

# INFLUENCE OF THE TWIST DRILL GEOMETRICAL PARAMETERS ON MAGNITUDE OF CUTTING FORCES

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The article is focused on decomposition of cutting forces on cutting elements. The cutting forces are described via geometrical parameters of the twist drill. In the course of experiments magnitude of the feed force and the torque were measured. The shape of the chip was the next evaluated parameter.

## Keywords

twist drill, cutting element, tool geometry, cutting element, measuring

## 1. Introduction

Monitoring the whole cutting edge of a twist drill is not enough nowadays. The main cause is the variable magnitude of the tool geometry depending on the point of distance from the drill axis. It must be divided into single elements. More accurate information about the influence of the geometrical parameters on the load magnitude can be obtained by dividing the cutting edge. The cutting edge is divided into elements of identical size and they are essential for our experiments. The cutting elements have an exact position opposite the drill axis and have defined tool geometry. The load magnitude (thrust forces, passive forces and cutting torque) on the elements is monitored.

Furthermore, the supporting parameters are monitored to understand the cutting process. The supporting parameters are mainly the magnitude and shape of the chips, roughness of the machining surface, acoustic behaviour, etc [Zetek 2005].

A practical comparison of twist drills with the shape of the cutting edge and the line cutting edge is carried out in the practical part of the experiment. Twist drills are evaluated according to the shape of the chip and the feed force and torque magnitude [Zetek 2005].

## 2. Decomposition of forces on cutting element

### 2.1 Cutting element definition

When we decomposed the cutting force on parts of the cutting edge (cutting elements) we found that the force magnitude on the element is strongly under the influence of the diameter location on the cutting edge. The element is marked as CE (cutting element). The CE is defined as the exact part of the cutting edge which has defined cutting geometry, location on the cutting edge and distance from the drill axis.

The experiments were created on the principle of drilling pre-drilled holes with testing drills (one predrilled hole is equal to one cutting element). The cutting edge is divided into single cutting elements using this principle. The magnitude and number of elements depend on the graduation of the drills which are used to prepare the workpiece [Sadilek 2008].

The range of the cutting edge was decomposed on twelve elements which have one length. It means that we used predrilled holes from

0.5 mm to 6 mm by step 0.5 mm. The holes were drilled to cylindrical boards. The board diameter was 120 mm and every board was 36 mm thick. For every predrilled holes and tested tool were made five repetitions. For a better introduction to tested drill was used for predrilled hole straight plate which had the function of drill guide.

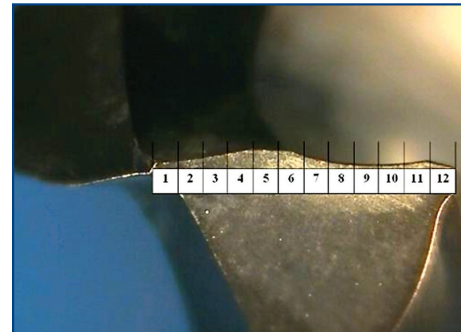


Figure 1. Indexing of location CE

### 2.2 Principle of force decomposition on CE

We get out from assumption that the cutting forces are decomposed on CE. We can decompose the resultant cutting force for the whole drill into the resultant cutting forces for the cutting elements. They can be decomposed to a single component to the tangential, radial and axial direction. The tangential (cutting) component is replaced by the cutting torque which is measured and evaluated [Sadilek 2008].

The measured data have a relative character only, because they do not describe directly the cutting force magnitude but only the magnitude of the cutting force for several elements. The absolute force magnitude for CE must be calculated from another equation (see formula 1).

$$F_{xi} = F_{xNi} - F_{xNi+1} \quad (1)$$

Where:

$F_{xi}$  is a random component of the resultant cutting force on the element  $i$  [N],  $F_{xNi}$  is a randomly measured component of the resultant cutting force on element  $i$  [N],  $F_{xNi+1}$  is a randomly measured component of the resultant cutting force on element  $i+1$  [N],  $i$  is the serial number representing the size of the predrilled hole in mm (if  $i$  is equal to 0 the predrilled hole diameter equals 0 mm).

