NONCONVENTIONAL ASPECTS IN EVALUATION OF THE MACHINABILITY BY DRILLING UNDER CONSTANT FEED FORCE

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ABSTRACT: The information concerning the evaluation of distinct materials machinability by drilling under constant feed force can be used in optimal design of the cutting conditions for workpieces made of such materials. It is important to identify a method able to ensure the determination of machinability indexes with an adequate precision and in a short time. A theoretical analysis led to some drilling schemes that could be applied in order to determine a method for the evaluation of materials machinability by drilling under constant force feed. An experimental equipment was designed, built and tested by considering a machining scheme resulted as a consequence of the analysis of the drilling schemes identified in the specialty literature. As a result of the experimental research developed by means of the equipment, some empirical mathematical models were established, in order to differentiate distinct materials from the point of view of machinability by drilling under constant force feed.
KEYWORDS: machinability by drilling, drilling constant force feed, drilling and chips

1. INTRODUCTION

The values of the machinability indexes are considered when there is the necessity to establish the sizes of machining parameters.

Machinability do not have a single definition; essentially, it can be interpreted as the ability of the workpiece material to be machined, as the wear it generate on the cutting edge and the shape of chips that can be obtained as a result of the cutting process [6].

Ease of processing hard materials hardness is also analyzed when the problem of machinability evaluation is taken into consideration.

Criteria that could be applied in order to evaluate the machinability are shown in table 1.

In order to evaluate the machinability by drilling, the following criteria could be used: cutting force, wear and drilling tool life, temperature in the machining zone, machining speed that can be used for an established tool life, chips shape etc.

In principle, the evaluation of machinability by drilling drill under constant force feed supposes to measure the depth of a hole drilled in a certain established time, when there is a known constant force feed.

There are many factors able to affect the values of the machinability index determined by using drilling under constant force feed: the tested material properties, the geometry of cutting tool active zone, the sizes of the cutting parameters, the presence and the type of cooling fluids and the ways in which these fluids circulate in the machining zone etc.

Table 1. Criteria for evaluation of machinability

Criterion	Size reference / symbol
Productivity	Number of parts machined in time unit
Machine cost	Currencies
Precision and surface quality cut	Machining accuracy and surface roughness parameters
Wear and tool life	Tool life T, in min
Cutting force	Size of main component of cutting force F_z, in daN
Temperature	Temperature θ, in ^{0}C
Chips shape	Coefficient of chip plastic deformation C_d

Over the years, the researchers were interested in developing and applying various tests in order to evaluate the machinability by drilling.

Thus, Jana et al. [4] studied the machining gap during constant velocity-feed glass micro-drilling by using a procedure of spark assisted chemical engraving.

A. Salak et al. and [8] developed tests aiming to evaluate the machinability of steels obtained by powder metallurgy.

P.A. Rey et al. [7] proposed models of cutting forces when orbital drilling of test pieces made of titanium alloy Ti-6Al-4V.

Within this paper, some solutions found in the specialty literature and which refers to drilling and eventually to drilling under constant force feed were examined, in order to establish some possibilities of improving the existent equipment that could be used for the evaluation of the machinability by drilling under constant force feed.

2. SELECTION OF A SCHEME DRILLING CONSTANT FEED FORCE

Hideaki et al. [3] described a drilling equipment which ensures the feed of the workpiece found in rotation movement to the drill tool placed on the machine tool table (fig. 1). This drilling procedure ensures an easier removal from the machining zone. Practically, the chips move down just under the action of their gravity force.

For such a process, one may determine the following indicators of machinability: the hole depth, feed rate, tool life and wear resistance of tool life material.

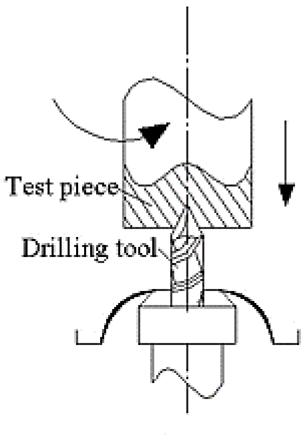

Figure 1. Drilling scheme able to ensure an easy chips removal from the machining zone (after [3])

The solution prevents the accumulation of the chips in the space found between the drilling tool and the workpiece material. At the same time, there is not the necessity to periodically extract the drilling tool from the hole, in order to ensure the chips evacuation.

