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Original Article

Optimization of Cutting Parameters Under the Constraint of Machining Time

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Abstract - *The choice of cutting parameters plays a crucial role in the life of cutting tools, the surface condition of machined parts, manufacturing tolerances and productivity. This paper aims to develop a new approach for optimizing cutting parameters for machining on CNC machine tools, such as cutting speed, feed rate, and depth of cut. This approach is based on the transfer from a single-objective system to a multi-objective system. A tool has been developed to determine the optimized cutting parameters directly.*

Keywords - *Cutting parameters, Multi-criteria, Workpiece quality, Machining time, Cutting speed.*

1. Introduction

Nowadays, producing at the lowest cost and optimizing and modeling systems or functions to simulate them are essential objectives to be achieved for the industrial environment. Any technical study must consider a product's life cycle, from its design to recycling (ISO 9000). With the industrial revolution, know-how was a fragment, giving way to the Taylorization of work, which was, at the time, the best industrial organization to respond to mass production. Today in the face of competition, the industry listens to the consumption needs of its customers, whose requirements are increasingly restrictive and challenging to meet, given the diversity and variety of the problems raised. The globalization of the industry encourages the transfer of knowledge, know-how, and equipment following the relocation of companies worldwide, where only survival and profit count.

Despite the evolution of manufacturing technologies such as additive manufacturing, machining by material removal plays an essential role in industrial manufacturing because of the quality of the surfaces obtained.

Several research works have been done on cutting parameters. Wilfredo et al. [1] studied the effects of cutting parameters on surface roughness and hardness in milling of AISI 304 steel.

Berkani et al. [2] investigated the effects of cutting parameters on surface roughness and cutting force when dry-turning stainless steel. Kaladhar et al. [3] investigated surface roughness during the machining of stainless steel. Nur et al. [4] studied the influence of machining parameters on surface roughness and cutting force during the dry turning of 316l stainless steel. Acayaba et al. [5] estimated an optimal surface roughness based on multiple linear regression and an artificial neural network. [6] Avevor et al. studied the influence of cutting speed on the thermomechanical conditions at the tool-chip interface. [7] Roger presented a method for optimizing cutting parameters in machining: a comparison of existing methods. Houalef et al. presented a method for optimizing cutting parameters under the constraint of design office requirements. [9] Meriem et al. presented a technique for optimizing cutting parameters by roughness analysis. [8] Mehmet Emre Kara presented an approach for the modeling and optimization of turn-milling processes for cutting parameter selection. [11] Savas et al. presented a method for optimizing the surface roughness in the process of tangential turn-milling using a genetic algorithm. [12] Santos et al. presented a method for the optimization of cutting conditions when turning aluminum alloys (1350-o and 7075-t6 grades) using a genetic algorithm.

This paper presents an approach for the optimization of cutting parameters to ensure good productivity and good surface condition.

2. Cutting Parameters

Cutting parameters, such as tool geometry, feed rate, and cutting speed, play a vital role in productivity, surface finishes, power consumption, production time, cutting forces and vibration generated [13, 14, 15].

2.1. Cutting Speed

The workpiece drives on the lathe at a certain speed ω, this angular speed being communicated by the spindle of the machine via the workpiece holder (Figure 1).

The relative speed of the part at this point for the tool is given by the following formula (1) [22] :

$$Vc = \frac{D}{2} \times \omega \quad (1)$$

Table 1. Influence of operation on cutting speed [16], [18]

Operations	Cutting speed
Turning or facing	Vc
Simultaneous turning and facing	0.8Vc
Cutting	0.5Vc
Thread	0.3Vc
Drilling or reaming	0.7Vc
Knurling	0.25Vc

The spindle speed is given by the following expression (2) [22].

$$N(tr/\,min) = \frac{1000 \times Vc \quad (m/\,min)}{\pi.D(mm)} \quad (2)$$

The cutting speed, Table 1, depends on the type of operation.

It should be noted that the cutting speed is constant only if the spindle speed and the diameter of the workpiece remain unchanged. In the face, for example, where the tool moves towards the center, the cutting speed varies continuously if the rotation of the part is carried out at a constant spindle speed. However, keeping the cutting speed constant is desirable for maximum productivity and better quality of the surfaces obtained.

