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SELECTED PROBLEMS OF FACE MICRO-MILLING OF HARD STEEL

У статті представлені результати досліджень подовжених і поперечних відхилень. Дослідження перевели під час точного торцевого фрезерування пластинами з кераміки інструментальної сталі 55NiCrMo у загартованому стані при твердості 52 HRC. Відхилення прямолінійності вимірювали до й після компенсації методом корекції шляхів пластини фрези стосовно оброблюваного виробу.

В статье представлены результаты исследований удлиненных и поперечных отклонений. Исследования перевели во время точного торцового фрезерования пластинами из керамики инструментальной стали 55NiCrMoV в закаленном состоянии при твердости 52 HRC. Отклонения прямолинейности измеряли до и после компенсации методом коррекции пути пластины фрезы по отношению к обрабатываемому изделию.

In clause results of researches of the extended and cross-section deviations are presented. Researches have translated during exact face milling by plates from ceramics of tool steel 55NiCrMoV in the tempered condition at hardness 52 HRC. Deviations of straightforwardness measured before and after indemnification by a method of correction of a way of a plate of a mill in relation to a processable product.

INTRODUCTION

Machined surfaces of many workpieces e.g. deck faces of engine blocks or mould joints, meets role of sealing faces, so flatness of the faces is of great practical importance. Simultaneously from many years is visible tendency of replacing some grinding operations of hardened steels with precision turning and milling [2, 3].

Possibility of shape accuracy increasing by controlling of wedge position, aplied in turning [9], has not been recognized well during face milling by large diameter mills and for matter of correctional path impact on deviations in various longitudinal and transverse sections. Park et al. [6] have compensated deviation in longitudinal section during face milling by tool path assigned to axis of small diameter end mill. In authors opinion compensation with correctional path assigned to axis of large face mills and with large angular error motion components could cause “undercutting” problem of work surface.

RANGE AND CONDITIONS OF RESEARCH

Research were carried out during symmetrical dry face milling of hot work tool steel 55NiCrMoV (52HRC)in conditions presented in tab. 1.

For registration of machined surface profiles incremental length gauge MT12B with resolution 0,0005 mm and ball-shaped contact tip was used (1a at fig. 1). The gauge was fixed to frame of milling machine and it was moving during measurement in axis *X* and *Y* of the milling machine coordinate system. Longitudinal profiles *Z* = f(*X*) and transverse profiles *Z* = f(*Y*) were registered in various sections of machined surface (fig. 4). Feedrate was parallel to X axis direction (fig. 1).

Table 1 – Selected cutting conditions

Workpiece:	55NiCrMoV (52HRC), a_e = 90 mm, *L* = 250 mm
Face mill:	*D* = 100 mm, *z* = 1, $\alpha_p = 6^o$, $\gamma_p = -6^o$, $\gamma_f = -11^o$
Cutting parameters:	v_c = 352 m/min, f_z = 0,06 mm/wedge, a_p = 0,1 mm
Cutting insert:	SNGN 120408 T02020, Al_2O_3+TiC
Wedge wear:	VB_c = 0-0,3 mm

Machined surface profiles were interpolated by polynomials (4-th order for longitudinal profile and 2-nd order for transverse profile) to make assesment of the deviations values $STRt_w$ and $STRt_p$ easier. The deviations value were gave as a distance between maximal and minimal position of approximated profiles *Z* = f(*X*) and *Z* = f(*Y*) measured relative to movement path of the gauge. Values of the deviations from profiles concave relative to adhered line were treated as positives and from convex ones as negatives.

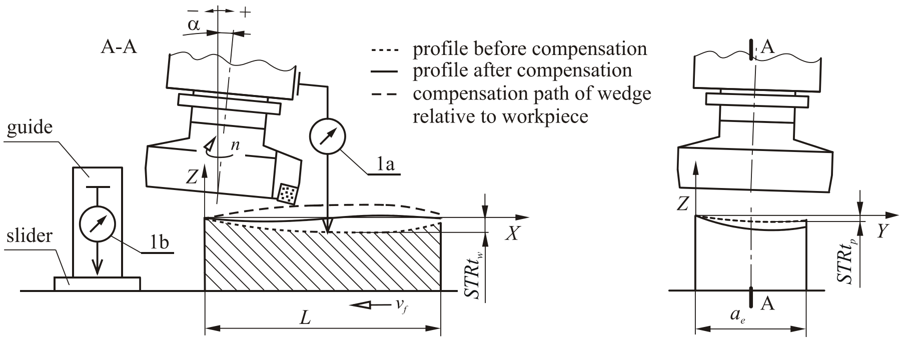

Figure 1 – Measurement scheme of movement accuracy of face mill and minimization of deviations in longitudinal sections [7]

It was checked before compensation if mechanisms of milling machine can realize few micrometers vertical displacements of face mill relative to workpiece. To this end path *Z* = f(*X*) assumed in control system was compared to real vertical displacement of milling machine units. The real displacement was measured by the incremental length gauge (1b at fig. 1), which measurement tip was touching slider of the milling machine moving vertically according to the imposed path $Z = f(X)$. The accuracy test was done in an idle run and during cutting.

