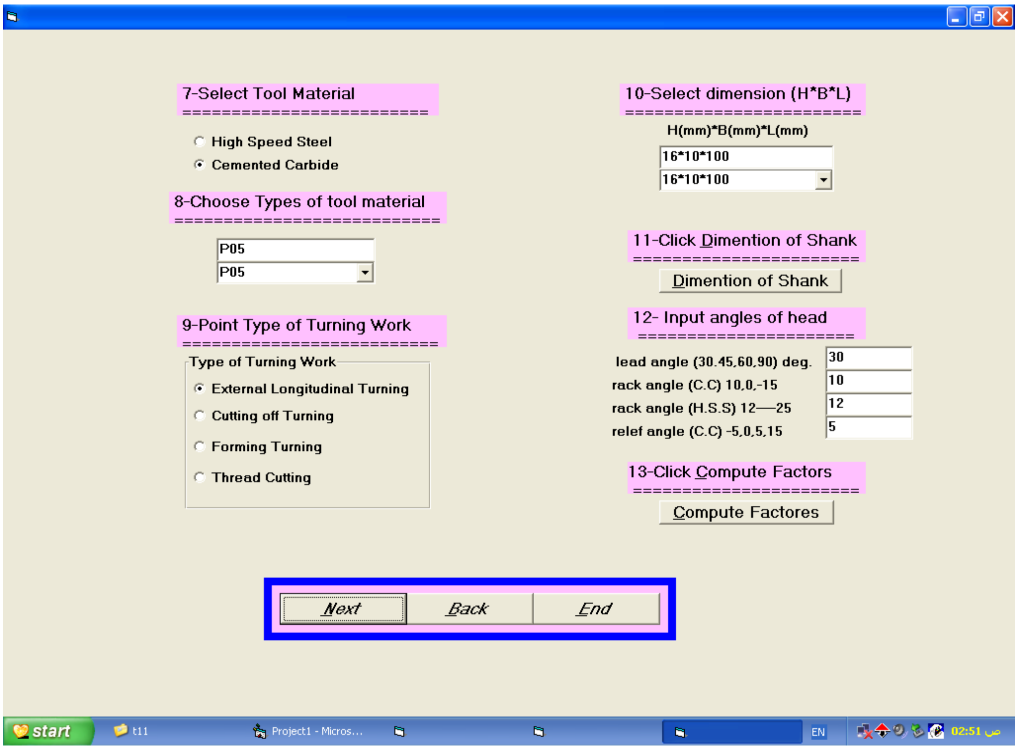


**Fig.4. Select the Parameter of Machining**

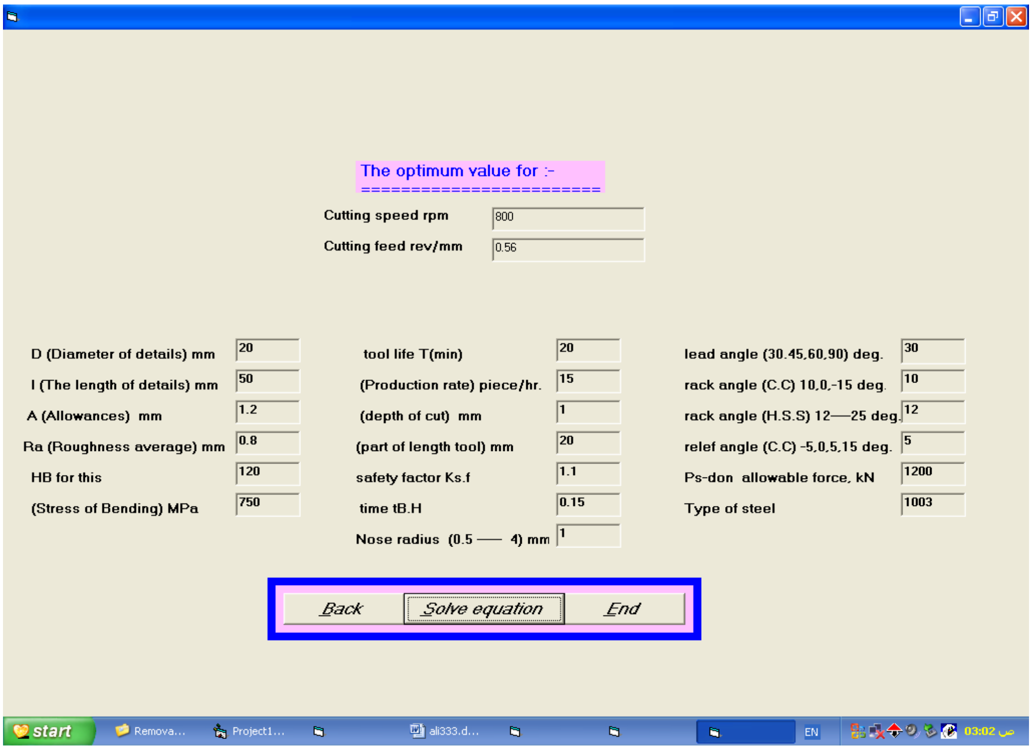


**Fig. 5. Final Results**

## 5. Procedure of Linear Programming

The sequences of solving equations are:

1. Examine a pair of straight lines and make their checks to parallel at the same time.
2. If straight lines are parallel, examine the next pair, but if the straight lines are not parallel, then determine the coordinates of $X1$and $X2$ to the point of the intersection.
3. Check the Signs of coordinates. If the coordinates are positive, then through the permutations in each of the inequalities found, the value of $X1$ and $X2$ will be determined, whether the point in the field of possible solutions. If any one of inequalities is not satisfied, then this point is discarded and conducted the same analysis for the next pairs.
4. If $X1$and $X2$, are positive and satisfy all the inequalities without exception, then determine the summation of the coordinates $\Delta o = X1+X2$ and store in the form of some significance A. All the above steps are followed until all pairs of straight lines are considered.
5. In the case of inconsistencies in the original data may show that there is the no field of possible solutions. A sign with out joint the system is equal to zero value of A, which otherwise is the sum of coordinates $X1+X2$, and will be the solution of the problem.
6. If the decision is on the line, it is parallel to the evaluation function, where a decision is taken by the coordinates of the point, more than coordinate X2 (i.e. when more than the value of the feed).