The chips detached from the workpiece material arrive in a recipient placed round of the drilling tool.

Another technological solution able to facilitate the evacuation of the chips during the drilling process is presented in figure 2. In this case, a hole had to be made in the workpiece found on the machine tool table. A hole of small length is achieved by the drilling tool found over the workpiece. The rest of the hole is achieved by the drilling tool found under the workpiece. The two drilling tools materialize both the rotation movement and the axial feed movement to the workpiece surfaces.

In the case of drilling tool found under the workpiece, the chips are easier removed under the action of the gravity force. As seen, the length of the hole achieved by the drilling tool placed under the workpiece is higher than the length of the hole achieved by the drilling tool found in a superior position.

A specific condition is generated by the existence of the hole in the machine tool table, in order to allow the access of the drilling tool placed under the workpiece. Another technological problem is the necessity to ensure the coaxial positions of the two drilling tools used in order to obtain a penetrated hole in the workpiece.

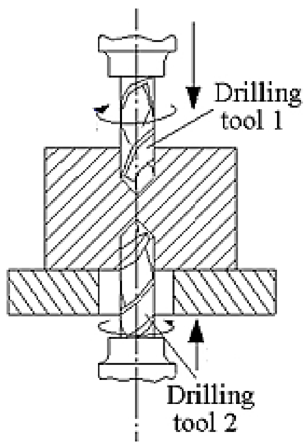

Figure 2. Drilling scheme in which two coaxial drilling tools are used in order to obtain a pierced hole (after [9])

Relatively long time ago (1936), Lindner proposed [5] a drilling scheme in which the feed movement of the drilling tool to the workpiece surface and along the hole to be obtained is achieved under the action of some counterweights and respectively under the action of the gravity force of the assembly including the rotating drilling tool (fig. 3).

Gherman et al. proposed [2] an equipment for testing the machinability by drilling under constant force feed which counterweights are used in order to generate the force feed.

Essentially, the machining scheme (fig. 4) involves the positioning and clamping the test piece in a chuck attached to the main shaft of the drilling machine. The test piece achieves the rotation movement and also the feed movement to the drilling tool found in a chuck placed on the machine tool table. As machinability index, the depth of the hole achieved in a pre-established drilling duration and machining conditions is used.

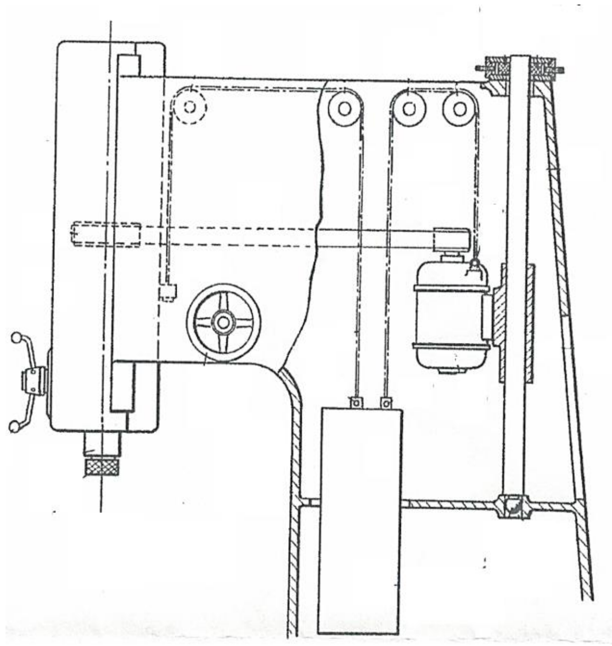

Figure 3. Drilling equipment that use a constant force feed (after [5])

As in the previous situation, the evacuation of the chips is achieved under their gravity force and, in this way, there is not the possibility of chips accumulation in the spiral grooves existing in the drilling tool. As a consequence, the values of the machinability indexes are not affected by the frictions forces generated by the chips accumulated in the spaces found between the drilling tool and the test piece.

