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AN EXPERIMENTAL METHOD TO EVALUATE THE ACTIVE FORCE IN FACE MILLING

BY

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Abstract. The evaluation of active force is of large interest for the calculation of the cutting power and the demands of the technological system. The way in which this component of cutting force is defined makes it impossible to measure directly by dynamometer means.

The work presents an experimental method for determining the active force in face milling, which implies the use of a piezoelectric dynamometer and a suitable software for the processing of experimental data.

The present paper also verifies whether the proposed system can describe with enough precision the events occurring on the arc of contact tool with workpiece.

Keywords: active force; cutter; dynamometer; dry machining.

1. Introduction

According to DIN 6584, the active force F_a lies on the working plane and its direction changes with the position angle φ (Fig. 1). This component of the cutting force determines the effective power necessary to detach the chips.

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The components of the active force F_a can be expressed in relation to the rotary coordinate system specific to the cutting tool by the component force F_c (tangential) and the component force F_{cN}, perpendicular to F_c (having radial direction with respect to the tool).

In relation to the coordinate system oriented after the direction of the V_f advance speed, the same active component can be expressed by the F_f component (radial direction versus tool) and the F_{fN} component (direction oriented perpendicular to the direction of the speed V_f).

If the workpiece is fixed in a tri-component dynamometer, the F_f and F_{fN} forces can be assimilated to its F_x and F_y components (see Fig. 1).

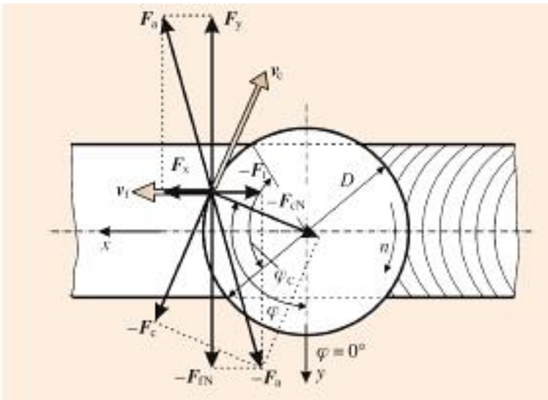

Fig. 1 − Components of cutting force in face milling
(Grote and Antonsson, 2009).

Regardless of the type of the dynamometer used to measure the cutting force (dynamometer platform for fixing the workpiece or a rotary dynamometer in which the cutting tool is mounted), the active force F_a must be determined off line by the help of a program in a suitable programming environment (Milfelner *et al*., 2005).

2. Methodology

In order to determine by calculation (off line) the active force Fa acting during the frontal milling, it was decided to adopt an experimental methodology in accordance with the recommendations of the literature (Milfelner *et al.*, 2005; Li *et al.*, 2006; Pérez *et al*., 2007), as following:

• Conducting an experiment consisting of the face milling of a workpiece manufactured in certain working conditions and the direct measurement of the components of the cutting force acting in the work plain using a tri-component dynamometer;

• Off-line processing of experimental data in order to determine the active force;

• Analysis of data obtained in order to assessing the possibility of using the working method for highlighting the events occurring on the contact arc of the tool with the workpiece.

2.1. Experimental Setup

Experimental tests were carried out on a parallelepiped steel blank OLC45/STAS 880-80 (10503 or C45/DIN) having the properties shown in Table 1 and Table 2.

Table 1
Chemical Composition of OLC 45 Steel in Mass Percent

C	Mn	Si	Cr	Cu	Ni	Mn	S	P
0.45	0.61	0.25	0.14	0.30	0.11	0.01	0.018	0.015

Table 2
Mechanical Properties of OLC45 Steel

Hardness (Brinell) (mean value)	218
Yield strength (MPa)	730

The tests were carried out on a milling machine type FUS25, in the following working conditions:

• cutting speed V_c equal to 50 m/min corresponding to a n_C speed of rotation of 250 rev/min, no cooling (dry cutting), feed rate f of 0.218 mm/rot, corresponding to a V_f advance speed of 54 mm/min, radial engagement of the tool a_e equal to 50 mm, axial engagement a_a (a_p) 1 mm, with symmetrical tool arrangement relative to the workpiece;

• cutting fool characteristics: 63 mm (Dc) diameter of front cutter, equipped with 8 carbide cutting inserts;

• the data acquisition system consisted of a dynamometer Kistler 9272, a multi-channel charge amplifier 5070 A and the Dynoware 2825A soft program;

The dynamometer was fixed on the milling machine table, so that the orientation of the axis system shown in Fig. 2 resulted;

• data acquisition features: tests were performed for a sampling rate of 1000 samples/sec (1 KHz), corresponding to a 1.5°/sample resolution for the angular position of the tool tooth on its contact arc with the workpiece.

