

Original Article

Optimization of Cutting Parameters Under the Constraint of Machining Time

Bachir Haoulef¹, Mohamed Rahou², Fethi Sebaa³

^{1,2,3}IS2M Laboratory, Department of Mechanical, University of Tlemcen, Algeria.

Received: 07 October 2022

Revised: 09 November 2022

Accepted: 22 November 2022

Published: 30 November 2022

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.

I. 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 its 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. [1] Wilfredo et al. 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. [8] 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. [27] 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] :

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



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

$$N(\text{tr/min}) = \frac{1000 \times V_c \text{ (m/min)}}{\pi \cdot D(\text{mm})} \quad (2)$$

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

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

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, it is desirable to keep the cutting speed constant for maximum productivity and better quality of the surfaces obtained. On many modern lathes, the spindle speed increases as the tool approach the axis, thereby 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].

$$V_f = f \cdot N \quad (3)$$

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]:

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

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, YoussefTouggui 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).

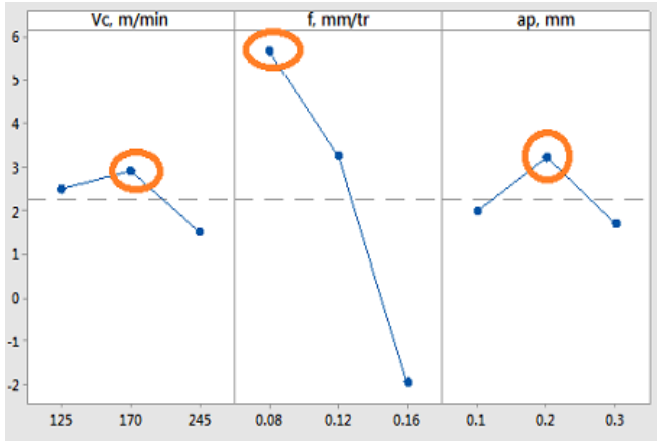


Fig. 1 Effects of Vc, f and ap on roughness (Ra) [24]

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.

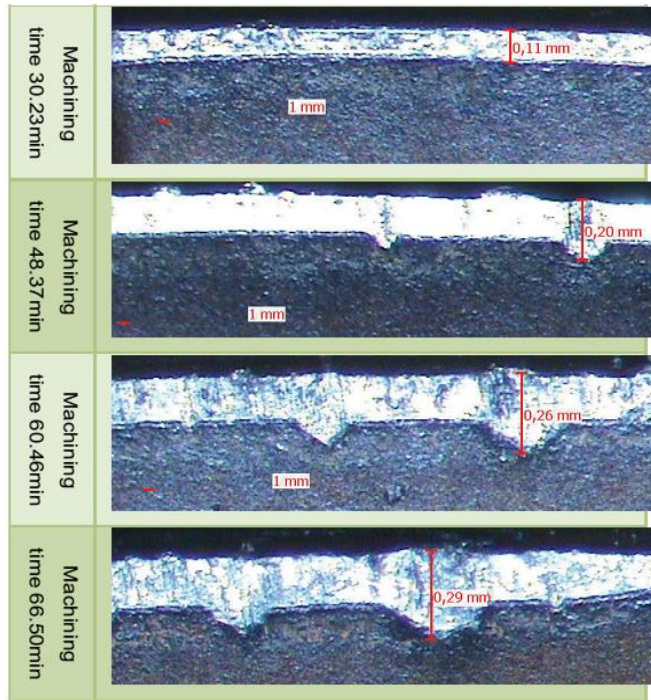


Fig. 2 Progress of tool wear for the setting of feed (0.25mm/tooth) and speed (160m/min) [25]

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.

