



METAL CUTTING IS IT STILL OF INTEREST TO ANYONE?

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Abstract: For almost 100 years, the phenomena in the metal cutting process have offered researchers in the field a wide range of research topics, and at the same time, as much satisfaction, both in terms of deepening theoretical knowledge, especially in terms of the practical results obtained. Interest in this field has declined dramatically, however, since the beginning of the third millennium. Has the cutting process reached the limits of knowledge by their exhaustion or has it become inefficient for industry compared to other new processes for manufacturing metallic, non-metallic materials and composites? Why is the field no longer as attractive to researchers? Here is what this paper tries to clarify and propose to researchers in the field to reinvent the approach of the cutting process, as an incomplete explored and still excellent perspective, not only for the manufacturing industry, but also for the theoretical foundations of the cutting phenomenon.

Key words: cutting process, the phenomenon of metal cutting, cutting geometry, fundamental research, applied research.

Rezanje metala još uvek nekoga zanima? Već skoro 100 godina fenomeni u procesu rezanja metala nude istraživačima u ovoj oblasti širok spektar istraživačkih tema, a istovremeno i isto toliko zadovoljstva, kako u pogledu produbljivanja teorijskih znanja, tako i u pogledu dobijenih praktičnih rezultata. Međutim, interesovanje za ovu oblast je drastično opalo od početka trećeg milenijuma. Da li je proces rezanja dostigao granice znanja svojom iscrpljenošću ili je postao neefikasan za industriju u poređenju sa drugim novim procesima za proizvodnju metalnih, nemetalnih materijala i kompozita? Zašto ova oblast više nije tako privlačna za istraživače? Evo šta ovaj rad pokušava da razjasni i predloži istraživačima u ovoj oblasti da ponovo osmisle pristup procesu rezanja, kao nedovršeno istražene i još uvek odlične perspektive, ne samo za prerađivačku industriju, već i za teorijske osnove fenomena rezanja.

Ključne reči: proces rezanja, fenomen rezanja metala, geometrija rezanja, fundamentalna istraživanja, primenjena istraživanja.

1. INTRODUCTION

Chipping/metal cutting, as the initiates know, is the method by which, under the action of relative movements between the semi-finished part and the cutting tool, the surplus material is divided into layers, and then it is removed in the form of chips, until the shapes, dimensions and surface quality indicated in the execution drawing of a piece are obtained.

Some processes of the method are known since prehistory and can be documented by the existence of artifacts, most often non-metallic, that have undergone such a transformation (carving, trepanation, drills, scratches, grinding, etc.), and then of the inscriptions and pictograms made on different supports describing various working processes (i.e. in ancient Egypt, a rotating tool - wimble was used to drill stones and found in the museums of antiquities of the world.

During the Middle Ages (or rather, between Antiquity and the Renaissance) the cutting processes develop, less as a method but more as a number of objects subject to processing and as diversification of the fields of use, without mentioning, however, concerns to explain any process on the cause-effect relationship or to theorize the accompanying physical phenomena.

By the end of the 19th century, the demand for

objects processed by processes specific to the cutting method leads to the development of rudimentary installations – usually with action based on human force and less often of the water fall – and of tools, devices and other aids.

After 1850, the first concerns began to appear regarding the explanation of how to form chips and the phenomena underlying this process, for the most common procedures such as drilling and turning.

Thus, around 1870, the first attempts to explain the phenomenon of chip formation are mentioned, and between 1881 and 1883 Arnulph Henry Reginald Mallock reveals the importance of chip shearing and friction at the tool-part interface [1] as well as the influence of coolants-lubrication [2].

With the passage into the twentieth century, the concerns in the field intensify, in proportion to the scale of the industrial revolution and the transition to mass production, both from the point of view of materials subject to chipping and cutting tools, cutting processes and related machine tools, as well as in terms of researching the phenomenology of metal cutting and physical explanation of the cause-and-effect relationships involved.

The experimental equation of F.W. Taylor from 1907 that links the durability of the cutting tool blade to the cutting rate can be considered as the beginning of

the experimental modeling of the phenomena in the cutting, for the purpose of their management, control and prediction.