7. If the system's inequalities together and found the point, an summation the coordinates $X1+X2$ to be the maximum, so, the optimum cutting speed is $n = e^{x_1}$ and the optimum feed is $f = e^{x_2/100}$.

## 6. Case Study

This case study describes how to use this package. We show how the problems listed and solved by the program in a typical interactive computer session. In the first window (Fig.2); we must enter the information about the workpiece

D = 20mm  
L = 50mm  
A = 1.2mm  
Ra = 0.8µm  
R = 15 piece/hr, then select working materials  
Carbon steel, 1213, CNC turning machine (nmin=12.5rpm, nmax=2000rpm)  
In the second window (Fig.3) we must select the  
Tool material-cemented carbide (P05)  
Tool dimension -16*10*100(B*H*L)  
External longitudinal turning work  
Relief angel = 10 deg.  
Rake angel = 15 deg.

From this choice condition, the optimum cutting condition is achieved as the following:

Cutting speed (rpm) = 800  
Cutting feed (rev/mm) = 0.56

See Fig.5

## 7. Conclusion

Traditionally cutting conditions has been performed manually or by using tables by most companies. This package used to automate this function, and two approaches are considered, first: develop optimum and consistent individual calculation for each part. Reducing the number of errors made in preparing the calculations. Second: Minimize the cost of production, time of production and maximize profit rate.

**1.** This work is one of the ways that can be automatically calculate the optimum cutting condition to allow simplification of product manufacture.

**2.** Automatically calculating the optimum cutting conditions is an important element in (CAD/CAM) integration because it provides a basis.

