STUDY OF THE DRILLING PROCESS WITH HSS TWIST DRILLS

Éd Claudio Bordinassi
Instituto Mauá de Tecnologia – Mechanical Engineering Department – Praça Mauá, 1 – São Caetano do Sul – SP
ecb@maua.br

Marco Stipkovic Filho
Laboratório de Engenharia de Fabricação – Dept. de Engenharia Mecatrônica e de Sistemas Mecânicos - Escola Politécnica da Universidade de São Paulo – Av. Prof. Mello Moraes, 2231 – 05508.900 S. Paulo – SP. kovic@osite.com.br

Gilmar Ferreira Batalha
Laboratório de Engenharia de Fabricação – Dept. de Engenharia Mecatrônica e de Sistemas Mecânicos - Escola Politécnica da Universidade de São Paulo – Av. Prof. Mello Moraes, 2231 – 05508.900 S. Paulo – SP. gfbatalh@usp.br

Abstract. *This work aims to study the drilling process of steels with high-speed steel twist drills. The experimental procedure was carried out by the measurements of the drilling cutting forces, and for this, a strain gage dynamometer was constructed. The results of the experiments with variations of cut speed and feed rate to the ABNT 1020 and 4320 steels with conical and cross-sharpened high-speed steel twist drills are presented. The wear and the cutting forces against the number of holes for the ABNT 1040 and 5140 steel also are presented.*

Keywords. *Twist drills, drilling, hole, dynamometer, strain gage, machining, high-speed steel.*

1. Introduction

Hole producing is one of the most used processes in the manufacturing industry [1-2]. The great majority of manufactured parts of any industry type have at least a hole, and only a very small number of those parts carry already integrated holes in the raw workpiece. A hole making procedure seems at first sight to be a simple task. However, there are a lot of tools and process options available for this operation. As pointed by Halewi & Weil 1995 [1], it should be considered the technical specification for the required holes, such as material hardness, machinability, solid/cored, open/closed/blind, hole length and diameter, diameter tolerance, surface finish, geometric tolerance (straightness, roundness, concentricity, circular runout), location tolerance, drill marks, core hole details and special features (slot, thread, chamfer, radius, etc). Regarding the tools employed in hole making, for some tools the process is dominated by the tool dimension (Ex.: twist drill, insert drills and reamers) and for some others it is dominated by the machine dimension (Ex.: boring and milling tools). Each one of these tools has their capabilities and limitations. Some of these processes could be used to open a trough hole or other only used to enlarge or improve existing holes [2-3]. In this sense, holes have to be drilled or increased through the drilling process and this operation in general, it's done as one of the last ones executed in the pieces, when an amount of time and money already went expenses in to execution of these [3], having to offer great reliability. Figure 1 compares drilling processes with some machining processes in terms of cutting time and number of operations.

This work concentrates its attention in hole machining on ABNT 1020 and 4320 workpiece processed by drilling with high speed steel twist drills. A spoke-wheel type spindle dynamometer was built to monitor the tangential and thrust components of the drilling forces. In order to perform cutting forces measurements during the drilling operation on a lathe. As process variable to be evaluated by dynamometric measurements it was took the drill point sharpening geometry, workpiece materials differences as well as cutting speed and feed rate effects.

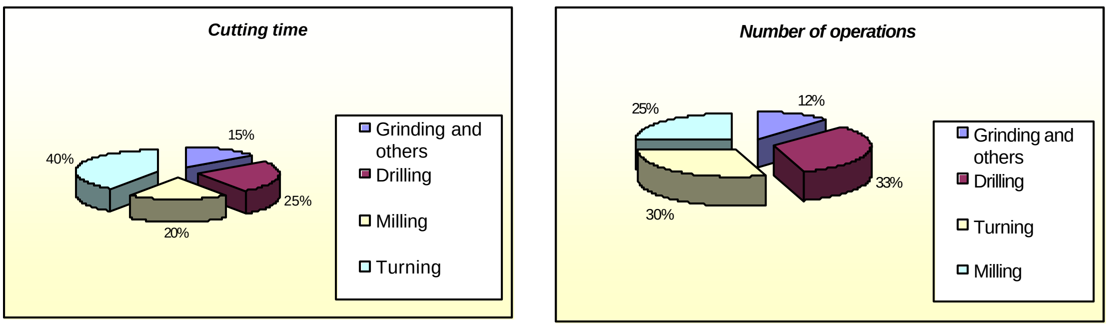

Figure 1 [3] – Processes with regard to the cutting time and number of operations

2. Data acquisition

The main elements of the data acquisition system are illustrated in figure (2).

