COMPARATIVE STUDY OF THE DRILLING PROCESS FOR VP 50IM AND DIN 1.2711 MOULD STEELS

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Abstract. *The present work aims to compare three steels, VP50IM (40 HRC and 32 HRC) and DIN 1.2711 (40 HRC), commonly employed in die and mould industry. The manufacturing properties were quantified due to their importance in the mould making processes. Such manufacturing steps are normally the most expensive parts in moulds total cost, especially those related to machining and polishing. The drilling process is considered the neck operation in industry. For this study, drilling tests were performed with a determined cutting condition, recommended by the tool manufacturer. To evaluate the drilling performance of these steels, the following tests were realized: Analysis of the flank wear behavior during the cutting path; Evaluation of the axial force and of the torsion moment during the tool life; Evaluation of the chip formation; Metallographic tests to evaluate the influence of microstructure on the machinability.*
Comparing the steel DIN 1.2711 with the steel VP50 IM 40 HRC, the second one presented better machinability according to the criterions: Tool life (twice better); Axial force; Torsion moment and Chip formation. However, the same steel with lower hardness (32HRC) presented a better behavior in the same criterions.

Keywords*: drill, mould industry, cutting condition*

1. Introduction

The present work aims to compare the performance of the steel VP50 IM (40 HRC) in relation to the steel DIN 1.2711 (40 HRC) and with the similar VP50 IM in a lower hardness, 32 HRC. These steel are typically employed in die and mould industry.

As mentioned in Mesquita *et al* (2004), there is a variety of influences that can affect the drilling process, such as: the choice of the cutting parameters, the cutting fluid supply, the tool geometry, the tool life, etc.

For this study, the drilling tests were performed with a determined cutting condition, recommended by the tool manufacturer. To evaluate the drilling performance of these steels, the following tests were realized:

- Analysis of the flank wear behavior during the cutting path;
- Evaluation of the axial force cut and the torsion moment during the tool life;
- Evaluation of the chip formation;

It is also used metallographic tests to evaluate the influence of microstructure on the machinability.

2. Experimental equipment, materials and procedure

The steels used in this work are destined to the manufacturing of injection moulds requiring high mechanical strength and hardness, as mentioned in Mesquita *et al* (2003). According to steel manufacturer, the specimens present the following average chemical composition (table 1):

Table 1. Characteristics of tested steel

Material	Average chemical composition	Normal condition of commercialization
DIN 1.2711	0,55C - 0,7Mn - 0,7Cn - 0,3Mo - 0,7Ni - 0,1V	Benefited
VP50 IM	0,15C - 0,3Mo - 1,55Mn- 0,35S - 3,0Ni - 0,125-1,0Cu-1,0Al	Annealed

It is recommended oil quenching (830/870°C) for steel DIN 1.2711. For steel VP50 IM, it is realized aging at 500°C (air/oil), Kovach *et al* (1969).

The accomplishment of the tests was based on the drilling of the blocks of steel VP50 IM with hardness of 32 and 40 HRC and of steel DIN 1.2711 with hardness of 40 HRC.

Tests of tool life had been carried out in blocks with dimensions of 60x100x400 mm and the axial force and torsion moment evaluation with dimensions of 60x100x50 mm as Fig.1.

Figure 1. Tested blocks

The drilling tests had been carried out in a 5-axes machining center, Hermle C 600 U (11,5 KW), programmable rotation up to 16000 rpm, axes course of x = 600 mm, y = 450 mm and z = 450 mm.

The test-pieces had been fixed with clamps on machine center table as Fig. 2.

Figure 2. Blocks assembly and the respective machining

The used cutting tools were manufactured by Titex Plus (code A3265TFL*8). It was chosen a geometry with helical canals and special sharpening of cutting edge to facilitate the chip flow, allowing cutting stability (figure 3 and table 2). The tests had been carried out without internal coolant.

a.

b.

Figure 3. Geometry used for the tests (tool - a; main edge form- b).

Table 2. Geometry specifications

Diameter [mm]	8
Length [mm]	70
Point angle [°]	118°
Helix angle [°]	30°
Rake angle [°]	- 12°
Incidence angle [°]	6°
Material	Carbide, micrograin (K03)

The fixturing tool support was always set in the same length position, in order to assure the same tool balance for all the situations.