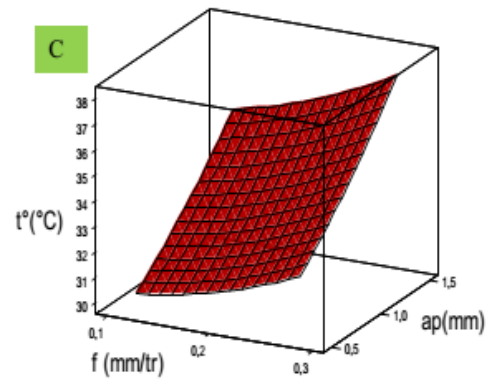
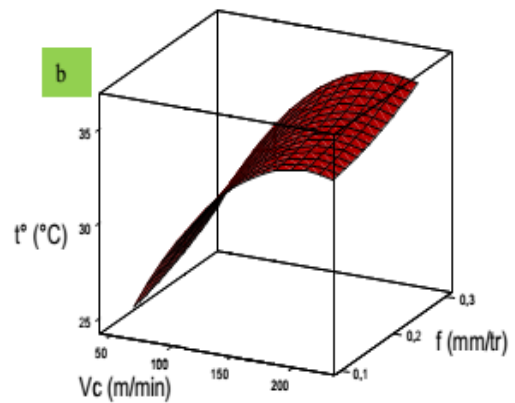
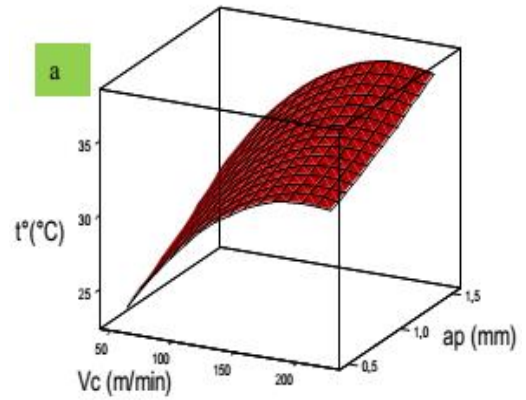


Fig. 3 3D response surfaces for t° as a function of Vc, ap and f.

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.

Chariotage	Tronçonnage	Filetage	Perçage	Alésage
Matières	Outil ARS	Outil ARS	Outil CM	Outil CM
	$V_c (f=a/10, a=3\text{à}5)$	$V_c (f=a/10, a=0,5\text{à}1)$	$V_c (f=a/10, a=3\text{à}5)$	$V_c (f=a/10, a=3\text{à}5)$
Aciers au Mn+S	55-60	66-75	205-225	270-300
Aciers au Mn+S	40-45	55-65	155-175	180-200
Acier au C ≤ 0,25%	35-40	45-50	144-160	180-200
acier au C ≤ 0,45%	28-31	37-41	127-130	155-175
Acier au C ≤ 0,65%	20-23	29-33	105-115	135-150
Acier au C ≤ 0,90%	18-21	25-28	105-115	130-145
Aciers alliés ≤ 5 au Cr+Mo	32-36	41-46	130-145	162-180
Acier alliés ≤ 5% au Cr+Mo	22-25	29-33	105-115	135-150
Aciers alliés ≤ 5 au Ni+Cr	18-20	23-26	100-110	120-130
Aciers alliés ≤ 5% au Cr	14-16	20-23	105-115	125-140
Fontes ferritique FGL200	43-48	54-60	160-180	215-240
Fontes Ferri-Perlit.FGL300	23-26	35-40	100-110	120-135
Fontes Perlitique FGL400	16-18	25-28	80-90	100-110
Fontes GS Ferrit.FGS600-3	16-18	22-25	60-68	90-100
Fontes GS Ferrit. FGS370-17	45-50	54-60	180-200	225-250
Fontes malléables à coeur blanc	45-50	54-60	195-215	240-265
Fontes malléables à coeur noir	29-33	38-43	115-130	180-200
Fontes malléables perlitiques	18-21	26-30	65-75	115-130
Aciers Inox Martensique	27-30	32-36	105-115	115-130
Aciers Inox Austénitique	34-38	41-46	155-175	175-195
Aciers à outils au Cr	13-15	63-70	75-85	75-85
Aciers à outils au Cr+Mo+V	22-25	110-125	135-150	135-150
Aciers à outils au W+Cr+V	18-20	22-25	90-100	110-125
Laitons au Zn+Al	90-100	105-125	220-225	250-280
Laitons à l'étain	35-40	44-50	80-90	100-110
Bronzes Cupro-Alu	32-36	39-43	90-100	120-130
Bronzes Cupro-nickel	22-26	29-32	80-90	100-110
Alliages légers au cuivre	220-250	290-330	>1000	>1000

