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Evaluation of the machining of a batch of parts by the turning process in carbon steels and cast iron

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Abstract: In the present investigation, the effect of main parameters for the development of parts in production such as feed rate and depth were evaluated, obtaining the machining costs depending on the characteristics of the material. The machining process used was that of turning in pieces with carbon steels and cast iron as the base material, varying the feed rate in a range between 0.2mm/tooth and 0.8mm/tooth and the depth between 1mm and 4mm allowing important parameters to be determined such as cutting speed and machine operating conditions to obtain a good final finish without affecting the surface of the piece and in production time required to optimize costs.
Keywords : carbon steels, cast iron, machining, turning process.

1. Introduction

The growing demand for manufactured parts manufactured for construction, handling and machine development has generated research to reduce costs throughout the production line[1]. The turning process is one of the indispensable processes in the industry due to the fact that it gives the exact dimensions to the pieces and the surface finishes necessary for a later use of this one without generating possible mechanical failures in the system that will be used, however, the precisión machining of highhardnessmaterials faces difficulties in preparingwithincertain dimensional accuracies and keepingthe mínimum surfaceroughness[2,3].

Elevated cutting temperature and non-uniform dimension increase the cutting force, and aggravated tool wear necessitate the use of cutting fluid in providing the sufficient lubrication reducing the possible damage in the piece[4,5], but the use of this fluid is an extra-cost and reduce the productivity, harms the environment and have negative effect in operator's health[6], thing that affect the cost of the production and it is necessary

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mitigate with other parameters control. Predicting tool wear is necessary to avoid catastrophic tool failure, that can affect the machining performance for the final part quality, it is necessary replace tools before a critical level[7]. The most frequently types of wear are abrasive wear in hard materials machining, adhesion wear and diffusion wear in high temperatures and high stresses in hard turning[8].

In order to optimize the production process of a determined quantity of pieces, it has been proposed to determine the operation ranges where influential parameters such as the cutting speed, cutting time and the useful life of the cutting tools are evaluated, where the greatest economic benefit is obtained by reducing the use of energy resources for minimum cost or maximum production, presenting a specific operation zone for each presented process[9,10].

The contribution of this article is to propose the evaluation of influential parameters in the machining of a batch of parts by the turning process in carbon steels and cast iron, showing a comparison in production performance due to the different structural characteristics of these materials, analyzing the operating conditions of the tools and machinery involved, allowing the best use of available resources to reduce costs by analyzing the variation of parameters such as feed rate and depth.

2. Materials and Methods

Below is a description of the process and the fundamental equations that govern this machining process to obtain a cost analysis suggested by the analysis of the variables involved, presenting a comparison between carbon steel parts and grey cast iron.

2.1 Process description

The machining process for this study is the turning process, in which the operation consists of cutting the part by means of a cutting tool, rotating the part holder at high speeds and giving it conditions of advance and depth to obtain a final shape and finish as shown in Figure 1.

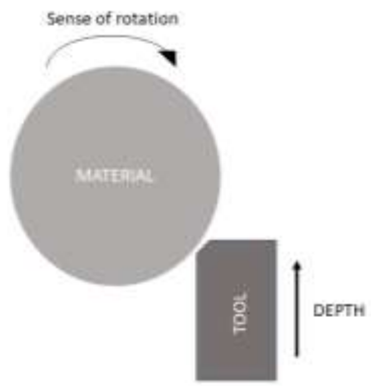

Figure 1. Description of the process.

2.2 Fundamental equations

For the turning process in cast iron it is necessary to analyze the following equations that allowed us to evaluate the operating costs for a production of specified parts. For the analysis of the minimum cost speed, input data such as the constant surface speed and the number of parts to be manufactured were provided. For a more detailed analysis, the non-productive time and the cutting time must be provided as we will see in equation (1)

$$tc = \frac{\pi L}{a.p.Vc.1000}, \qquad (1)$$

where L is the part length, a is the feed rate, p is the penetration and Vc is the cutting speed.