The tools wear had been measured and registered through the software Leica Qwín Pro version 2.40, in images acquired by a stereomicroscope Leica (increase up to 40x), with a camera JVC TKC1380, connected to a personal computer. It was defined a end tool life for a flank wear of VB= 0,2 mm or VBmax= 0,3 mm or until a catastrophic failure occurred.

The wear measurements were carried out in accordance with norm ISO 3685-1977, and with regular time intervals, of one (1) by one (1) minute, for each wear variation and three (3) by three (3) minutes, in the cutting edge stabilization points. The objective of so many measurements was to verify the cutting behavior, by differentiating the wear curves.

The values of the axial force (Fz) and the torsion moment (Mt) had been acquired by a Kistler 9272 piezeletric dynamometer and amplified by a Kistler 5019b multichannel load amplifier. All the tests were performed using inlaid filters of the software acquisition because of the programming easiness; stability independently of the temperature, humidity and precision of components; and the relation cost benefit.

The measurements of axial force and torsion moment were carried out during the tool life tests. The first measurement for each cutting tool was carried out in the beginning of each experiment.

The chip shapes had been collected during the tests. The chips considered better were the ones which had the better flow along the helical drill flute and were less oxidized.

For the test capability, each cutting condition was three times replicated. The cutting parameters were supplied by the Titex Plus and the literature as Tab. 3.

Table 3. Applied cutting parameters

Cutting speed (vc) [m/min]	50
Feed per revolution [mm/rot.]	0,1
Hole depth [mm]	25
Refrigeration	External, emulsion (Vasco 1000, 9%)

3. Results

3.1. Tool life tests

Figure 4 shows the tool life results in terms of the flank wear versus the machined length. For steel VP50 IM (32 HRC), the tests had been interrupted due to material limitation for the experiments (tool life of 35 m). It was shown that this steel has better machinability than the others, as expected.

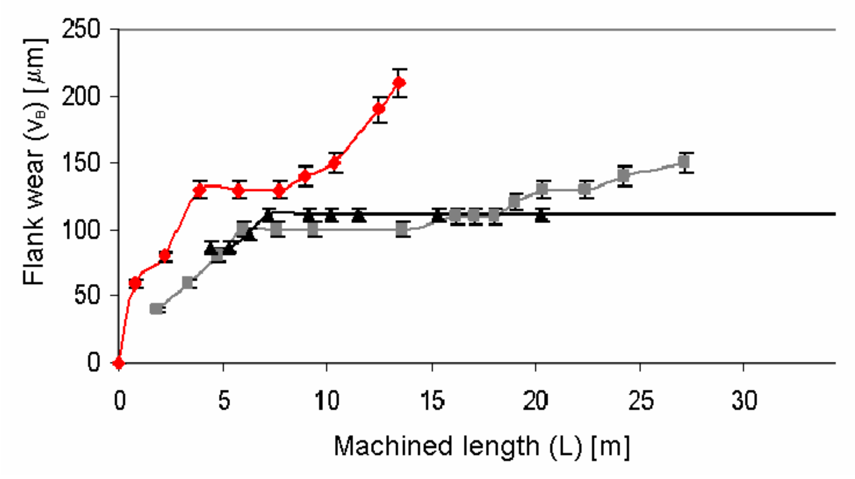
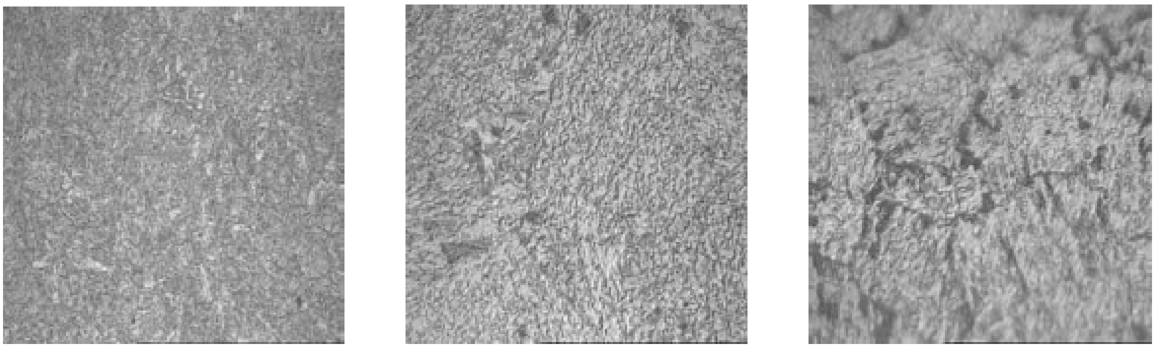


Figure 4. Flank wear in function of the machined length

The machinability of the steel VP50 IM (40 HRC) in relation to the steel DIN 1.2711 was proven better. This behavior can be characterized by the more number of carbides in the steel DIN 1.2711 microstructure as Fig. 5 and, as induced in table 1, by the greater sulphur concentration on the steel VP50 IM.