Matières

P. de coupe pour outil ARS P. de coupe pour outil CM

Calcul des paramètres de coupe en ARS

Vc1 pour a=3à5 m/mn

Vc2 pour a=0,5à1 m/mn

fz mm/tr

D mm

S1 Tr/mn

S2 Tr/mn

F1 mm/mn

F2 mm/mn

Calcul

Fig. 4 Rolling cutting parameters

Chariotage	Tronçonnage	Filetage	Perçage	Alésage			
Matières	Outil ARS	Outil ARS	Outil ARS	Outil ARS	Outil CM	Outil CM	Outil
	Vc (m/min)	Avance par tour pour L=3	Avance par tour pour L=6	Avance par tour pour L=12	Vc (m/min)	Avance par tour pour L=3	Avanc
Aciers au Mn+S		0,05	0,08	0,1	135-150	0,15	0,20
Aciers au Mn+S	34-38	0,05	0,08	0,08	105-120	0,15	0,20
Acier au C ≤ 0,25%	32-36	0,05	0,06	0,06	105-120	0,15	0,20
acier au C ≤ 0,45%	25-28	0,05	0,05	0,05	80-90	0,15	0,20
Acier au C ≤ 0,65%	18-20	0,04	0,05	0,04	63-70	0,10	0,15
Acier au C ≤ 0,90%	16-18	0,04	0,05	0,04	54-60	0,10	0,15
Aciers alliés ≤ 5 au Cr+Mo	23-25	0,05	0,06	0,06	72-80	0,10	0,15
Acier alliés ≤ 5% au Cr+Mo	16-18	0,04	0,05	0,04	58-65	0,10	0,15
Aciers alliés ≤ 5 au Ni+Cr	14-16	0,04	0,05	0,04	54-60	0,10	0,15
Aciers alliés ≤ 5% au Cr	14-16	0,04	0,05	0,04	54-60	0,10	0,15
Fontes ferritique FGL200	36-40	0,015	0,20	0,20	105-115	0,30	0,35
Fontes Ferri-Perlit.FGL300	18-20	0,10	0,15	0,10	63-70	0,20	0,25
Fontes Perlitique FGL400	14-16	0,10	0,08	0,08	50-56	0,15	0,20

ARS

CM

Matériaux

Acier au C ≤ 0,65%

Vc

20

m/mn

fz (L=3)

0,04

mm/tr

fz (L=6)

0,05

mm/tr

fz (L=12)

0,04

mm/tr

D

20

mm

S

318,4713

Tr/mn

F (L=3)

12,73885

mm/mn

F (L=6)

15,92356

mm/mn

F (L=12)

12,73885

mm/mn

Calcul

Fig. 5 Cutting parameters.

Matériaux	Outil ARS	Outil Carbure
	Vc m/min	Vc m/min
Aciers au Mn+S	16-20	65-130
Aciers au Mn+S	16-20	65-130
Acier au C ≤ 0,25%	16-20	65-130
acier au C ≤ 0,45%	16-20	50-100
Acier au C ≤ 0,65%	13-16	65-95
Acier au C ≤ 0,90%	13-16	65-90
Aciers alliés ≤ 5 au Cr+Mo	16-20	50-90
Acier alliés ≤ 5% au Cr+Mo	13-16	65-95
Aciers alliés ≤ 5 au Ni+Cr	13-16	65-95
Aciers alliés ≤ 5% au Cr	13-16	65-95
Fontes ferritique FGL200	10-20	50-80
Fontes Ferri-Perlit.FGL300	10-20	50-80
Fontes Perlitique FGL400	10-20	50-80
Fontes GS Ferrit.FGS600-3	10-20	50-80
Fontes GS Ferrit. FGS370-17	10-20	50-80
Fontes malléables à coeur blanc	10-20	50-80
Fontes malléables à coeur noir	10-20	50-80
Fontes malléables perlitiques	10-20	50-80
Aciers Inox Martensique	5-8	25-40
Aciers Inox Austénitique	5-8	25-40
Aciers à outils au Cr	8-12	35-75
Aciers à outils au Cr+Mo+V	8-12	35-75
Aciers à outils au W+Cr+V	8-12	35-75
Laitons au Zn+Al	16-50	80-150
Laitons à l'étain	16-50	80-150
Bronzes Cupro-Alu	16-50	80-150
Bronzes Cupro-nickel	8-15	15-45
Alliages légers au cuivre	100-130	100-200