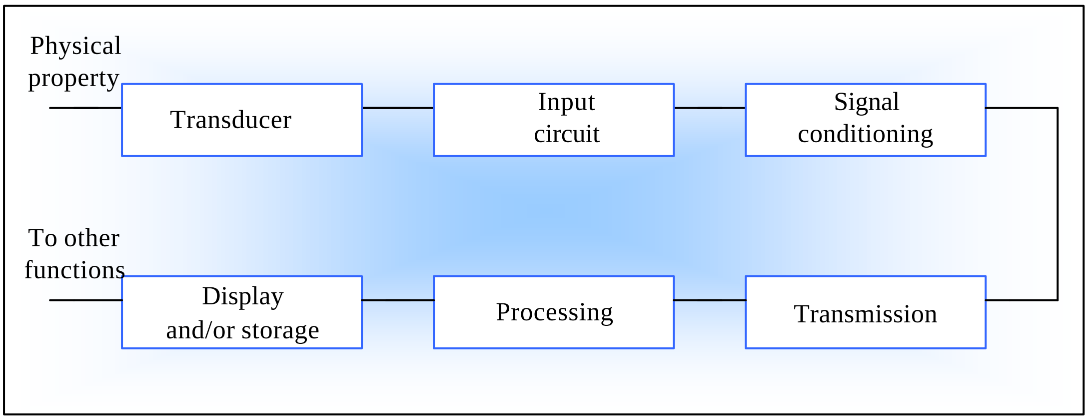

Figure 2 [4] – General data acquisition system

The strain gage based transducer (figure 2) was built, calibrated and used during all the experiments. It is based on one previously proposed by DAAR [2]. The drilling dynamometer built for this work includes some changes in the instrumentation and signal acquisition system. As construction goal the developed drilling dynamometer was designed in order to allow for the measurement of torque and thrust components of the drilling force.

The "strain gage", actually is the more versatile deformation instrument of measurement for most of the cases, for having reduced size, base of measure of many lengths, great precision and sensibility, facilitate to reading in distance and applications in static and dynamic measurements [4-5], and for these reasons it was used in the instrumentation of the dynamometer.

The built dynamometer can be observed in the figure 3. It consists of a stem to fix in the machine, where the transducer is assembled with the instrumented ribs, with a pin to support the mandril. In this pin there is a cover for protection of the equipment. The ribs were instrumented to form a complete Wheatstone bridge, in such a way that the reading of a channel doesn't affect the other, during the acquisition.

The instrument was calibrated, being obtained two curves that were used to transform the values of micro-strains obtained during the process respectively in force and torque values.

A hardware (System ST5000) and a software (AQUISI Mi–V0.26) developed by Spectra Tecnologia, were used for the further tasks after the transducer (fig. 2), being obtained graphics records of the drilling forces variations along the time. Through available statistical tools offered by the software, it was possible to establish values for each region of the signal, as well as an averaged value of the forces along the time. An example of signal record can be observed in the figure 4, for drilling of an ABNT 1020 workpiece.