DIN 1.2711 (40 HRC)
VP50 IM (32 HRC)
VP50 IM (40 HRC)

Figure 5. Microstructure of the test-materials (1000 x)

All tests presents a progressive flank wear greater than corner wear, which characterizes a good choice of tip tool geometry, as Fig. 6.

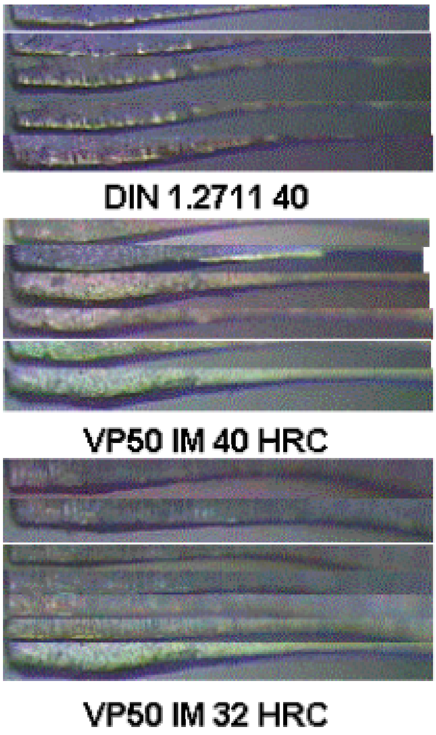


Figure 6. Flank wear progress for test-materials

3.2. Axial Force and Torsion Moment Measurements

Figures 7 and 8 show the evolution of axial force and torsion moment during the tool life tests. It was observed that the axial force and the torsion moment are higher when machining DIN 1.2711, proving its poor machinability.

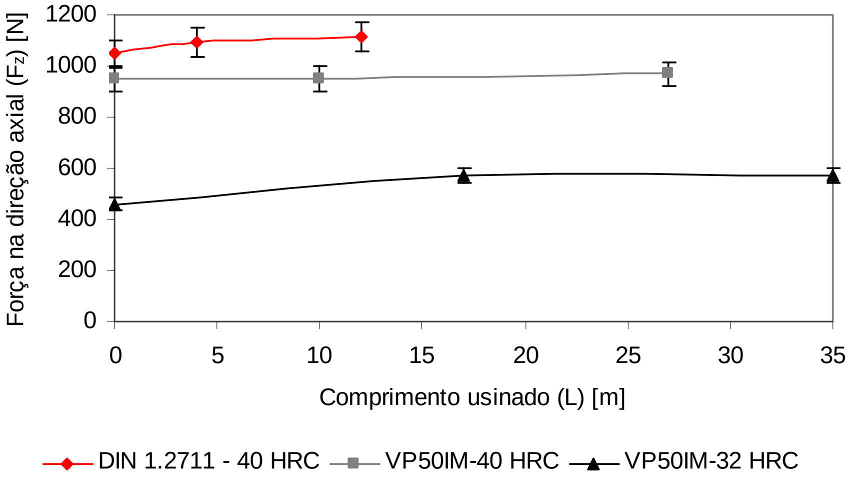


Figure 7. Axial force evolution with cutting tool wear

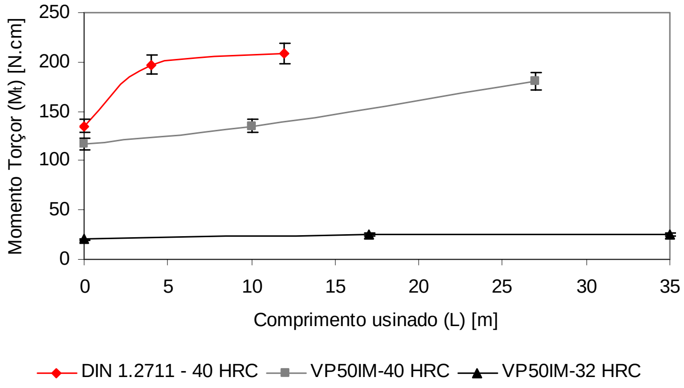


Figure 8. Torsion moment evolution with cutting tool

3.3. Evaluation of the chip formation

The figure 9 shows that the both materials presented identical chip characteristics. However, the steel DIN 1.2711 presents a higher oxidized and fragmented chips percentage, characterizing high temperature in the cutting region, as well as a strong process vibration, what influences directly on the cutting tool life.