The last century of the 2nd millennium is characterized by a large and rapid development of industrial production in which cutting processes occupy an increasingly significant percentage, so that the first years of the current millennium record a percentage of about 30% of the total manufactured parts that include cutting operations: turning, broaching, drilling, milling, threading, toothing, grinding, honing, lapping, etc.

At the same time, the interest of producers has gone from quantity to quality, optimization, efficiency, maximization of profit, minimization of resources used, etc. [2,3]. Normally, the attention paid to the phenomenology of metal cutting has increased proportionally. There were approached research topics belonging to all the cutting processes, looking for answers regarding the influence of:

- parameters of metal cutting process,
- the cutting tool geometry,
- the quality of the semi-finished materials and the tool materials,
- coolant-lubricating fluids,
- structural/ kinematic composition of machine tools,
- tool fastening/fixing/entrainment systems,
- the systems and fastening for semi finished (parts),

on the following aspects (without their string being meant to be exhaustive):

- cutting forces,
- the power / mechanical work consumed by the operation,
- the durability of the cutting tool edge,
- machinability of the material,
- the shape of chips,
- the time of phase/ cutting operation,
- dynamic stability of the process,
- the temperature released during the process,
- the quality of the worked surface,
- precision of processing.

The results of the researches in the field have been published - all over the world, especially in the countries that have been on the front line of industrialization - in the form of Research/Work Reports, Scientific Papers, Dissertations, PhD Theses. If all these results were gathered in one place – the current technique would allow the allocation of a "cloud" for this – it would result in a vast database, which analyzing it in terms of how it was or is or is or maybe will be used, we would find the following:

- A very small part of this huge database has been capitalized by adding and supplementing theoretical knowledge that leads to the description and understanding of the phenomena of splinting.
- Another small part of these researches were capitalized by the large companies producing cutting tools and machine tools respectively by compiling interactive libraries used to choose the type of tool, its geometry and the working parameters most appropriate to the desired machining by cutting.
- Another part, it was used to improve the performance of various cutting processes, usually for particular cases that generated the need for research

and therefore lost their validity over time or became obsolete.

- Most of the results of the published applied researches have neither found their expected echo nor have been capitalized sustainably.

The above approximations, of the proportions of use of the results of research in the field of metal cutting and the way in which it was made, can give an overall picture of the decrease in interest in research work in the cutting of metals, non-metals and composites. Let's try to see why, because "only knowing the cause, the effect can be eliminated" (*sublata causa, tollitur effectus*).

2. BASIC CONCEPTS

First of all, let us try to delimit our area of interest in the present argumentation.

The directions of research taken into consideration refer to the classical processing processes belonging to the cutting method.

The research papers were carried out as a result of two distinct needs:

1. The first is in connection with the need to research the phenomenological bases of the method. These researches were approached first in universities with scientific and technical profile and then also in departmental research institutions, governmental or private. In these cases, the research funds are not allocated mainly to research in the field of metal cutting but to the accompanying physical phenomena (temperatures, vibrations, mechanical work of elastic / plastic deformation, erosions, frictions, chemical dissociations, etc.) and the topics are chosen according to the curiosity / interest or skills of the research team participating in the national or international research grants competitions.

2. The second "engine" is the emergence of new materials, with mechanical characteristics so different from those of the existing ones that for their processing by cutting, the manufacturing companies cannot afford to extrapolate the working parameters of the usual processing processes, nor do they assume the risks of not knowing the output quantities from the cutting process in the form of forces, moments, consumed powers, temperatures released in the process, emissions, the quality of the surfaces obtained, the micro-structural integrity of the processed parts, etc. Research funds in these cases are allocated on the basis of topics specified by the private beneficiary through a research contract.

The goal is usually related to the behavior in chipping of new materials, recommended working regimes to improve the quality of the processed surface, reduce cutting efforts, introduce new types of cutting tools, coolants-lubrication or new load-bearing or kinematic structures or driving to advanced machine tools.