Matériaux Fontes ferritique FGL200

ARS CM

Vc 15 m/min

fz 0,1 mm/tr

D 20 mm

S 238,8535031847 Tr/mn

F 23,88535031847 mm/mn

Calcul

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.

References

- [1] Luis Wilfredo Hernández González, and R. Pérez-Rodríguez et al., "Effects of Cutting Parameters on Surface Roughness and Hardness in Milling of AISI 304 Steel," *Dyna (Medellin, Colombia)*, vol. 85, no. 205, pp. 57-63, 2018. *Crossref*, <http://dx.doi.org/10.15446/dyna.v85n205.64798>
- [2] Berkani S, et al., "Statistical Analysis of Aisi304 Austenitic Stainless Steel Machining Using Ti (C, N)/Al₂O₃/Tin CVD Coated Carbide Tool," *International Journal of Industrial Engineering Computations*, vol. 6, no. 4, pp. 539-552 2015. *Crossref*, <http://dx.doi.org/10.5267/j.ijiec.2015.4.004>
- [3] Kaladhar M, et al., "Determination of Optimum Process Parameters During Turning of AISI 304 Austenitic Stainless Steels Using Taguchi Method and ANOVA," *International Journal of Lean Thinking*, vol. 3, no. 1, 2011.
- [4] Nur Rusid, et al., "Machining Parameters Effect in Dry Turning of AISI 316L Stainless Steel Using Coated Carbide Tools," *Journal of Process Mechanical Engineering*, vol. 231, no. 4, pp. 1 - 8 , 2015. *Crossref*, <https://doi.org/10.1177/0954408915624861>
- [5] Acayaba, Medrado G, and Muñoz De Escalona P, "Prediction of Surface Roughness in Low-Speed Turning of AISI316 Austenitic Stainless Steel," *CIRP Journal of Manufacturing Science and Technology*, vol. 11, pp. 62-67, 2015. *Crossref*, <http://dx.doi.org/10.1016/j.cirpj.2015.08.004>
- [6] Y. Avevor A, and A. Moufika, "Studied the Influence of the Cutting Speed on the Thermomechanical Conditions At the Tool-Chip Interface," *22nd French Congress of Mechanics Lyon*, August 24 To 28, 2015
- [7] Roger Serra, "Optimization of Cutting Parameters in Machining: Comparison of Existing Methods," CFM 2013 - 21st French Mechanical Congress, Bordeaux, France, 2013.
- [8] B. .Haoulef, M. Rahou, and F. Sebaa, "Optimization of Cutting Parameters Under the Constraint of Design office Requirements," *International Journal of Latest Engineering Science*, vol. 5, no. 03, 2022. *Crossref*, <http://doi.org/10.51386/25816659/ijles-v5i3p101>
- [9] M. Dib, et al., "Optimization of the Parameters of Cut by Roughness Analysis," CFM 2015 - 22nd French Mechanical Congress, Lyon, France, 2015.