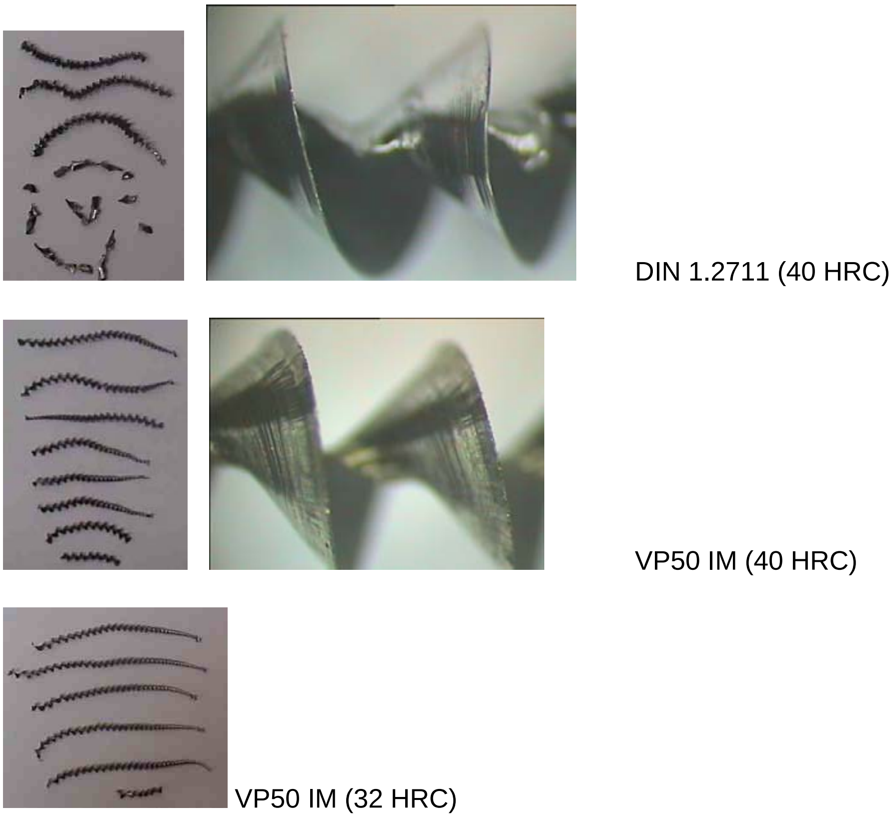


Figure 9. Analysis of chip formation for the tested materials

4. Conclusions

As criterion for comparison of machinability, it was evaluated the flank wear behavior for a cutting parameters combination, the axial force evolution and the torsion moment during the tool life and the chip formation for the materials.

The following conclusions can be formulated:

1. The cutting tool life for steel VP50 IM (32 HRC) is significantly superior than the same material with higher hardness (40 HRC). In the same experiment conditions, the tool life for steel VP50 IM (32 HRC) presented low flank wear, after 35 m machined lenght, while the material with superior hardness (40 HRC) presented a machined lenght of 27 m.
2. The cutting tool life for steel VP50 IM (40 HRC) is significantly higher in comparison to steel DIN 1.2711 (40 HRC). This behavior can be credited to the more number of carbides in the microstructure of the steel DIN 1.2711 and the higher sulphur concentration in the steel VP50 IM.
3. The measured axial force for steel VP50 IM (32 HRC) was around 520 N and for VP50 IM (40 HRC) approximately 970 N. While for steel DIN 1.2711, this force was approximately 1100 N.
4. The same behavior was observed for the torsion moment. For DIN 1.2711, this moment was approximately 200 N.cm, significantly higher than the one for VP50 IM (40 HRC), 180 N.cm. For VP50 IM (32 HRC), the torsion moment was approximately 35 N.cm.
5. The chip shape was quite similar for the two hardness of the steel VP50 IM. The difference was more significant in relation to the steel DIN 1.2711, where the chips observed were more oxidized and with a large variation in their size, characterizing a strong process vibration.

5. References

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6. Responsibility notice

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