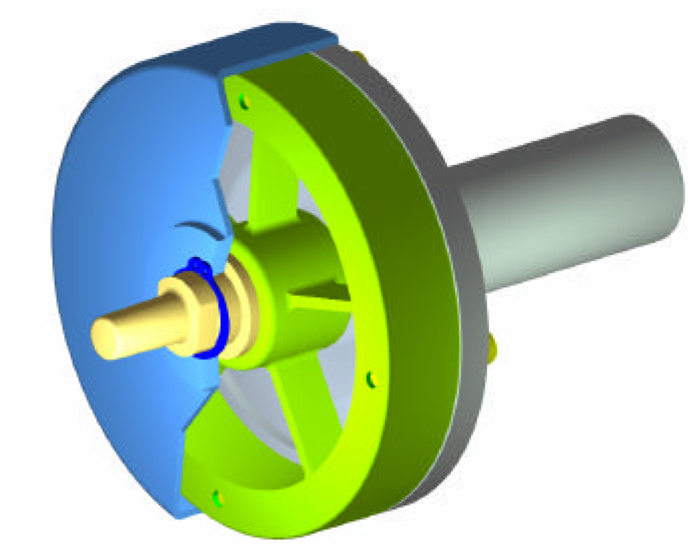

Figure 3 – The drilling dynamometer

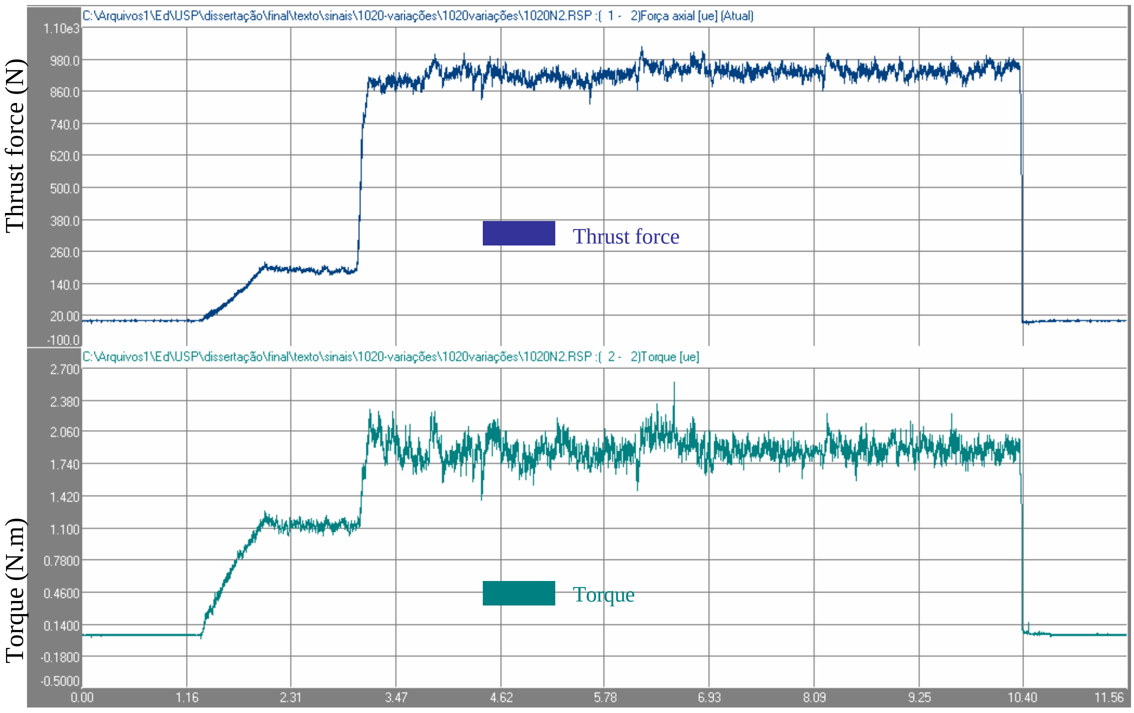

Figure 4 – Signal recorded during the drilling of the ABNT 1020 steel workpiece.

3. Experimental procedure

3.1 Drilling dynamometer mounting

The built drilling dynamometer was fixed in a CNC lathe Traub, model TND 360 with command system TX-8, for the execution of the experiments, and it can be viewed on the figure (5).

