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ASSESSMENT OF SOME RELEVANT LOCAL VARIABLES IN MACHINING BY USING THE SPLIT TOOL TECHNIQUE

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Summary. *In this paper two of the main variables involved in machining processes have been experimentally measured in order to supply reliable data for Finite Element simulation assessing. The implemented strategy is based on the split tool technique which permits to isolate the contribute of the investigated variables different zones of the tool.*

1 INTRODUCTION

The relevance of machining processes in modern manufacturing is more and more increasing due to different reasons: first of all machining represents the last step of the manufacturing sequence; moreover the development of new high performance machines tools and tool materials permits to cut hard materials without relevant difficulties. For instance, die manufacturing industry bases its manufacturing process on hardened steels milling. Finally, the development of FE simulation allows to analyse, with a new and powerful approach, the evolution of relevant machining variables concerning both the workpiece and the tool.

Anyway, it must be considered that simulation effectiveness has to be fully assessed and furthermore most of the reported results are referred to simplified 2D configurations. In addition, it is not so easy to obtain experimental data on relevant local process variables, such as pressures, temperatures and other thermal data: on the contrary the availability of reliable measurements would be necessary to assess the efficiency of the numerical simulations.

The research here addressed is just focused on these issues. In fact, an innovative experimental-numerical procedure was developed to measure the distribution of two of the most impacting variables on the tool rake face, namely the normal pressure and the entering thermal flow. The procedure is based on the use of a so called “split” tool, i.e. a tool characterized by a narrow cut which divides the tool itself in two parts, fully independent as concerns the mechanical and the thermal effects produced by pressures and heat flows applied

on each of them. In this way, the distribution of the considered variable can be derived utilizing a set of tools at the varying of the dimension of the two parts in which the tool is divided.
The innovation content of the above approach is quite evident taking into account that usually only the average pressure, obtained as the ratio of the cutting force vs. the contact area, and the average thermal flow, calculated as a percentage of the mechanical power involved in the machining process, are available.

2 MEASUREMENT OF PRESSURE DISTRIBUTION ON THE RAKE FACE

The measurement of the pressure on the rake face has interested the researches all over the world since the half of the last century. Some interesting studies may be recognized in literature, based on different techniques and approaches, but probably the one proposed by Tonshoff [1] is the most effective. It is based on an innovative concept of subdivision of the influence areas of a given variable.

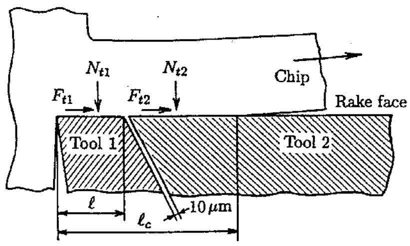

Figure 1: The split tool

Looking to Figure 1, the mechanical actions on the contact length l_C may be regarded as the sum of the actions on the tool portions l and l_C-l. A simple approach to measure the different contributes based on load cells in not possible due to the small dimensions of the tool. For this reason the authors developed an innovative technique based on the measurement of the strains induced by the normal pressure [2]. More in detail, a narrow slot was cut on the tool along the contact length and a strain gage was applied on the tool flank, close to the tool tip (Fig.2).

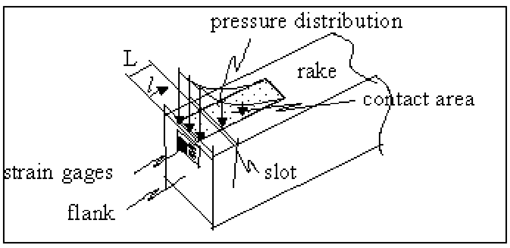

Figure 2: The utilized tool set-up

In this way the normal force acting on the former portion of the tool may be calculated on the basis of the measured strain, while the complementary force may be derived as difference between the global load, measured by a dynamometer, and the previous one. A particular attention was paid in order to avoid any error induced by the presence of the slot, both due to chip intrusion and flexional strains that could invalidate the measure. Thus a calibrated plate was inserted in the slot in order to avoid both the mentioned problems.

The tests were repeated with different tools characterized by slots cut at different distance from the tool tip. In this way the pressure distribution was rebuilt starting from the measured strains and applying an effective inverse approach.

The tests were carried out on a lathe, using an AA6060-T5 tube, while a HSS prismatic tool was used. The tool clearance angle was 6° in order to allow the strain gage positioning while the slot depth was 5 mm. The distances between the tool tip and the slot were 0.25, 0.35, 0.45, 0.60, 0.75 and 1.0mm respectively. Figure 3 shows the utilized equipment.