**3.** Reduce the amount of manual effort and time required to prepare the optimum cutting condition.

**4.** This package provides a data base of manufacturing knowledge that can be readily accessed.

## Nomenclature

| | |
|---|---|
| A | allowances, mm |
| B | width of shank, mm |
| $B\phi$ | width of milling cutter |
| C1 | constant, independent |
| Cmin | min. cost |
| D | diameter of details in mm |
| Dnp | translate diameter for multistage shaft |
| E | module of elasticity |
| $f$ | Feed, rpm |
| H | height of shank, mm |
| KL | Loading factor |
| $K_{S.F}$ | Safety factor |
| L | total length of shank, mm |
| l | the length of details, mm |
| Lw.p. | length of work piece |
| ℓB.P. | Part of total tolls length, mm |
| m | variable indicator |
| N | power of machine, Kw |
| **n**max | maximum velocity of machine, m/min |
| **n**min | minimum velocity of machine, m/min |
| R | production rate, Piece/hr |
| r | noise radius, mm |
| rR | number of workpiece |
| Ro | surface of roughness, µm (Ra, Rz, Rmax) |
| T | tool life, min |
| t | depth of cut, mm |
| $t_{B.H.}$ | time, min |
| $P_{s-don}$ | allowable force, kN |
| $X_p$ | distance from right edge to the position of the force |
| η | efficiency of machine |
| σ | Stress, MPa |
| z | number of cutting teeth |
| δ | tolerance, mm |
| $C_s$, $C_y$, $C_z$, $C_v$ | constant factor (5) |
| $k_1$, $k_2$, $k_3$, $k_4$, $k_5$, $k_6$, $k_7$ | empirical factor (5) |
| $k_v$, $k_s$, $k_y$, $k_z$, $k_{cz}$ | Correction factor (5) |
| $n_s$, $n_y$, $n_z$, | indicator of degree (5) |
| Xs, Xv, Xy, Xz | indicator of degree (5) |
| ys, yv, yz | indicator of degree (5) |
| $r_s$, $r_z$ , $u_s$, $u_z$, $z_s$, $z_z$ | indicator of degree (5) |
| $\Phi_1, \Phi_2, \lambda$ | Angles, degree |

## 8. References


[1] Hamdy A. Taha, Operations Research. Macmillan publishing company, New York, Fourth Edition 1987.

[2] Dr.surender Kumar, Dr. A. K. Jha; Technology of computer Aided design & Manufacturing (CAD/CAM:CAE) DHANPAT RAI and SONS 1993.

[3] Erik Oberg and others, Machinerys Handbook, $24^{th}$ Edition, new york

[4] V.V. Arabatti and others, Production Technology, McGraw-Hill, Mew Delhi.

[5] A.G. Kocelovoy and R.K. Mesheryakova , Machine building technology, handbook,voi.1,2, Moscow, 1985.

[6] V. E.Averchenkov and others, System Automatically Project-Technological processes, Minck-1993

[7] Yascheritsin P. I. and Eremenko M.L. Theory of Cutting , Minck-1990.

[8] U. Rembold, B.O. Nnaji, A. Stoor; Computer integrated manufacturing and engineering; Wesiey publishing Inc. 1993.

[9] Serope Kalpakjian and Stevaen R.Schmid, Manufacturing engineering and Technology, Fifth Edition, by person Education, Inc.,2006.

# حساب نظام القطع المثالي اوتوماتيكيا لمختلف أنواع عمليات التشغيل

**علي حسين كاظم*        هدى حاتم****

*قسم هندسة عمليات التصنيع/ كلية هندسة الخوارزمي/ جامعة بغداد*

** البريد الالكتروني:(kadhumali59@yahoo.com )*

*** البريد الالكتروني: (Hoda_Abode@yahoo.com )*

**الخلاصة**

يهدف البحث الى حساب نظام القطع المثالي لمختلف أنواع عمليات التشغيل بمساعدة الحاسوب، تم تصميم برنامج يساعد على حل محددات نظام القطع بطريقة البرمجة الخطية ، البرنامج كتب بلغة البيسك . يقوم البرنامج بحساب القيم المثالية لعناصر نظام القطع ( التغذية وسرعة القطع ) اوتوماتيكيا . وذلك بعد إدخال المعلومات الأولية عن المشغولة وحالة عملية القطع ، يقوم البرنامج بحساب دقيق وذلك بحل مجموعة من العلاقات التجريبية بعد تحويلها إلى موديل رياضي وحسب نوع طريقة التشغيل (خراطة ،تثقيب ،تفريز ). تم تحويل البرنامج الى مجموعة من الواجهات لتسهيل استعماله . البرنامج يقلل من الجهد والوقت الضائع في الحسابات المثالية لأنظمة القطع ، هذه القيم المثالية تحسن من خواص المشغولة وتساعد على زيادة الإنتاجية.