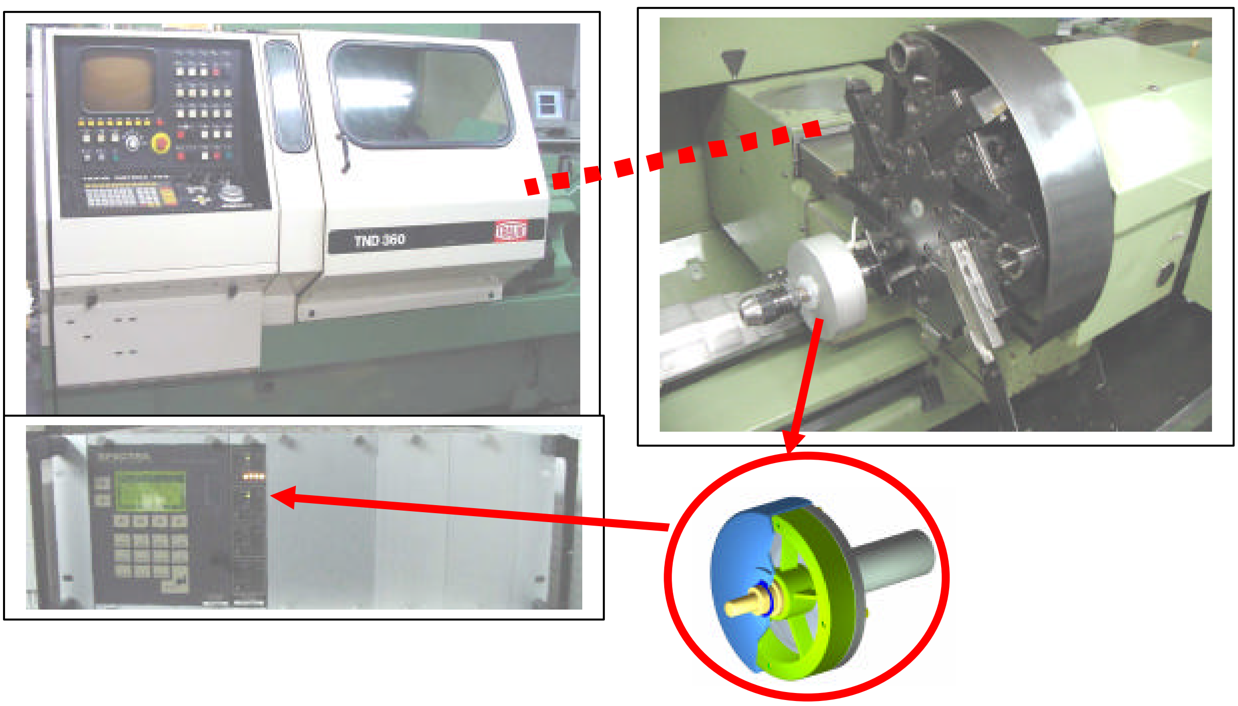

Figure 5 – The drilling dynamometer mounted on the TRAUB TND 360 NC lathe.

3.2 Experimental Material

An experimental plan was developed in order to verify the performance of the built drilling dynamometer. The experiments regarded different workpiece materials, under different drill geometry sharpening, as well as feed rate and cut speed variations. All the used drills were of the type N, P-5, high speed steel ASTM A-600 M2. The experimental planning included the following investigations:

3.2.1 Drilling forces evaluation vs. sharpening conditions

Workpiece: **ABNT 1020 steel, cold rolled**
Tool: ƒ **6mm High speed steel Drill, conical sharpened DIN 338, and cross sharpened - NAS 907**
Drilling parameters:

- With feed rate of 0.109 mm/revolution:
  Cut speeds: 10, 15, 20, 25, 30 and 35 m/min;
- With cut speed of 25 m/min:
  Feed rates: 0.05, 0.1, 0.15, 0.2 and 0.25 mm/revolution;

Workpiece: **ABNT 4320 steel, hot rolled**
Tool: ƒ 6 **mm High speed steel Drill, conical sharpened - DIN 338**
Drilling parameters:

- With feed rate of 0.109 mm/revolution:
  Cut speeds: 10, 15, 20, 25, 30 and 35 m/min;
- With cut speed of 25 m/min:
  Feed rates: 0.05, 0.1, 0.15, 0.2 and 0.25 mm/revolution;

3.2.2 Drilling forces evaluation vs. wear evolution

It was made measurements also with constant feed rate and cut speed, observing the wear in the main cut edges of the drill. The parameters and materials used in the measurements were:

Workpiece: **ABNT 1040 steel, cold rolled**
Tool: ƒ 6 **(Drill (6mm, conical sharpened - DIN 338)**
Drilling parameters: V_c = 25 m/min; f = 0.109 mm/revolution

Workpiece: **ABNT 5140 steel, hot rolled, tempered and grinded workpiece**
Tool: ƒ 6 **(Drill (6mm, conical sharpened - DIN 338)**
Drilling parameters: V_c = 20 m/min; f = 0.109 mm/revolution

Circa more than 700 holes were machined during the measurements, cut fluid was used in abundance and composed by 5% mineral oil and water. The wear measurements were carried out using a microscope JENA 3313 (Figure 6).

Figure 6. Wear measurements of the drills using a microscope JENA 3313.