On many modern lathes, the spindle speed increases as the tool approaches the axis, compensating for the decrease in diameter. But in the case of minimal diameters, this compensation is impossible due to the limited speed range allowed by the machines. Similarly, when a part, as is often the case, has different diameters or is conical or curved in shape, the rotational frequency must be corrected according to the diameter to maintain the cutting speed constant (Figure 2).

2.2. Feed Rate Vf

The feed rate Vf (mm/min), Figure 4, is the speed at which the machine moves the tool relative to the frame. The feed per revolution f (mm/Tr) is the value of the tool displacement when the part has made one revolution. It is key data for the quality of the machined surface. The feed affects not only the thickness of the chips but also how they break. The feed rate Vf is given by the following formula (3) [22].

$$Vf = f\,.\,N \quad (3)$$

2.3. Depth of Cut (Ap)

In turn, the depth of cut ap (see Figure 4) is the difference in radius between the unmachined surface and the machined surface (i.e. half the difference between the unmachined diameter and the machined diameter). The depth of cut was continuously measured perpendicular to the direction of the feed and not along the tool’s edge.

2.4. Chip Width and Thickness

The chip thickness h is measured perpendicular to the cutting edge. The width b_D of this chip is measured parallel to this edge. For a feed per revolution f and a depth of pass p data, the chip thickness and width vary with the edge orientation angle k.(Figure 4).

In addition, for substantial cuts (negligible tool nose radius compared to the other parameters), the chip section is given by the following expression (4) [22]:

$$A_D = f.\, a_p = h.\, b_D \quad (4)$$

For a section of chip removed, we have the choice, by playing on kr, between obtaining a long and thin chip or a shorter and thicker one (Figure 5).

A thin chip distributes the cutting force over a more significant part of the edge, reducing the stresses (mechanical and thermal) imposed. On the other hand, a chip that is too thin (less than the “minimum chip”) prevents an actual cutting of the material, generates high stresses and wears out. Prematurely the tool: we must then compensate by increasing the feed.

Table 2 illustrates the different angles of the attack effect:

- The feed gave the same chip thickness.
- The chip thickness gave the same feed.
- The effective length of the edge taking into account the same depth of cut.

Table 2. Influence of entering angle on feed, edge length and chip thickness [17], [20]

%	1	2	3
Ko	***f /h***	***h/ f***	***bD/ ap***
90	100	100	100
80	102	99	102
75	103	97	103
60	110	87	110
45	141	71	141

3. Cutting Parameter Effects

Several researchers have been developed. In this context, Youssef Touggui et al. [24] present a study on the optimization of cutting parameters when turning AISI 316L stainless steel. This work shows that the factors Vc, F, and ap influence the surface state (Figure 1).

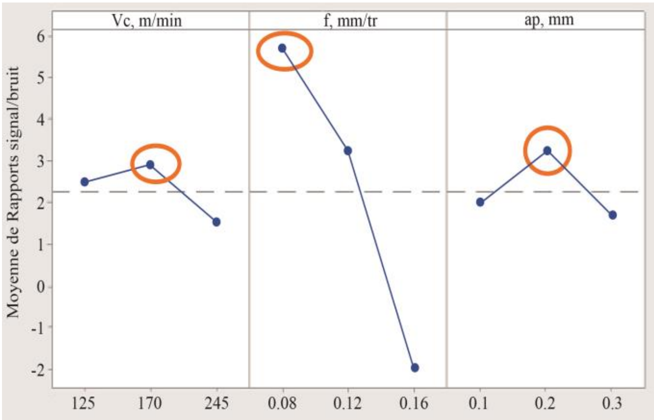

Fig. 1 Effects of Vc, f and ap on roughness (Ra) [24]

The work of Mulugeta Berhane Haile [25] presents a study on the influence of cutting parameters on tool life; this study is grouped in Figure 2.