Regardless of how the research was initiated or the one in which the financing of the research contracts was made, the type of research approached is experimental research and their results are almost without exception, experimental computational (empirical) relationships, nomograms for choosing cutting regimes - the depth of cutting, the feed and the cutting speed (a_p , f , v) - or

pairs of their recommended values for various combinations of: cutting process, tool material, semi-finished material, quality of the processed surface, type of coolant-lubrication, specific working conditions, etc. For example, Figure 1 shows a generic form of experimental relationship very often used in the last 50... 70 years to describe the output size of the process - Cutting force -1 (the cutting forces can be measured in terms of three components: cutting force F_c , feed force F_f and passive force F_p - only the index in the formula changes: c, f, p).

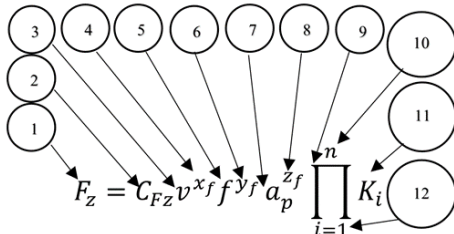


Fig. 1. Generic form of the empirical relationship for modeling the cutting force at turning

Analyzing the relationship, it is found that it takes into account the following components of the process: - input variables – the three parameters of the working regime v (3), f (5) and a_p (7), affected by the specific exponents x_f (4), y_f (6) and z_f (8),- product Π (9) of a series from $i = 1$ (12) to n (10) coefficients K_i (11) which take account of the influences:

- coolant-lubrication,
- tool material –steel, metal carbides, diamond, etc.,
- the material of the blank - steel, cast iron, non-ferrous, non-metallic - by its hardness HB,
- type of cutting – orthogonal, cutting, profiling,
- type of feed – longitudinal, tangential, mixed,
- the shape of the tool clearance face – with or without a splinter crusher, with or without a facet, etc.
- a C_{Fz} coefficient (2) resulting from the processing of the experimental data and which, in principle, identifies all other working conditions during the experiments and which cannot be individualised by K_i -type coefficients.

3. ARGUMENTATIVE EXAMPLES OF INTEREST IN CUTTING RESEARCH

Experiments, as a rule, are carried out in a number relevant to a previously adopted experimental program, in correlation with the type of mathematical regression that will be used for the processing of experimental data.

The collection of experimental data was done, initially manually using analog mechanical measuring equipment, then dynamometers with tensometric stamps and electronic axes and in the last quarter of a century piezoelectric dynamometers with digital transformation of the measured signals. The equipment for processing the experimental results has evolved from manually drawn and rationally interpreted graphs to systems for automatic data collection and processing using dedicated software and high-performance electronic computing systems. Figure 2 exemplifies the way of

graphical processing of the experimental results, with the specification that each of the points on the graph are actually the "poles" of some "clouds" of experimental data.

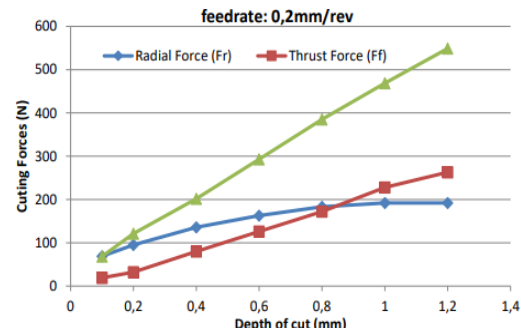


Fig. 2. Graphical representation of depth of cut a_p influences upon cutting forces at orthogonal turning

Not much different are other numerous cases of studies of the influences of the different parameters of the splinter or cutting tool on wear, tool durability, machining quality and accuracy, splinter dynamics [4], high-speed turning [5], etc. For example:

- figure 3 shows the result of a study from 25 years ago on the wear on the laying face (VB) of the lathe knife reinforced with metal carbide plates depending on the depth of cutting (a_p) when turning, for three types of semi-finished material;