4. EXPERIMENTAL RESULTS

The experimental results obtained under feed rate and cut speed variations, using twist drills with conical and cross sharpened, for the ABNT 1020 steel, can be viewed in Figures (7) and (8):

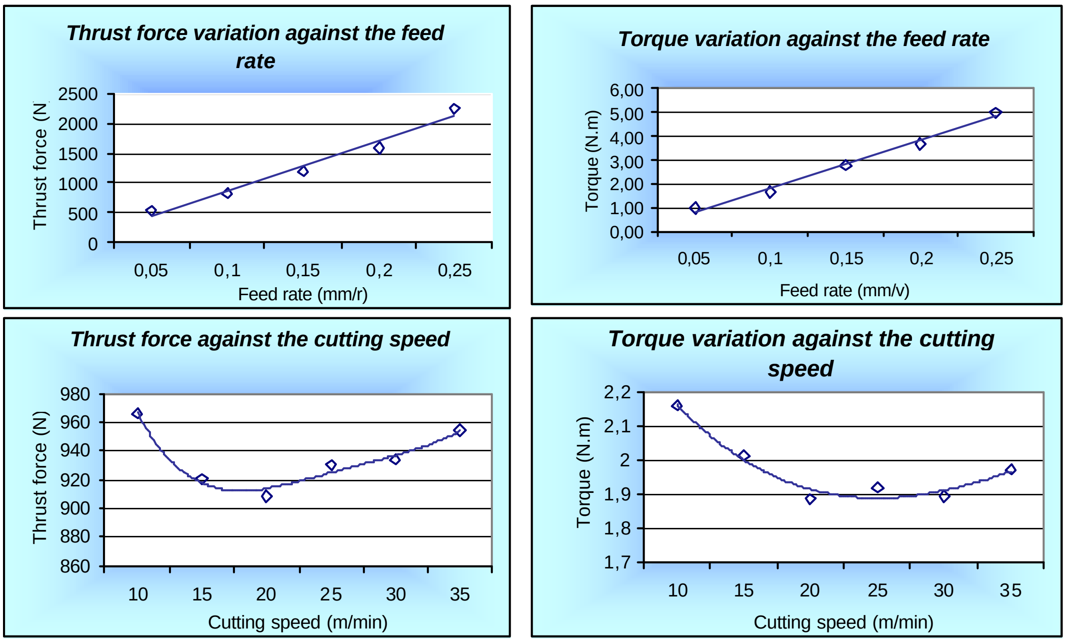

Figure 7 – Torque and Thrust forces variations versus feed rate and cutting speed for drilling ABNT 1020 steel with conical sharpened HSS drills.

The values found in the graphs above, show that, with the variations in the feed rate and cut speed, happen changes in the cutting forces. The variation in the feed rate can be justified by the change in the amount of material to be removed by the drill, doing with that the cutting forces increase. Already the variations of cutting forces found with the changes of cutting speed, suggest that with the increase or decrease of this, the conditions of the process vary and consequently they happen changes in the temperature, and in the specific cutting pressure, doing with that happen changes in the couple part/tool, where the cutting forces begin with a certain value and soon after they decrease. This decrease also can be justified by the change in the hardness of the material [6]. The minimum value found was around 20m/min.