The validity condition for the previous relation is that the sum of all the elementary loads must be equal to the resultant load of the tool. Respectively the sum of all elementary components must be equal to the sum of all components for the resultant cutting force.

$$F_x = \sum_{i=1}^n F_{xi} \quad (2)$$

Where:

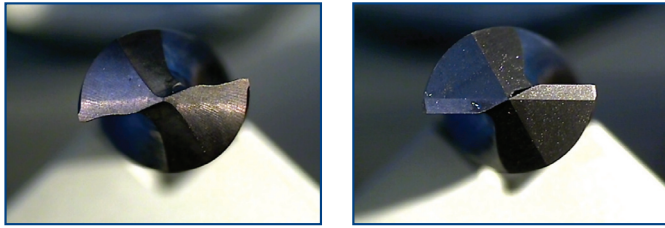
$F_x$  is a random component of the resultant cutting force [N],  $F_{xi}$  is a random component of the resultant cutting force on the element  $i$  [N],

## 3. Measuring of forces on cutting elements

### 3.1 Tested tools

Twist drills were selected for the experiments. The drills are 12 mm in diameter and they are made from sintered carbide deposited with a commercial thin layer. Two drills were used for the whole experiment.

They have different geometrical parameters [Zetek 2005]. The first drill has a straight cutting edge and the second drill has a cutting edge shaped. The shapes of all the cutting edges are shown in Figure 2.



**Figure 2:** Twist drill with cutting edge shaped – B (left figure) and straight – A (right figure)

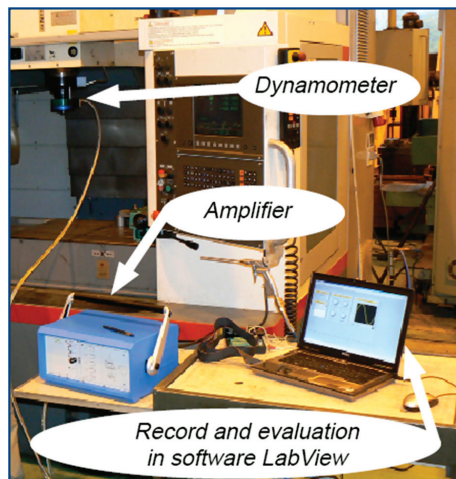
### 3.2 Equipment used for experiments

Department workshop laboratory equipment was used for the experiments. A four-component rotating Kistler 9132C dynamometer was used to record the force values. The dynamometer was joined to the measuring system which consists of an amplifier, connecting cables, connector block, measuring card and notebook. The notebook was equipped with LabView 8.2 measuring software. The thrust force and the passive force and the torque were obtained. The components of the measuring system are shown in Figure 3.

For whole experiment was used workpiece material C45 and following cutting conditions:

- Cutting speed –  $v_c = 80 \text{ m.min}^{-1}$
- Feed –  $f_{rev} = 0.1 \text{ mm.rev}^{-1}$
- Cutting surrounding – dry

The tool geometry was measured using a Multi Check PC500 optical microscope. The parameters which we cannot measure using this equipment were measured in collaboration with Hofmeister, Co. The tool wear check was carried out during the experiment using the Multi Check PC500 optical microscope.



**Figure 3.** Parts of measuring system

### 3.3 Sequence of operations in the experiments

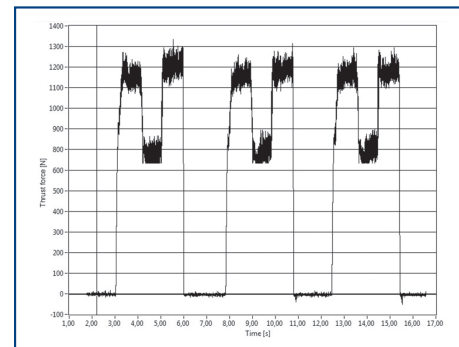
The experiments were carried out as follows:

- measuring of the drills using the microscope (shape of cutting edge, mask for tool wear measuring, tool inclination angle);
- workpiece clamping by three-jaw chuck;
- pre-drilling of pilot holes (one diameter for one workpiece);

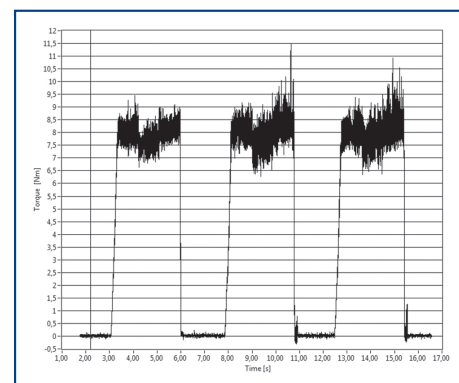
- drilling of five holes using one of the tested tools (measuring the torque, the passive force and the thrust force);
  - collecting and analyzing the chips;
  - changing the workpiece;
  - measuring the drills by microscope.
- The procedure was repeated until the whole range of the diameters was measured.

### 3.4 Measured data

The magnitude of the thrust force and the passive force and the torque were measured during machining. The data were recorded in a text file in the time sequence. The text file was evaluated using a script created in the Matlab environment. The table of relative cutting values was arranged for all variants of input parameters. These values are given in table 1.