The costs that are generated by the operator for the manufacture and the machine used per unit time are associated with W and the cost of the tool is associated with Z. Therefore, to determine the cost per piece, equation (2) is proposed as follows

$$Cp = W.tnp + W.tc + \frac{Nah}{N}(W.trf + Z). \qquad (2)$$

For the analysis proposed in this article, the machining cost per piece is a parameter that will be established according to the cutting speed, so the equation (3) was obtained.

$$Cp = W.tnp + \frac{W.K}{V} + \frac{Nah}{T_1.V_1^{\frac{1}{n}}}.V^{\frac{1-n}{n}}, \qquad (3)$$

deriving equation (3), the lowest cost speed was obtained as equation (4)

$$Vmc = V_1.(\frac{n}{1-n}.\frac{W.T_1}{W.t_{rf}+Z})^n. \qquad (4)$$

To determine the tool life at minimum cost, equation (5) is proposed

$$Tmc = \left(\frac{1-n}{n}.\frac{W.t_{rf}+Z}{W}\right). \qquad (5)$$

To calculate the maximum production speed it was proposed to calculate the tool life; from the time required to create a part, equation (6) is obtained

$$tp = tnp + tc + \frac{Nah.trf}{N}, \qquad (6)$$

by replacing the cutting time and the number of tools according to the cutting speed, the ratio between the production time and the speed is obtained. Therefore, the maximum production speed must be found to reduce the time it takes to manufacture a part, so equation (7) is obtained.

$$Vmp = V1.(\frac{n}{1-n}.\frac{T1}{trf})^n. \qquad (7)$$

3. Results and Discussion

In order to evaluate the manufacturing costs of the parts, parameters such as progress were measured, where the effects on the development of the process can be observed. Figure 2 shows the cutting speed required for the selected materials, and it can be seen that given the hardness and ease of chip removal characteristics, carbon steel parts require higher speeds to obtain the desired final finishes, working in a speed range between 28 m/min and 45 m/min to obtain the maximum production required.

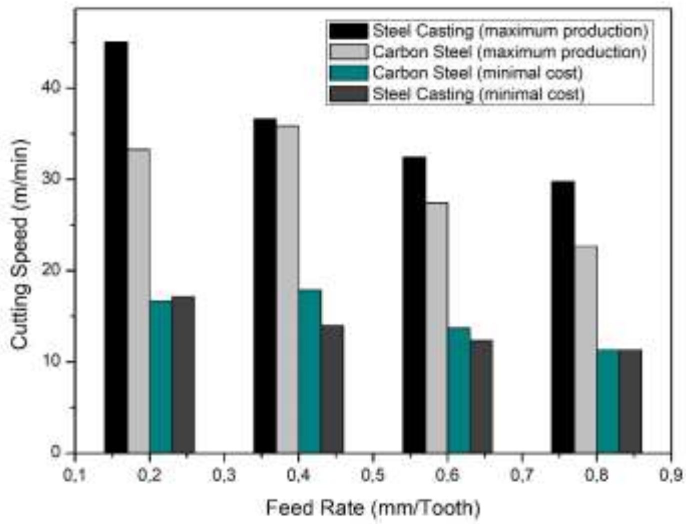

Figure 2.Cutting speed of carbon steel and steel cast iron respect the feed rate.