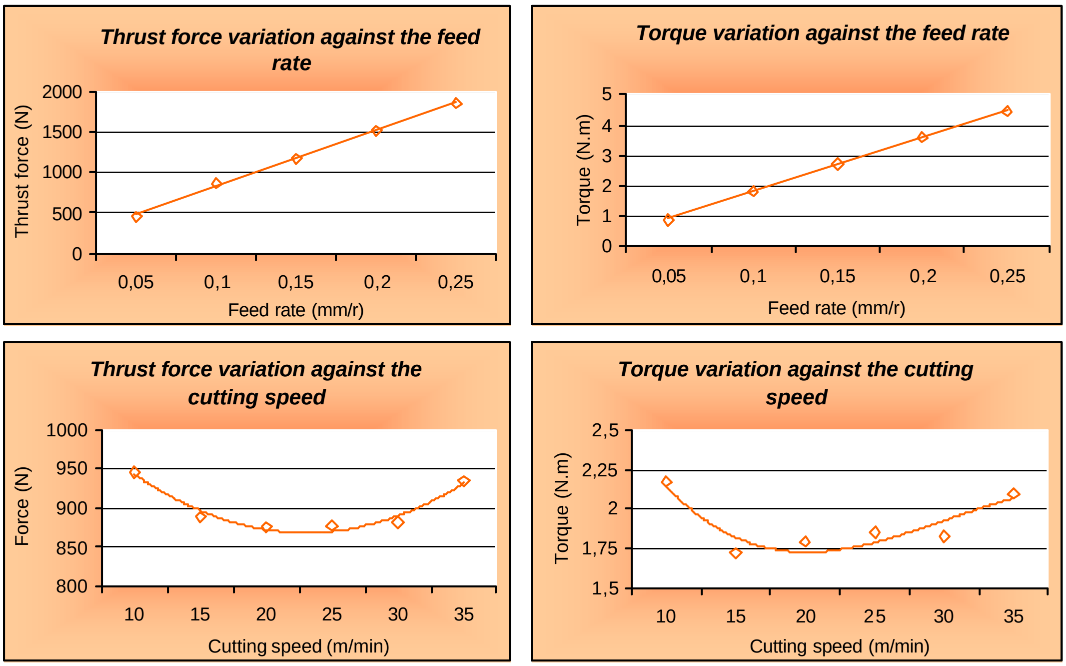

Figure 8–Torque and thrust forces variations versus feed rate and cutting speed for drilling ABNT 1020 steel with cross sharpened HSS drills.

It is also important to remember that the above plots shows variations in the cutting forces, not bigger than 10 %.

The cutting forces variations for the drill with conical and cross sharpened, had the same behavior, even so with different values. In all measurements, the cross sharpened drill presented smaller solicitations (circa 4 to 6 % less). With the increase of the feed rate, this difference arrived to 12% for torque and 20% for thrust force. This difference shows that the decrease of the chisel edge of cut causes smaller cutting forces during high feed rates, mainly the thrust force, where the traverse edge used to have larger influence.

The refrigeration was also shown extremely important during the measurements, and with the increase of the depth of the holes in all the materials, it was noticed an increase in the cutting forces. In the holes where high feed rates were used (0.25mm/ revolution), it was noticed sticking of the chips in drill rake surfaces, due to the high temperatures developed there.

In the figure 9, it can be observed the values found during the drilling of the ABNT 4320 steel.

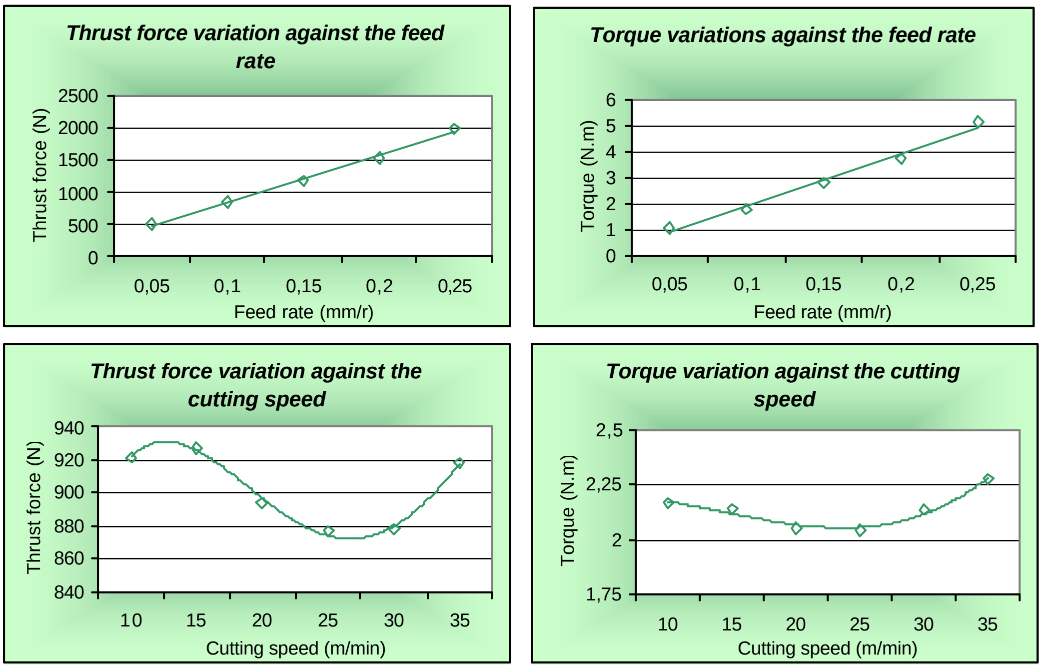

Figure 9. Torque and Thrust forces variations versus feed rate and cutting speed for drilling ABNT 4320 steel with conical sharpened HSS drills.