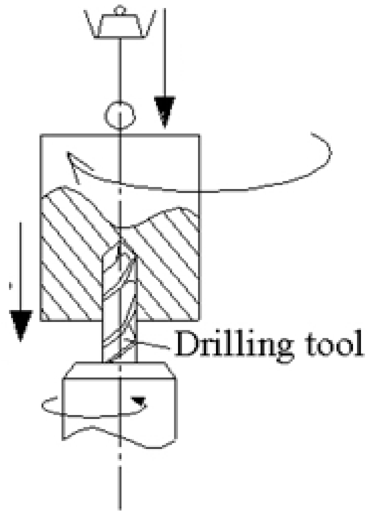

Figure 4. Drilling zone valid in the case of the equipment for evaluation of the machinability by drilling under constant force feed, proposed by Gherman et al. [2]

A problem specific to this testing scheme is the necessity of ensuring the coaxial position of the rotating test piece and drilling tool; in order to adequately solve this problem, a supplementary activity of controlling and setting the coaxial position of the test piece and the drilling tool must be achieved

3. PROPOSED SCHEME OF DRILLING UNDER CONSTANT FEED FORCE

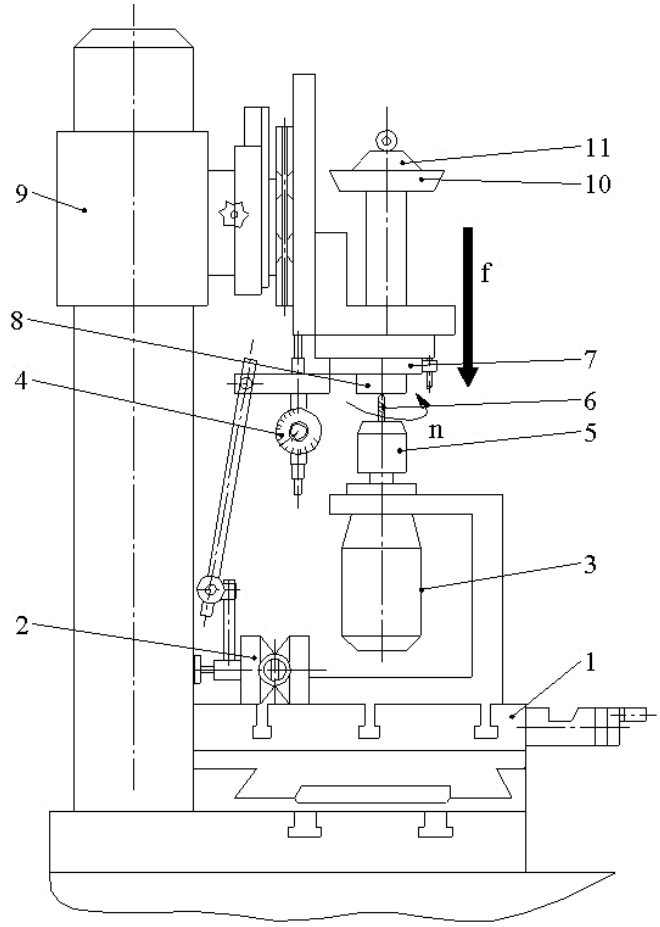

Figure 5. Device for machinability by drilling under constant force feed

Taking into consideration the above mentioned equipments for drilling or for testing the machinability by drilling under constant force feed, an improved solution (fig. 5) was designed and materialized within the Department of Machine Manufacturing Technology from the “Gheorghe Asachi” Technical University of Iaşi (Romania).

The equipment uses a workshop drilling machine endowed with a column on which a bush could be axially moved. The bush supports the guide of a slide on which usually the electric motor for tool rotation is placed.

In the case of this equipment, the slide could be moved by means of two cylindrical guiding bars and a ball sliding subsystem is used in order to support a vise in which the test piece is placed.