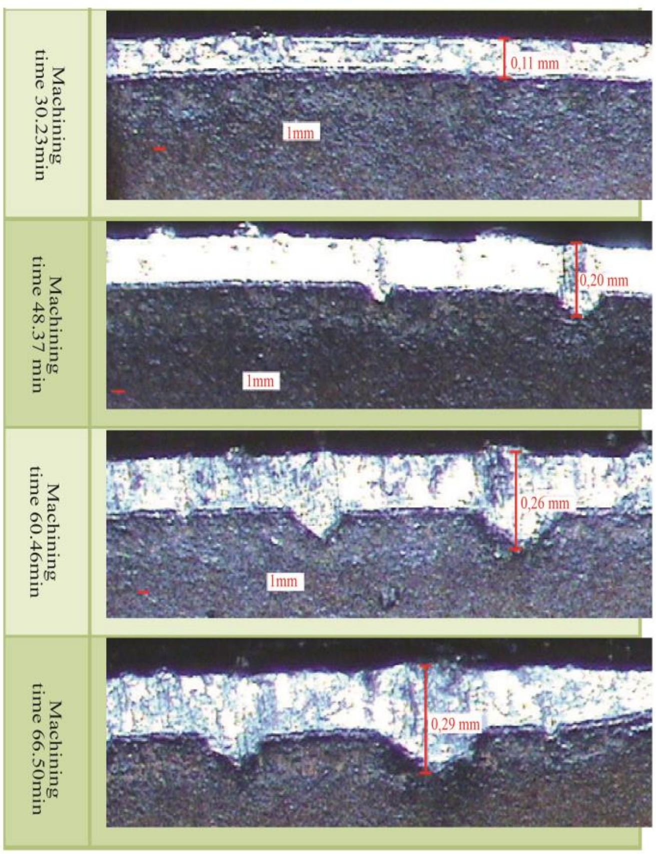

Fig. 2 Progress of tool wear for the setting of feed (0.25mm/tooth) and speed (160m/min) [25]

HAMLAOUI et al. [26] contribute to optimizing cutting parameters to minimize the cutting temperature when machining HDPE-100 pipes. The results of this search are grouped in Figure 3.