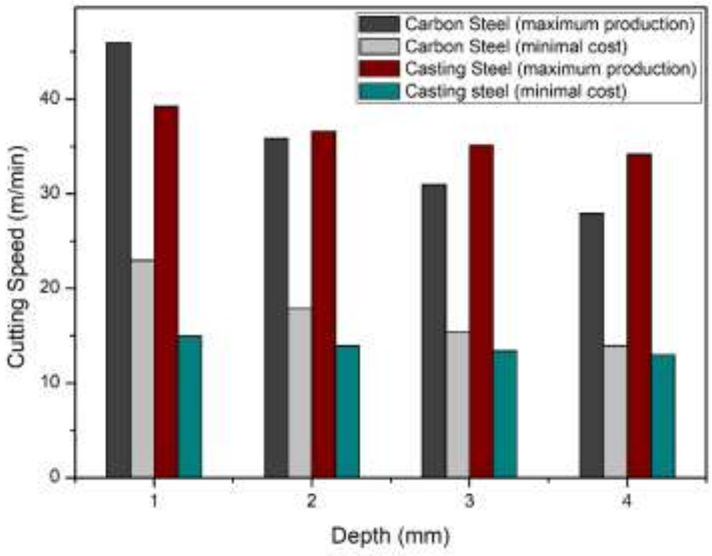

Figure 3.Cutting speed of carbon steel and steel cast iron respect the variation of depth.

Due to the low machining capacity of cast iron, it is not possible to handle high speeds in the process since this has a direct effect on the finish of the material, generating small incrustations, due to the work to which they are to be subjected they give way to mechanical failures in the final work structure. Figure 3 shows the behavior of the process by varying the depth of cut, showing that the lower speeds must be used for the cast irons in the process arrangement to generate parts at minimum cost, because as a result the parts will have fewer imperfections since the working conditions are ideal.

Since the objective of this work is to perform an economic analysis, an important parameter to define is the cost of the manufacturing time per piece that each material has. Figure 4 shows the performance of the two materials used, where a stable yield for the production cost of carbon steels can be observed, showing a variation of 18.5% in manufacturing costs as the progress is varied. On the other hand, in the case of cast iron, there is a significant variation in costs for parts manufactured with a feed rate of 0.2mm/Tooth and 0.8mm/Tooth due to the working conditions employed, because the resources used for the devastation of the outermost layers of the material are greater to obtain a final finish of the desired material.

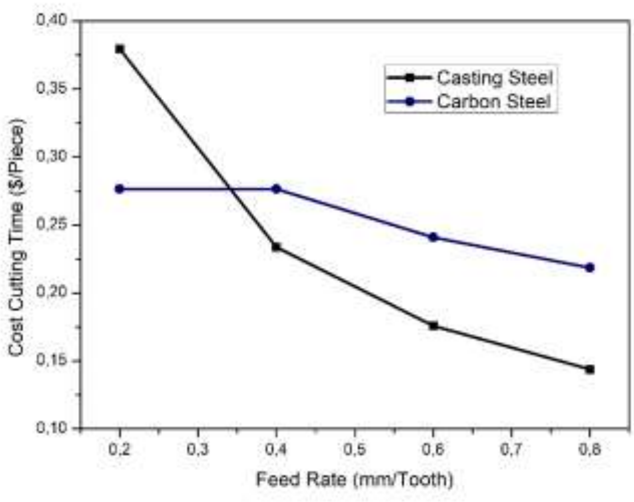

Figure 4.cost of cutting time by material respect the variation of the feed rate.

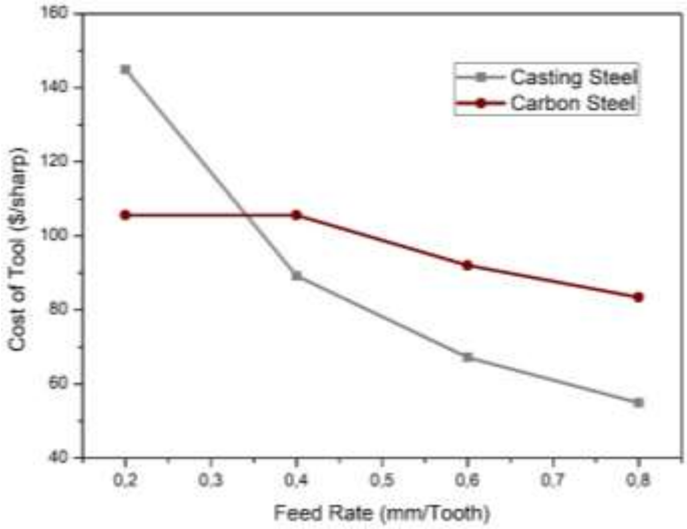

Figure 5. Cost of tool respect the feed rate variation.