The slide is put in connection with a plate on which there are the counterweights used in order to generate the constant force feed. The sizes of counterweights are established by taking into consideration the weight of the subassembly for clamping the test piece.

On the machine tool table there is the electric motor for achieving the rotation movement of the drilling tool.

The depth of the hole achieved during the machinability test could be determined by using a dial clamped in an electromagnetic support.

Essentially, in order to achieve an evaluation of the machinability by drilling under constant force feed, the drilling tool is put in contact with the plane surface of the test piece and the probe of the dial gauge is set at zero.

When the drilling tool is rotated, it will gradually penetrates in the test piece material, under the action of the counterweights. If there is a pre-established duration of the test, the depth of the hole achieved in such conditions is considered as a machinability index, from the point of view of the cutting forces necessary to obtain a certain depth of the hole.

If the ratio of the hole depth to the drilling process duration is calculated, a supplementary information concerning the speed of drilling tool penetration in the test piece material is obtained.

4. EXPERIMENTAL RESULTS

The equipment for evaluation of the machinability by drilling under constant force feed was experimented using test pieces made of electro technical copper and aluminum, respectively.

A factorial experiment with three independent variables at two levels was designed and materialized. As independent variables, the drilling tool diameter, the force feed and the rotation speed of the drilling tool were selected. The experimental conditions and results are presented in table 1 (for test pieces made of copper) and table 2 (for test pieces made of aluminum).

The experimental results were processed by means of a specialized software, based on the use of the least square method [1]. In this way, the following empirical mathematical models were determined:

- In the case of test pieces made of copper:

$h=15.164+1.195d+4.229F+8.424\bullet 10^{-5}n$

- In the case of test pieces made of aluminum:

5. CONCLUSIONS

The machinability could be defined as the technological property of a material to be machined in the best conditions convenient for the producer; this means to use high machining speed, to generate a minimum wear of the tool and minimum energetic and mechanical solicitations of the technological system, to obtain low values for the surface roughness parameters and convenient shapes of chips etc. In the case of the evaluation of the machinability under constant force feed, a subsystem able to ensure a constant force feed is included in the equipment for testing the machinability and the length of the machined surface obtained in previous established work conditions is considered as a machinability index.

Table 1. Values of the drilling process input factors and experimental results obtained in the case of test pieces made of copper

Exp. No.	**Diameter of drilling tool *d* (mm)**	**Force feed, *F* (daN)**	**Rotation speed, *n* (min^{-1})**	**Depth h (mm) of hole, after 30 s**
1	**3**	**5**	**7**	**8**
1	2,5	2,354	1331	0,85
2	2	2,354	1331	1,48
3	2,5	3,189	1331	2,44
4	2	3,189	1331	1,82
5	2,5	2,354	1774	1,18
6	2	2,354	1774	1,04
7	2,5	3,189	1774	1,34 bis1,42
8	2	3,189	1774	1,86

Table 2. Values of the drilling process input factors and experimental results obtained in the case of test pieces made of aluminum

Exp. No.	Diameter of drilling tool d (mm)	Force feed, F (daN)	Rotation speed, n (min^{-1})	Depth h (mm) of hole, after 30 s
1	**2**	**3**	**4**	**5**
1	1	1,445	910	1,46
2	2	1,445	910	1,72
3	1	1,945	910	2,22
4	2	1,945	910	1,31
5	1	1,445	1123	2,2
6	2	1,445	1123	2,68
7	1	1,945	1123	2,33
8	2	1,945	1123	3,55

The study of the specialty literature proved the existence of research preoccupations concerning the investigation of the machinability by drilling under constant force feed. As a result of analyzing some constructive solutions used in order to evaluate the machinability by drilling under constant force feed, an improved testing scheme and equipment were designed and achieved. Some experiments highlighted the possibilities of using the equipment in order to evaluate the machinability by drilling under constant force feed in the case of test pieces made of copper and aluminum. In the future, there is the intention to extend the experimental research by taking into consideration other materials and machining conditions.

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