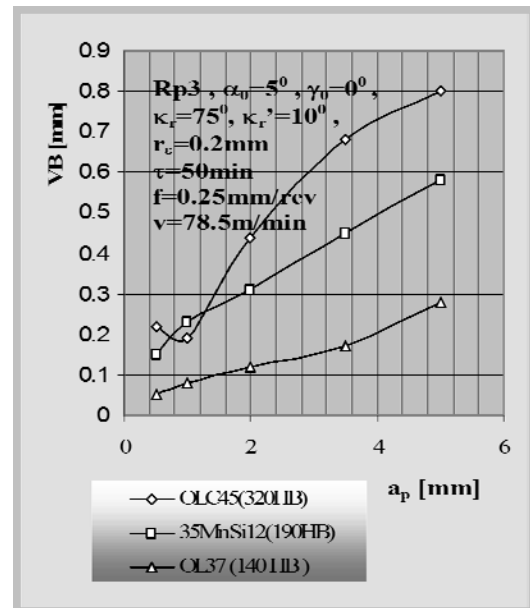


Fig. 3. The influence of depth of cut a_p on wear index VB

- figure 4 is shown the result of a study from 20 years ago on the degree of crumbling of chips at adaptive turning that has as an automatic adjustment parameter the longitudinal advance.

The mentioned study also confirmed the aspects revealed by other researchers regarding the variation of the chip thickness which leads to the appearance of some phenomena such as: vibrations, variations in the size of components of the total turning force, acoustic phenomena, premature wear of the tool, a reduction of the dynamic stability field of the turning process [6].

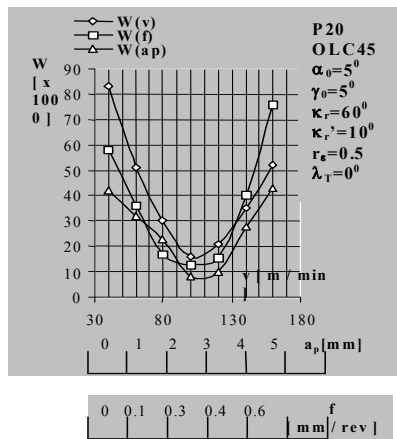


Fig. 4. The influences of a_p , f , v) on the breakage degree of the chip W for OLC 45

- in Figure 5, the result of a study on the influence of the presence of coolant-lubrication in the processed area on the durability of the tool edge reinforced with metal carbide inserts is presented

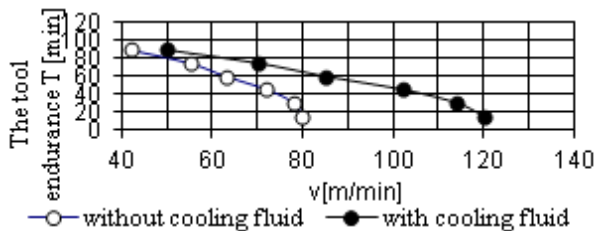


Fig. 5. The influence of the cutting speed v on T (tool life)

- the impact of the cutting parameters on the surface roughness and dimensional accuracy of hardened steel with CBN cutting tools was also experimentally studied, highlighting the variation of vibration, cutting forces, and tool wear under various cutting conditions.[7].

- other experimental study topics concerned the milling of composite materials for example to optimize and compare tilted helical milling processes in the case of carbon and glass fiber reinforced polymer composites. An uncoated carbide end mill were used and finally the microstructure were analyzed using optical-digital and scanning electron microscopy, respectively. [8].

- many other theoretical and/or experimental scientific papers aimed at streamlining the processing process, especially the optimization of the costs of processing by cutting through the control of working parameters. There are hundreds of such researches, but here we recall only the remarkable theoretical results obtained by the pioneers König & Depireaux [9], Spur Z. [10], Duca [11], Solomentsev [12] and practical ones of E. Dodon [13] and many others.

4. FINAL REMARKS

The authors hope that this paper will remind researchers in the field, especially PhD students and young researchers, that chipping/metal cutting was, is and will be for a few more decades one of the predominant methods used in the manufacture of material goods.

Moreover, from the work emerges the idea that the

physical phenomena that govern the phenomena during the cutting process are incompletely known, described mainly on the basis of experimental observations and is therefore far from being able to be conducted efficiently. In other words, the work is a plea, an encouragement for the sustained resumption of research in the field, introducing in the working instruments the latest conquests of the audio-video monitoring technique, of non-destructive investigation, of post-electron-microscopic examination, metallographic, spectrographic, x-ray diffractometric, etc., of experiment planning, of data acquisition and processing using computational computing and simulation techniques, etc.

Consider the exposed ones as an encouragement, it being as necessary for the brilliant researcher as the beginner one, as is the sack for the bow of the most virtuous violinist.

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