STUDY OF SHORT-TERM MACHINABILITY TESTS FOR THE SAE 12L14 FREE-CUTTING STEEL

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Abstract. *This work was carried out aiming to evaluate the machinability of ABNT 12L14 steel through short-term tests. The machinability was assessed in a variable cutting speed test , using the destruction of the cutting edge as life criteria. Obtained results were used to determinate the Taylor´s equation for the tested steel and the equation found was compared to the one previously obtained through the long term (wear rate) test. The resulting curves showed good agreement, with a close to 1 correlation coefficient, proving the value of the short-term test as a machining evaluation tool.*

Keywords*: Machinability, Short-term test, Cutting speed, Tool life, High-speed steel, ABNT 12L14 Steel.*

1. Introduction

According to Mill and Redford, 1983, machinability is an index that compares how difficult (or easy) it is to machining a material. This characteristic can be found through a variable called machinability criterion. As reminded by several authors (Ferraresi, 1970, Stemmer, 1995, Diniz, 1999) the principal criteria are related to the efforts observed in machining, superficial roughness and tool life time.

The determination of the machinability of materials should be done carefully, because the materials can have an excellent machinability related to a determinate criterion, but a very low one related to another.

By the economical point of view it is interesting to establish test methods that allows the determination of a material machinability in a quick and precision way, because the machining process responds to a significant part of the products final cost.

It’s important to remark that the machinability index of a material is not only dependent of the material’s characteristics but also the machining conditions. This way, the machinability rank defined for a particular set-up of conditions can be changed in different conditions.

The machinability of a material can be obtained through different kinds of tests. These tests are used to obtain a relation between materials, cut conditions, tools, or even cutting fluids, showing which one has the best performance during the machining, using the parameter in which are interested, and the results obtained through on test doesn’t necessarily agree with the ones obtained through the others.

The machinability assays are divided in two basic categories or groups (the ones who require machining and the ones who not), with sub-divisions among these.

The first one, make a distinction between ranking tests, which indicates the relative machinability between two or more pairs of tool-piece for specific cutting conditions, and, the absolute tests, who indicates the machinability of two or more pairs of tool-piece for a range of cutting conditions. Another distinction is done between the short-term and the long-term machinability tests.

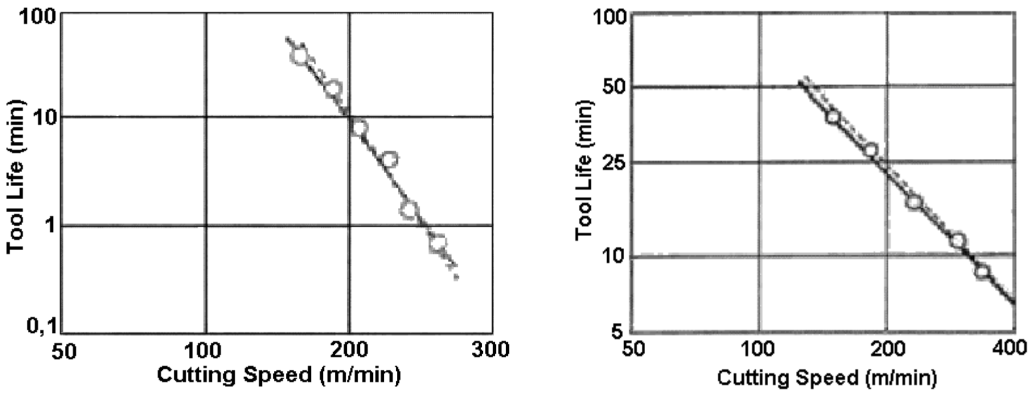
The ranking tests are very used, especially in industries, where quick and cheep decisions are needed. Though, this test reports two big disadvantages, which are: they can't provide quantitative relationships, and they are dependent of the results of the cut conditions, and there is no guarantee that the classification will remain the same if some parameters are change.

The short-term test can be divided in those who need machining, and those who doesn't, and in ranking and absolute. The long-term tests are always absolute.

Between the absolute assays, the most usual, and which provides most trustfully results is the tool wear rate test, which consist in the machining of workpieces, with periodic stops to measure the tool flank wear. This procedure is repeated until the tool's life criterion is reached, and should be realized at least two times for each cutting speed. This test aims the obtain the Taylor equation for the tested material. In this way, the obtained results are valid for all the studied conditions. The disadvantages of using this test are the high time, material and tool consumption.