- [10] Varun S, and Shilpa Parkhi, "Optimization of Multiple Process Parameter of Milling (Multi-Objective) on AISI 202 Stainless Steel Using Taguchi Based Grey Relational Analysis," *International Journal of Engineering Trends and Technology*, vol. 68, no. 10, pp. 81-86, 2020. Crossref, <http://dx.doi.org/10.14445/22315381/IJETT-V68I10P214>
- [11] Savas V, and Ozay C, "The Optimization of the Surface Roughness in the Process of Tangential Turn-Milling Using Genetic Algorithm," *International Journal of Advanced Manufacturing Technology*, vol. 37, pp. 335-340, 2008.
- [12] Santos M C Jr, et al., "Multi-Objective Optimization of Cutting Conditions When Turning Aluminum Alloys (1350-O and 7075-T6 Grades) Using Genetic Algorithm," *International Journal of Advanced Manufacturing Technology*, vol. 76, pp. 1123-1138, 2014. Crossref, <https://doi.org/10.1007/s00170-014-6314-5>
- [13] A. Salmanasnia, et al., "Multiple Surface Optimizations with Correlated Data," *The International Journal of Advanced Manufacturing Technology*, vol. 64, pp. 841-855, 2013. Crossref, <https://doi.org/10.1007/s00170-012-4056-9>
- [14] H. Chibane, et al., "Correlation Between Vibrations and the Defects Generated During the Machining of A Carbon/Epoxy Composite Material T800s/M21," 20th French Congress of Mechanics, 2011.
- [15] L. Corso, et al., "Using Optimization Procedures to Minimize Machining Time While Maintaining Surface Quality," *The International Journal of Advanced Manufacturing Technology*, vol. 65, pp.1659-1667, 2013. Crossref, <https://doi.org/10.1007/s00170-012-4288-8>
- [16] Claude Marty, and Jean-Marc Linares, "Industrialization of Mechanical Products," Hermes Science, Paris, vol. 1, 1999.
- [17] Claude Marty, and Jean-Marc Linares, "Industrialization of Mechanical Products," Hermes Science, Paris, vol. 3, 1999.
- [18] Chevalier Bohan, "Manufacturing Guide", Paris, 2003
- [19] Rahul Reddy Sandi, Chanikya Anasuri, and Dr. Shyam Kumar. S, "Cutting Tool Selection - Geometry, Workpiece, Tool Material: A Simulated, Library-Based Interactive Approach," *SSRG International Journal of Mechanical Engineering*, vol. 8, no. 11, pp. 18-30, 2021. Crossref, <https://doi.org/10.14445/23488360/IJME-V8I11P103>
- [20] Rahou.M, and Sebaa. F, "Automation of Cutting Parameters", 4th International Conference on Computer Integrated Manufacturing Cip'2007, 03-04 November 2007, Setif, Algeria, 2007.
- [21] Naife A. and Talib "Studying the Effect of Cutting Speed and Feed Rate on Tool Life in the Turning Processes," *Diyala Journal of Engineering Sciences*, pp. 181-194, 2010.
- [22] Rahou M, et al., "Automation of Machining Instructions "Case of Cutting Parameters",," *International Conference on Advances in Mechanical Engineering Istanbul 2016 - Icame'16 10-13 May 2016*, Yildiz Technical University, Istanbul, Turkish, 2016.
- [23] Hassi A, Khathat M, and Lagha M, "Automation of Cutting Parameters" Duea Memory, University of Tlemcen, 2008
- [24] Y.Touggui, et al., "Optimization of Cutting Parameters When Turning AISI 316L Stainless Steel Using ANOVA and the Taguchi Method," ISMRE 2018, Algeria, 2018.
- [25] Mulugeta Berhane Haile, "Optimization of Cutting Parameters on Compacted Graphite Iron (CGI) Machining, Master of Science Thesis," *School of Industrial Engineering and Management Royal Institute of Technology*, 2011.
- [26] N. Hamlaoui, et al., "Optimization of Cutting Parameters To Minimize Cutting Temperature When Machining Hdpe-100 Tubes," 24th French Mechanical Congress, Brest, August 26 To 30, 2019.
- [27] Mehmet Emre Kara, *Modeling and Optimization of Turn-Milling Processes for Cutting Parameter Selection*, Industrial Engineering, Msc. Thesis, 2015
- [28] Benard Ansemetti, "Manufacturing and Metrology Quotation," Hermes Science, Lavoisier, Paris, vol. 3, 2003.