For the drilling of the ABNT 4320 steel, the observations regarding the variations of the measured cutting forces were almost same of the ABNT 1020 steel, even so it was verified that with the increase of the depth of the hole, the cutting forces had a larger trend to increase, due to the largest cutting stength that this material offers, and in this case, probably, a more efficient refrigeration, as for example refrigeration by internal channels in the drill, could attenuate this. In the drilling executed in the lathe, there is a less efficient refrigeration than in another machines, as in a Verical Machining Center, for example, where the tendency of the cut fluid, is to arrive at the botton of the hole by gravity. In the case of the lathe, as the depth of the hole increases, the refrigeration becomes more and more faulty, because don't exist many favorable factors to its flow into the hole, and a lot of times this can be dispersed before reaching its objective that is the interface between the material and the tool, therefore causing a smaller tool life, as well as causing the wear to happen in an accentuated way.

In figure 10 it can be observed the measured data collected for the drilling of the ABNT 5140 steel, as well as a photo of the drill after having machined 165 holes. It is noted that the cutting forces also suffered alterations along the drill life, so much for the torque, as for the thrust force. In the first region, it is noticed a loading increase, and that is justified, for the beginning of the adhesion of particles in the rake surface of the drill and beginning of the wear in the main edges [7]. After the adhesion, there is a good condition for the chips exit, due to the increase of the rake angle, doing with the ones that the cutting forces decrease. To proceed, the deterioration of the main edges of cut happens, and together, an increase in the cutting forces, that continued to grow until the end of life of the drill.

The wear values placed in the graph, refer to the average of the maximum wear of the main edges of cut. The wear was practically constant until the hole of number 70, where it happened an accentuated elevation, behaving in similar way to the measuremets accomplished by Lee [8]. This fact needs to be analyzed better, even so it’s probably due to changes in the structure of the material of the drill, causing its accelerated deterioration. It was accepted that the drill would have reached to it’s life end, due to the high wear found in the edges and because the process become unstable, as the drilling depth increased, evidencing its brief collapse.

For the drilling of the ABNT 1040 steel (Figure 11), the behavior of the analyzed data was similar to the ABNT 5140 steel. There was an increase in the cutting forces, and a decrease that showed a small increase trend during all the measurements. For this material it was opted to end the measurements after the drill had executed more than 500 holes, and there was not significant indication of increase in the values found for the wear, just indicating a small increase along the main edge of cut.