**Figure 4.** Diagram of the thrust force  $F_f$  record



**Figure 5.** Diagram of the torque  $T_c$  record

The evaluated value from figure 4 and figure 5 is taken for example from a time between 4 and 5 seconds. Values around 1200 N is for drilling in full and therefore not relevant for evaluating the power relationships of CE.

### 3.5 Processing of evaluated force and torque values

The measured data are essential for finding the absolute magnitude of the measured values. The absolute magnitude of the forces and the torque was calculated using equation (see formula 1). The magnitude of the forces and the torque are shown in Figures 6 and 7. The following figures, each one CE represented by the column and tested drills are marked letters, see 3.1.

Element		1	2	3	4	5	6	7	8	9	10	11
A	Tc [Nm]	8.04	7.81	7.68	7.11	6.50	5.80	5.07	4.27	3.37	2.52	1.48
	Ff [N]	1161	798	690	594	463	369	297	231	163	108	53
B	Tc [Nm]	9.10	8.61	8.27	8.03	7.32	6.38	5.48	4.70	3.97	2.84	1.69
	Ff [N]	1714	1103	874	812	672	566	461	375	282	192	99

**Table 1.** Relative values of measuring parameters

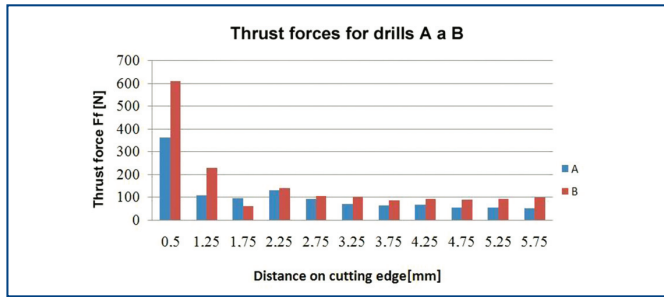


Figure 6. Absolute values of thrust forces

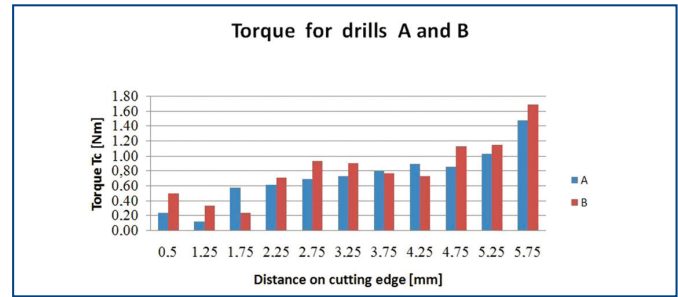




Figure 7. Absolute values of torque

Element		1	2	3	4	5	6	7	8	9	10	11
Distance on cutting edge [mm]		0.5	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75
Element size [mm]		1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
A	Tc [Nm]	0.24	0.12	0.58	0.61	0.69	0.73	0.80	0.90	0.85	1.04	1.48
	Ff [N]	362	108	96	131	94	72	65	68	55	55	53
B	Tc [Nm]	0.50	0.34	0.24	0.71	0.94	0.91	0.77	0.73	1.13	1.15	1.69
	Ff [N]	611	229	62	140	107	104	86	93	89	93	99


  



Short chip



Long split chip



Long solid chip

Table 2. Shape of the chips and absolute values of measuring parameters

#### 4. Conclusions

The geometrical parameters were described on the cutting elements. The location of the cutting element has a dominant effect on the load of the cutting edge. A further parameter with a greater influence was the tool angle inclination. The thrust force magnitude rises and the torque magnitude decreases if the cutting element location is nearer to the tool axis. The shape of the cutting edge is also fully described.

The distance between the tool axis and the cutting element has a major influence on the cutting speed and the torque respectively. If the distance is bigger, the torque is also bigger and the thrust force is smaller. The change of the torque magnitude is non-linear although the cutting edge has a linear character. The cutting force decreases when the cutting speed is bigger.

If we analyze the shape of the chip we can say that drills with the thrust cutting edge split the chip into small pieces (short chip) at the first part of the cutting edge. Drills with the cutting edge shaped split the chip better at the middle part of the cutting edge.

We can generally say that drills with the line edge split the chip better and uniformly distribute the thrust force along the whole cutting edge. Drills with the cutting edge shaped have the main part of the load concentrated on the point of the twist drill. Drills with a straight cutting edge are tended to vibrate during the collaring with comparison to the drill with the cutting edge shaped.

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