Considering the characteristics of the tool utilized, the dimensions of the workpiece and the relative position of these two elements it result the positioning diagram from Fig. 3.

Fig. 2 – Cutting force measurement system.

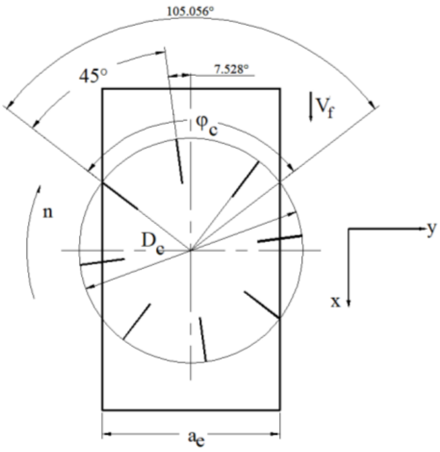

Fig. 3 – Cutter rotation and cutting edge location angles.

According to Fig. 3, it follows that the contact angle of the cutter with the workpiece is approximately 105°, which makes the number of teeth simultaneously in contact to be two or three.

3. Results and Discussion

Following the testing we recorded the evolution of components, F_x (F_f) and F_y (F_{fN}) of the resultant cutting force in the form of graphs (see Fig. 4) as well as numerical form, in order to be exported to a programming environment enabling the active F_a (Table 3) force to be calculated.

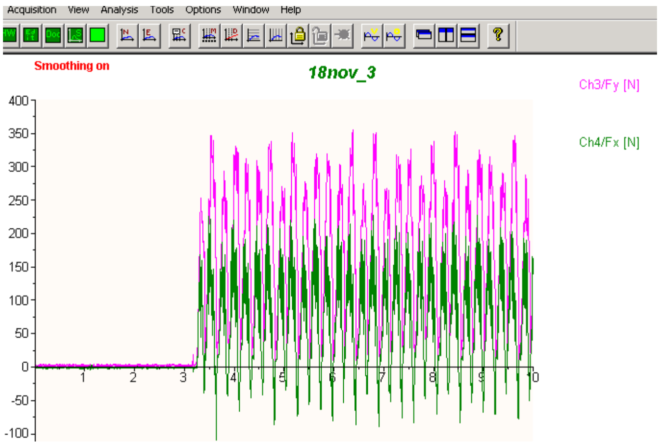

Fig. 4 – Measured cutting force components.

Table 3
Measured Cutting Force Components in Numeric form

Point nr.	Time [s]	F_x value [N]	*Fy* value [N]
301	5.051	255.142	173.462
302	5.052	298.309	176.071
303	5.053	263.382	165.802
304	5.054	301.025	158.31
305	5.055	271.042	144.928

To calculate the active force F_a, the geometric relationship that can be deducted from Fig. 1 has been used:

$$F_a = \sqrt{F_x^2 + F_y^2} = \sqrt{F_f^2 + F_{fN}^2} \quad (1)$$

Using the Eq. (1) for each point considered, the graph of the evolution of the active force F_a, shown in Fig. 5, was achieved. The number of the acquisition point in which the calculation was made is on the abscissa and the corresponding value of the force calculated with the Eq. (1) is on the ordinate.