This way, the use of absolute short-term machinability tests became interesting. The most used are the cutting speed progressive and discrete increment. The former is carried-out through the machining of a test-bodie with progressive increase of the cutting speed, for the external cylindrical turning. Its objective is the determination of the Taylor´s curve constants. Figure 1 (a) shows obtained results by the progressive increment assays.

According to Kiang and Barrow´s methodology (apud Mills and Redford, 1983), the cutting speed discrete increment, was developed to surpass the difficulties found in the conic turning and the cutting speed progressive increment tests, it can be done in NC machines, that doesn't allow cutting speed acceleration. This is achieved by machining with a discreet increment of the rotation of the lathe. Figure 1 (b) shows obtained results by the discreet increment test.



(a) (b)

Figure 1. Comparison between results obtained through the tool wear rate test and (a) cutting speed progressive increment and (b) cutting speed discrete increment [Mills and Redford, 1983].

Evangelista, 2001, found extremely good correlation between the long-term and the discrete increment short term machining test for a SAE 1045 steel with microstructure and properties controlled to suit AFNOR standards. However, the results for a 1040 steel presented a poor relationship for the formerly mentioned tests.

2. Experimental Procedure

2.1. Studied Material

The studied material is a laminated SAE 12L14 steel, resulfurized and rephosphorized. Because of the percentual composition of lead, sulphur and phosphorous, this material is considered a free-cutting steel. Both the microstructure and the material properties were controlled to suit AFNOR standards. Table 1 shows the chemical composition of the tested steel.

Table 1. SAE 12L14 composition.

SAE/AISI/ABNT	C max.	Si max.	Mn	P	S	Pb
12L14	0,15	0,05	0,85 - 1,15	0,04 - 0,09	0,26 - 0,35	0,15 - 0,35

2.2. Cutting parameters

Table 2 shows the high-speed cutting tool geometry according AFNOR NF A03-654. The cutting parameters are shown on table 3.

Table 2. Tool geometry.

Tool Type	Material	Norm	Dimension (mm)	Rake Angle	Clearance Angle	Inclination Angle	Approach Angle	Nose Angle
Grinded	M2 HSS	AFNOR A03 654	12x12x121	25°	8°	0°	75°	90°

Table 3. Cutting conditions.

Feed [mm/rev]	0,1
Depth of cut [mm]	1
V_0 [m/min]	46

2.3. Short-term Tests

The french standards AFNOR NF A03-654, suggest a short duration assay, with cylindrical turning. The objective of this test is to drive the tool to destruction through incremental increase of cutting speed during the machining. For this, an initial cutting speed (V_0), and three accelerations must be defined. The V_0 is defined considering both the carbon content and the hardness of the material.

The determination of each cutting speed is done according to equation 1.

$$V_N = V_{N-1} + 0{,}5 \cdot V_0 \quad (1)$$

The determination of the minimal acceleration used on the tests was done through the uniform accelerated motion equation.

$$V_F = V_0 + a \cdot t \quad (2)$$

Where V_f is the final cutting speed registered when the tool nose destruction occurs, and a is the acceleration.

To obtain the acceleration, the machining time for the body proof length is needed. It can be obtained through calculation, or through the program execution (without workpiece).

The two remaining accelerations, to complete the assay, will be taken in relation to the minimal acceleration. The chosen relation is 50% for the second acceleration and 100% for the third. The mathematical expression for this is done through equation 3:

$$a_N = a_{N-1} + 0{,}5 \cdot a_0 \quad (3)$$

Once the parameters were chosen, the turning of three proof bodies for each acceleration is carried out, and the information is organized on a table. After the test conclusion, it will be possible to build a bi-logaritmical graphic of *t+Vo/a vs a*, using the medium values obtained by the burn of the tool. The constants *n* and *C* of the Taylor´s equation are determined by the reading of two points in the graphic, and replace those values in the equation indicated by the AFNOR for this of test (equation 4):

$$\log\left[t_m + \left(\frac{V_0}{a}\right)\right] = \left[\left(\frac{n}{n+1}\right) \cdot \left[\left(\frac{\log C}{n}\right) - \log\left(\frac{n}{n+1}\right)\right]\right] - \left(\frac{\log a}{n+1}\right) \quad (4)$$

Therefore, two assays with different accelerations are sufficient to define a line and to determinate the n and C values, what permit the obtention of the Taylor equation coefficients *K* and *x*.

$$n = \frac{1}{x} \quad (5)$$

$$C = K^{1/x} \quad (6)$$

3. Results and Discussion

Table 4 and 5 show the cutting speed and tool life obtained for the tested accelerations, and the comparison between the tool lives obtained through Taylor equation for the short and long-term tests, on three different cutting speeds. The long-term test results were obtained from previously carried out tests.