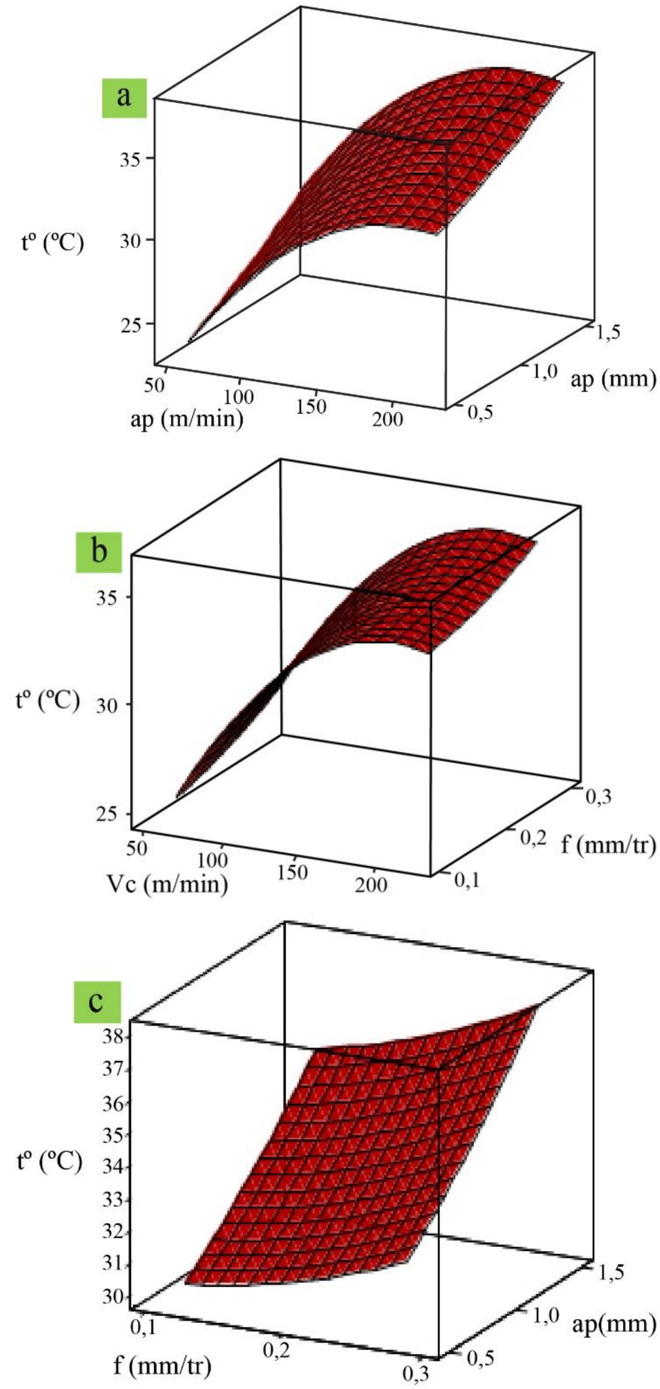

Fig. 3 3D response surfaces for t° as a function of Vc, ap and f

4. Tool Developed

This software has several functions, not only the choice and optimization of the calculation time of the cutting parameters but also the search for a good surface condition. Figures 4, 5 and 6 show an example of the calculation of these parameters for turning, parting off and threading operations.