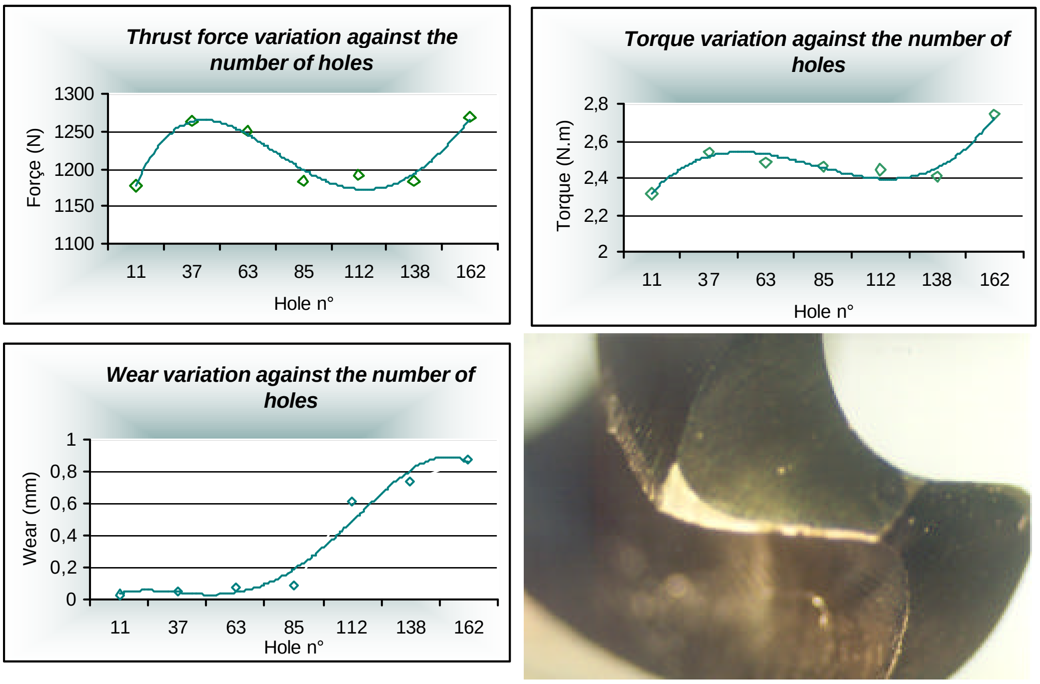

Figure 10 – Variation of thrust force, torque and wear for the drilling of the ABNT 5140 steel with conical sharpened.

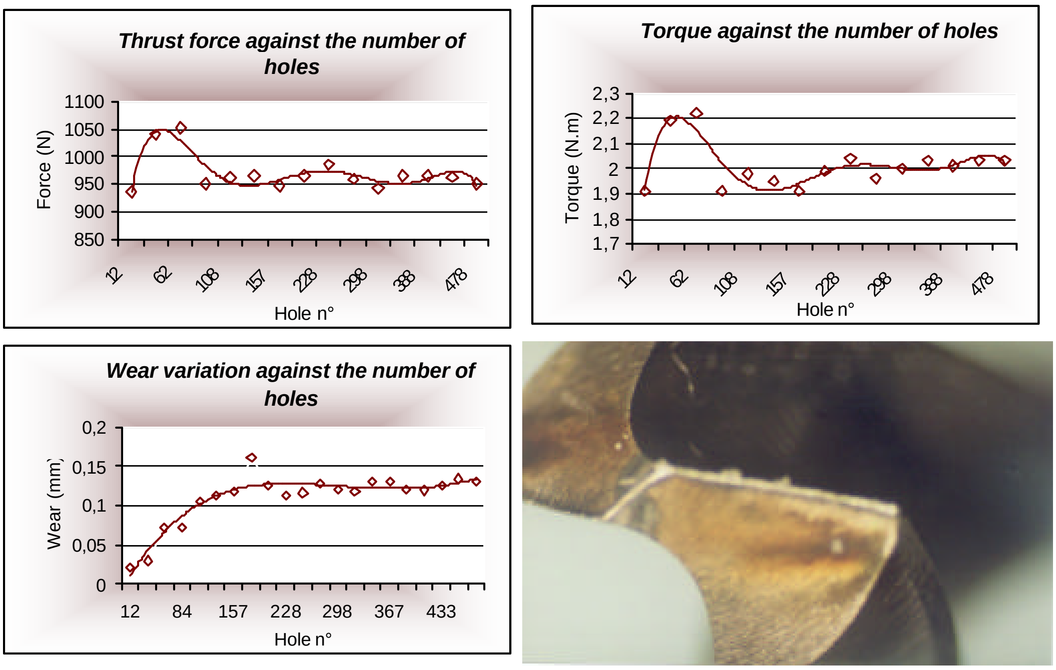

Figure 11 – Variation of thrust force, torque and wear for the drilling of the ABNT 1040 steel with conical sharpened.

5. Conclusions

- The self developed dynamometer provided a satisfactory performance along the development of this work.
- The experimental recorded force signals allowed for a investigation of the tool life of HSS twist drills.
- The experimental measured cutting forces varied in agreement with the considered cutting parameters following previous results from the literature.
- The experiments confirm that the cross-sharpened drills presented smaller solicitations when compared with conical sharpened and this difference increases proportionally to the feed rate progress.
- However not systematic investigated, the temperature was observed as an important factor during the machining of steel samples with twist drills. Its effects can be increased due to great loading or faulty refrigeration, as well as its increase could cause its damages and its life reduction.
- To study the mechanism of the sudden increase of the wear in the twist drills of high-speed steel it is necessary a more deep investigation, of the material microstructure during the wear development.

6. References

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