Figure 5 shows the cost of the cutting tools used to manufacture 1000 pieces of different materials, which shows a 60% cost reduction for cast iron, due to the fact that the operating conditions for 0.2mm/tooth advances present a high cost due to the characteristics of the material on its surface.

Figure 6 shows the different performances in the cutting time by varying the feed and depth parameters for the materials used in this study. In Figures 6A and 6B we can see the significant increase in time for carbon steel and cast ironsteel parts of 40.9% and 12.3% respectively, due to the easy machinability of the materials and their operating ranges to obtain better final finishes. Figure 6C and 6D show the behavior of the cutting time with respect to the variation in the process feed rate, showing that carbon steels have a constant machinability for feed rates between 0.2 mm/tooth and 0.45 mm/tooth, using a long time due to the hardness of these materials in the outer layers due to the heat treatments to which they are subjected. In the case of cast iron, there has been a downward trend in working time as the progress made has been increasing, allowing a 62% decrease in this resource to be observed.

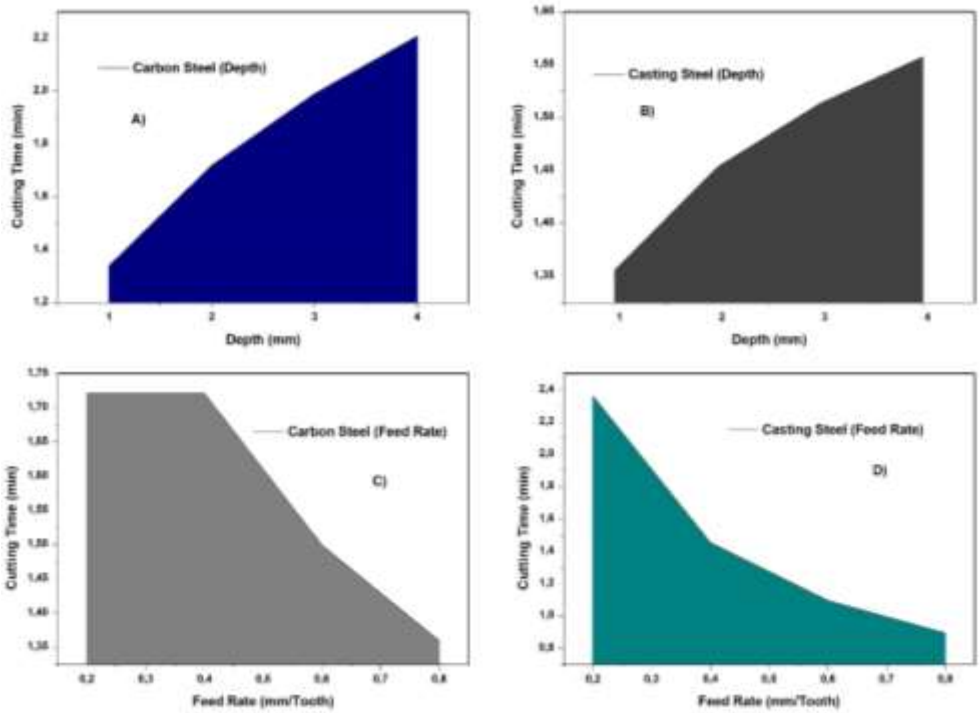

Figure 6. Cutting time performance respect the variation of feedrate and depth.

4. Conclusions

It can be concluded from this study that operating conditions such as changes in feed rate and depth directly affect operating ranges and part manufacturing costs. The necessary manufacturing resources are increased as the depth increases due to the devastation required to obtain the dimensions and finishes of the final part. On the other hand, by increasing the advances, resources are saved in cutting times, but the tooling costs for both materials increase, presenting a technological advantage for carbon steels since their cost does not vary significantly as much as the cast irons in the different cutting ranges. This work allowed us to observe that the manufacturing costs of pieces that present hardness in their surface increase, given that the finishes are presented in small cutting ranges.

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