Table 4. Final cutting speed obtained for each used acceleration.

Final V_c [m/min]	t [min]	a [m/min^2]	t + V_c/a [min]
322	10’	25,4	10,85
460	6’23’’	38,1	7,27
598	5’22’’	50,8	6,49

Table 5. Comparison between the tool lives obtained from the short and long-term machinability tests using the respective Taylor equations.

Vc	132	140	150
Long-term	44,70	32,30	22,00
Short-term	45,02	32,50	22,17

The tool life results, for short and long-term tests, are represented on Figure 2, where the coincidence of the two Taylor equations on the cutting speed range used for the long-term test indicates a good agreement between them. Figure three shows the correlation obtained between the results of the two machinability tests. The data representing the long-term test were obtained directly from the previously carried pout tests, while the others came from the application of the Taylor’s equation obtained from short-term tests.

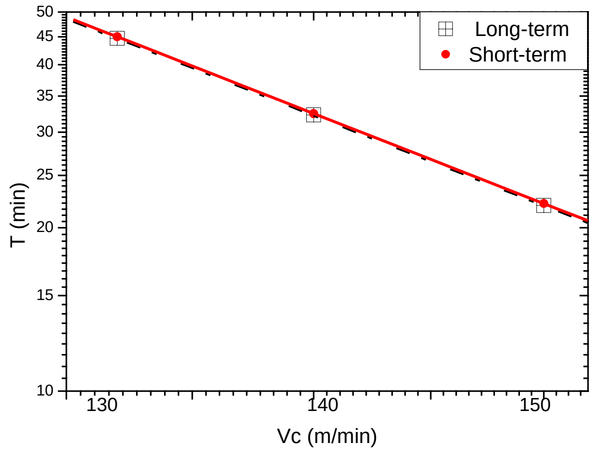


Figure 2. Comparison between Taylor equation obtained through long-term and short-term machinability tests.

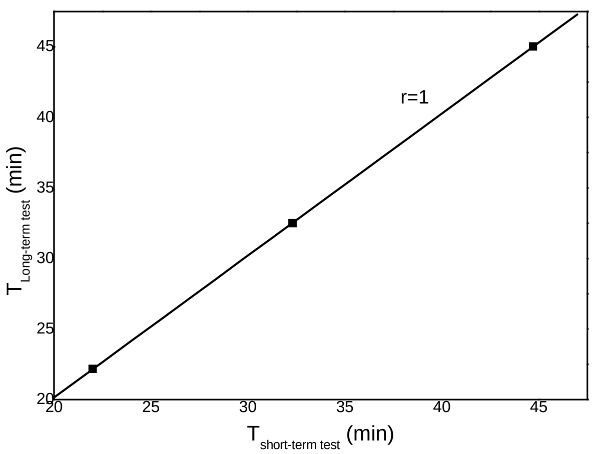


Figure 3. Comparison between tool life obtained using the equations obtained through long-term and short-term machinability tests.

4. Conclusions

The analysis of the obtained data showed good agreement between long and short-term machinability test results. Thus, the short duration assay reached the main objective of this work, which is to present an accurate result for the tool life quickly and with low cost. It shows the possibility of successful replace of the long duration assay for the short duration assay, for the studied material, and for the same conditions adopted in this research.

The studied steel had shown a stable behavior during the experiment, when regarding its lifespan in the long-term test, which make it easier to forecast its tool life according to Taylor´s equation.

The short duration machinability assays, according to the procedures proposed by AFNOR A03-654 norm, have shown its applicability with good results for microstructure controlled steels. However, additional long-term machinability tests must be carried out in order to prove the reliability of the test, and to possibly expand its range of application to other materials.

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