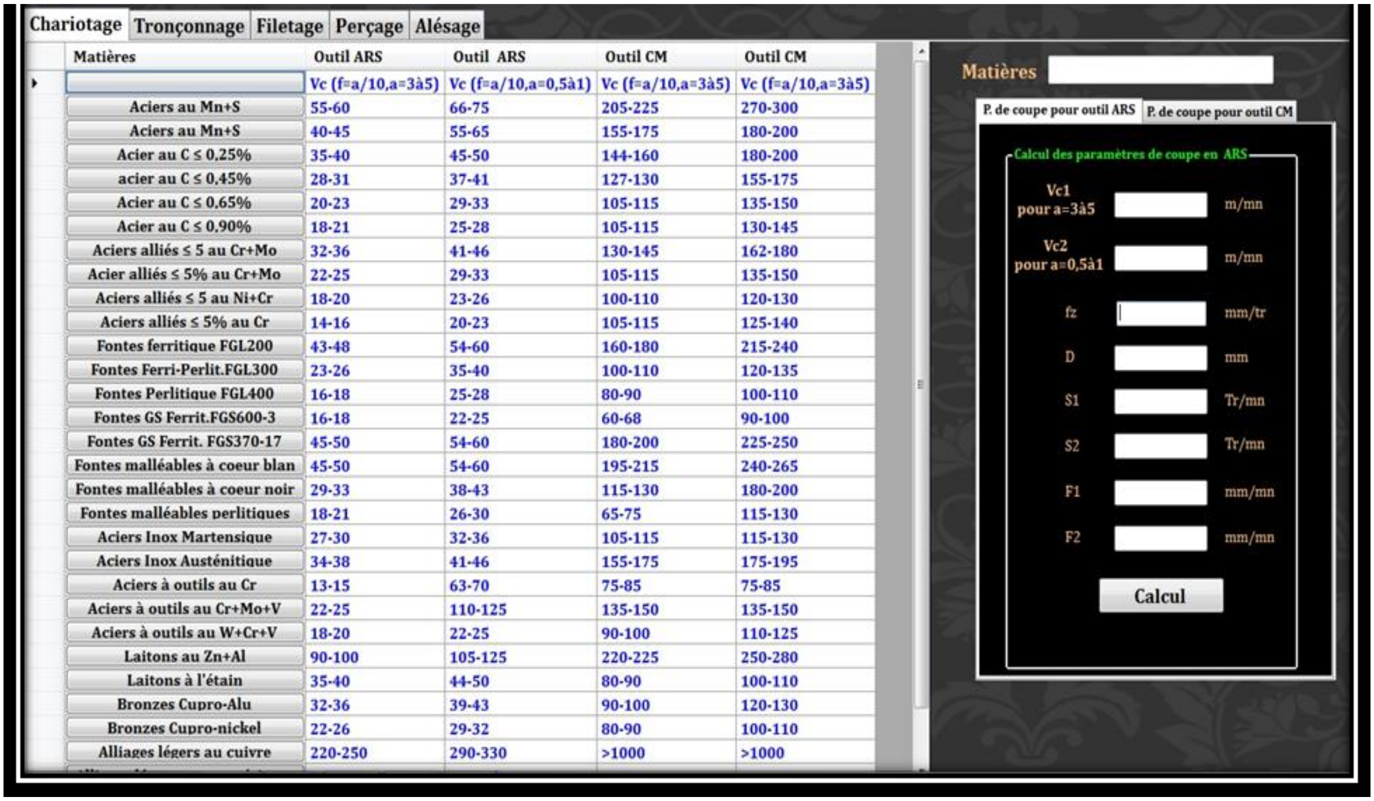

Fig. 4 Rolling cutting parameters

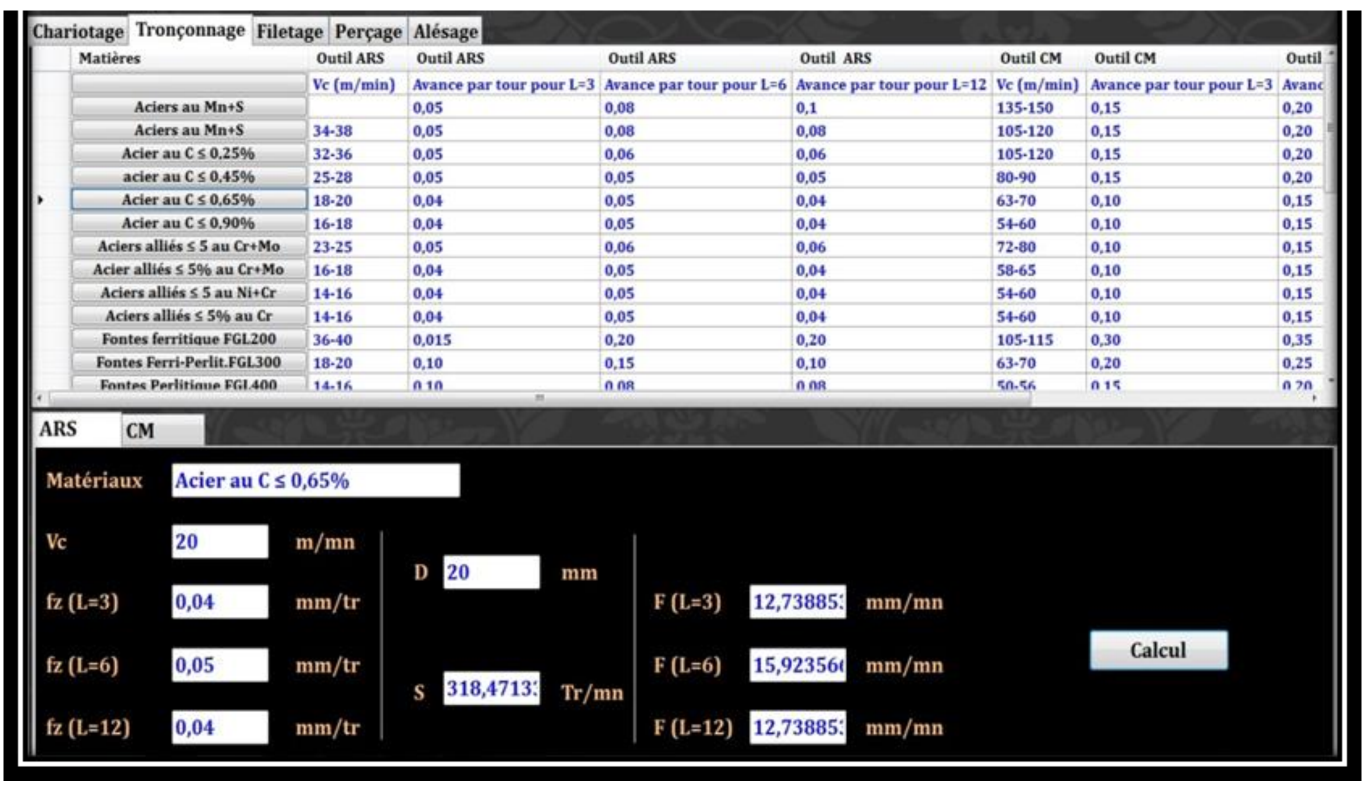

Fig. 5 Cutting parameters

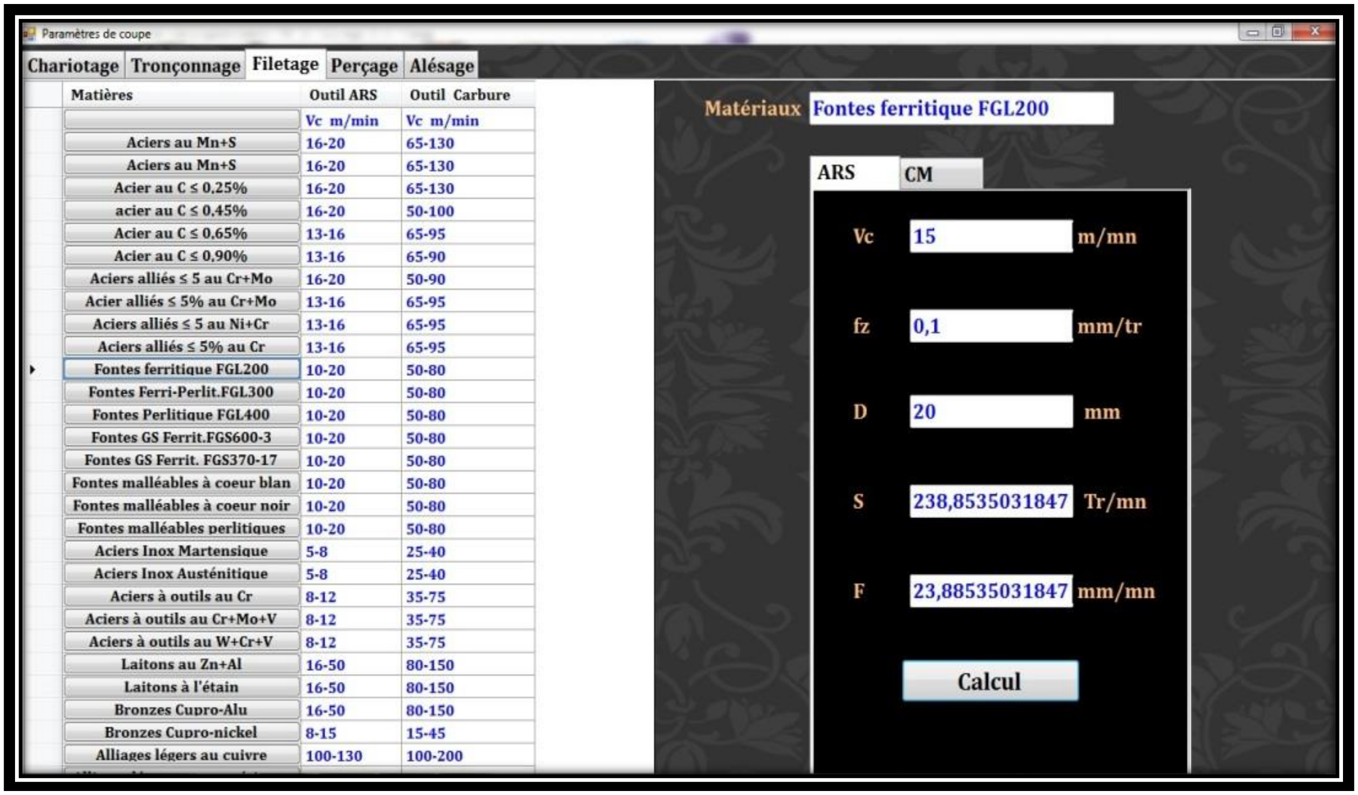

Fig. 6 Thread-cutting parameters

5. Conclusion

The search for a good product in a short time with a minimal cost led us to develop a tool to help manufacture mechanical parts under the previous constraints. For this purpose, the software has been developed based on the state of the art on the effect of the choice of cutting parameters on the quality of the part. This tool fulfils several functions, not only the choice and optimization of the calculation time of the cutting parameters to optimize productivity, machining time, machining cost and surface condition but also the possibility of integrating this software into numerically controlled machine tools.

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