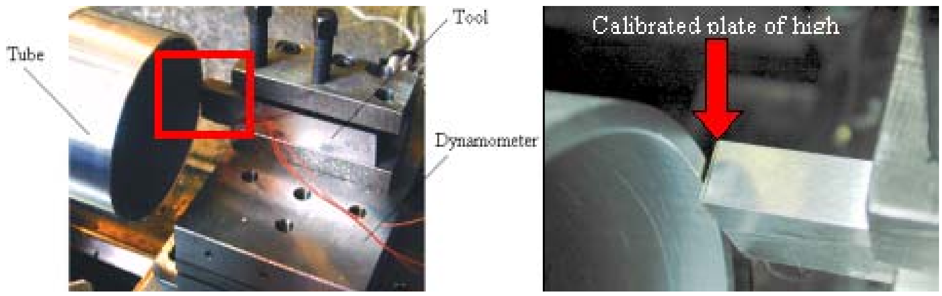

Figure 3: The equipment mounted on the tool

Figure 4 reports the obtained results. For each utilized tool the measured average pressure on the former portion of the tool is reported and it is compared with the pressure distribution predicted by the numerical simulation.

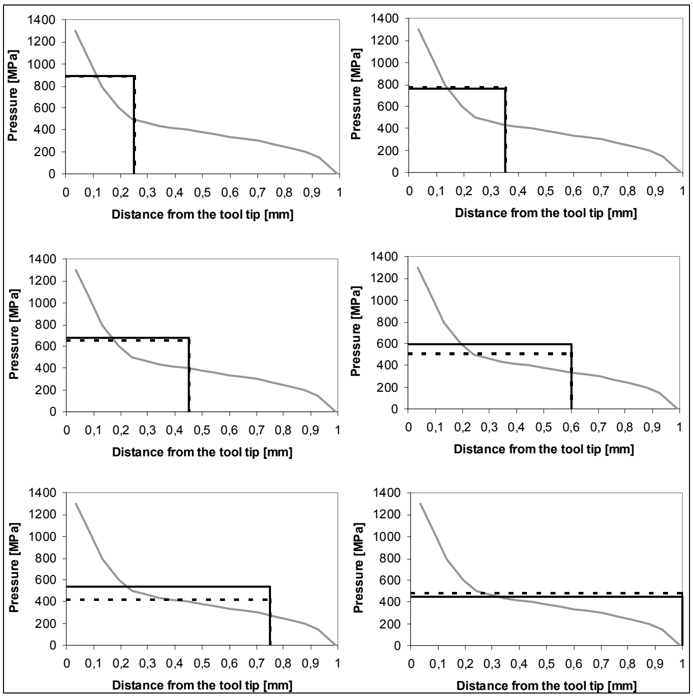

Figure 4: Pressure distribution on the rake face (continuous=FEM, dotted=Measured)

4 MEASUREMENT OF HEAT FLOW ENTERING IN THE TOOL

The split tool technique was used again for this task (Figure 5). In this case a thermocouple was applied on the tool flank, close to the tool tip and the separation of the thermal effects had to be ensured. Therefore the calibrated plate inserted into the slot had to work as thermal shield too: for this purpose a Tantalum plate was utilized.

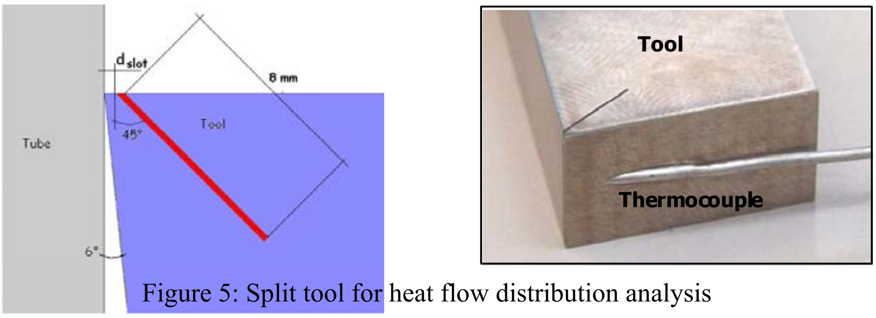

Figure 5: Split tool for heat flow distribution analysis

Once the temperature history was measured for a cutting time of 15 seconds (i.e. after that steady-state conditions were achieved), it was utilized in order to determine the heat flow able to induce the temperature itself [3]. This task was carried out by using an inverse approach, starting from the result of a pure thermal (then reliable) FE simulation, carried out on a commercial code. Figure 6 reports the calculated heat flow distribution: a relevant peak occurs at about ¼ of the contact length, close to the tool tip.

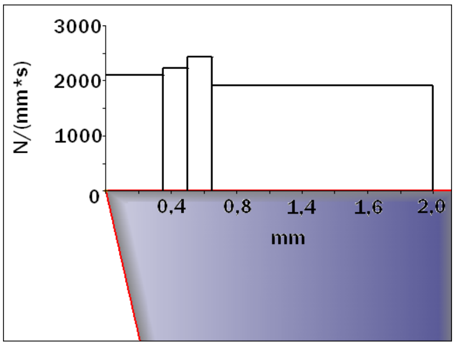

Figure 6: Heat flow distribution on the rake face

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