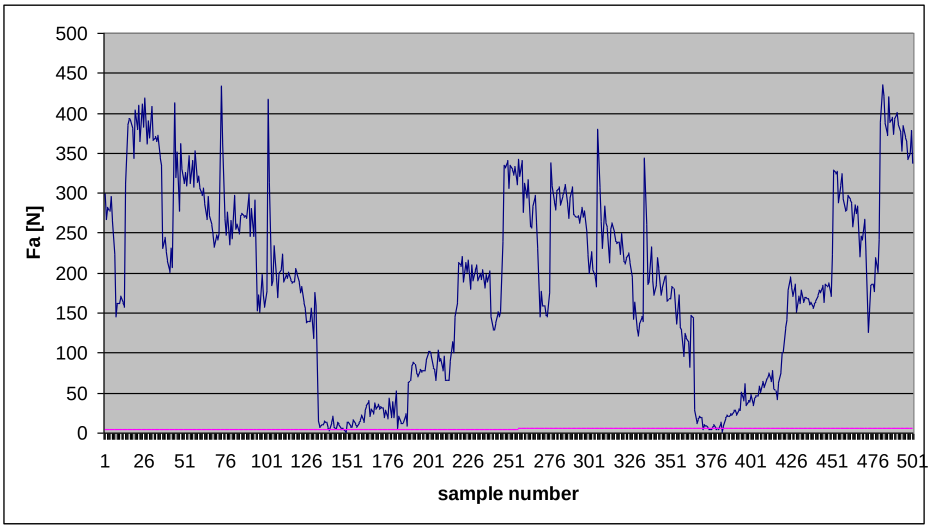

Fig. 5 – Calculated active force component F_a .

Also, the Eq. (1) was used to achieve details of the evolution of the active force, for a complete rotation of the milling (Fig. 6) or for any number of points (Fig. 7).

In this way, it was revealed:

• the time when on the arc of contact of cutters tools with the workpiece is the maximum number of teeth simultaneously in action (points M in Fig. 6);

• the time when on the arc of contact of cutters tools with the workpiece is the minimum number of teeth simultaneously in action (m points in Fig. 6);

• points M and m have a periodicity of occurrence strictly equal to the angular step of the cutter (Fig. 4);

• the evolution of the F_a component can highlight some events on the contact arc of the cutter with the workpiece, such as the radial runout of the cutting edges, the shock generated by the entrance of the teeth into/out of the cutting, the appearance of the burr at the output of the teeth from the cutting;

• the extent to which the events on the contact arc can be detailed depends on the sampling rate (number of samples/s) as highlighted in Fig. 7.

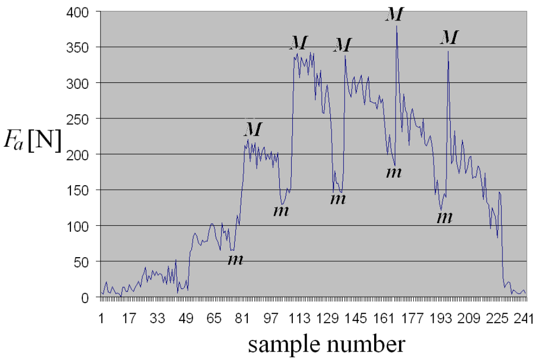

Fig. 6 – Calculated active force component F_a for one rotation of the cutter.

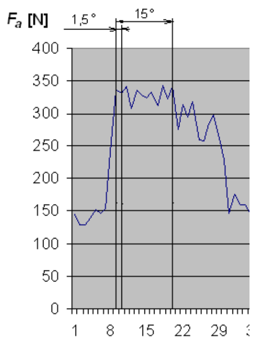

Fig. 7 – Detail of calculated active force component F_a.

3. Conclusions

The experimental method presented proves its usefulness in assessing major events on the contact arc of multi-toothed tools, highlighting the influence of the relative position of the tool's teeth on the cutting effort, dynamic phenomena produced at the entrance/output of teeth in/from the cutting, the appearance of burrs at the edge of the workpiece.

The study of more complex phenomena, such as change of the instant chip thickness on the contact arc and implicitly the specific cutting force, the influence of the cutting microgeometry on cutting efforts is necessary to develop a research with the use of single-tooth tools.

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METODĂ EXPERIMENTALĂ PENTRU EVALUAREA FORŢEI ACTIVE LA FREZAREA FRONTALĂ

(Rezumat)

Evaluarea forței active prezintă un interes deosebit pentru calculul puterii necesare desfăşurării unui proces de așchiere şi pentru evaluarea solicitărilor sistemului tehnologic.

Modul în care această componentă a forței de așchiere este definită face imposibilă determinarea ei strict cu autorul dinamometrelor.

Lucrarea prezintă o metodă experimentală pentru determinarea forței active la frezarea frontală, care presupune utilizarea unui dinamometru piezoelectric tip KISTLER 9272 (destinat în special pentru operații de strunire şi găurire) şi a unui soft adecvat pentru prelucrarea datelor experimentale.

Totodată lucrarea de față confirmă că modul de lucru propus poate să descrie cu suficientă precizie o serie de evenimente majore ce se produc pe arcul de contact al sculei cu semifabricatul, dar trebuie modificat în cazul în care se urmăresc fenomene mai complexe.