Mirror image relative to X axis of profile in longitudinal section intersecting axis of face mill was assumpted to be compensation path of face mill in next pass. Beginning of the path was assigned to front of face mill which formed machined surface due to tilt of face mill axis by α angle (fig. 1). After compensation pass profiles were registered in the same sections what in the pass before compensation.

RESULTS AND ANALYSIS OF RESEARCH

Imposed vertical displacement of milling machine table was realized with accuracy creating basis for compensation of a few micrometers deviations, without necessity of hydraulic or piezoelectric precision positioning systems applying (fig. 2). Real displacement $Z = f(X)$ of face mill relative to workpiece was much lesser accurate (fig. 3).

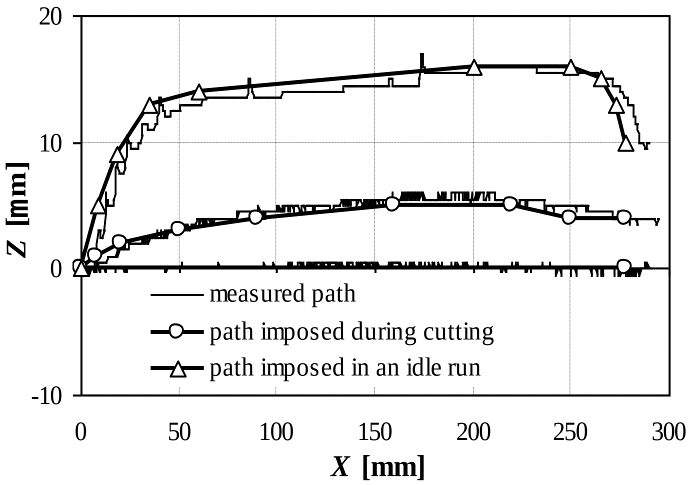

Figure 2 – Comparison of imposed vertical displacements with real (measured) displacements of milling machine table

In middle longitudinal section intersecting axis of face mill deviation $STRt_w$ has the highest value [3, 7]. Correction of wedge path relative to workpiece has allowed decreasing to about 5 μm and equalizing deviations $STRt_w$ in all longitudinal sections. However increasing of values $STRt_p$ has appeared at beginning of length X (fig. 3).

Reason for increasing of the $STRt_p$ value was increasing of the mill axis tilt angle α+dα measured relative to tangent to compensation path in contact point of wedge with workpiece [8]. For example rising of compensation path by 5 μm on length $X = l_\psi \approx 28$ mm has caused rising of transverse profile at the ends of workpiece width measured on length X=1 mm by similar value. In case of concave deviation before applying the compensation path it caused increasing of deviation $STRt_p$ after compensation (fig. 3). Limiting analysis at the figure to less milling width it can be easily imagine that impact of compensation path on deviation in transverse section will be lesser.

Efficiency of machined surface flatness improvement by correction of wedge path depends on value and sign of the α angle of face mill axis tilt in feed direction as well as shape of compensated longitudinal profile. The most often profile in longitudinal section declines on milling length (is degressive). At fig. 4 is shown some typical machined surfaces before and after compensation for degressive profile in longitudinal section and various angles α.

If $\alpha > 0^\circ$ and tilt of longitudinal profile $d\alpha = dZ/dX < \alpha$ compensation path, being mirror image of longitudinal profile relative to X axis, will caused decreasing of deviation $STRt_w$ and increasing of deviation $STRt_p$ [7]. If $\alpha > 0^\circ$ and $\alpha > d\alpha$ whole machined surface will be cutted repeatedly by back of the mill.

When longitudinal profile is degressive although tilt of face mill axis by angle $\alpha = 0^\circ$ deviation $STRt_p$ will not be zero, but transverse profile will be concave and formed by back of the mill. Whereas after compensation both $STRt_w$ and $STRt_p$ deviations can be minimized, what causes bi-directional lay formation on whole machined surface (fig. 4) [4,5,7].

In case of face mill axis tilt by angle $\alpha < 0^\circ$ transverse profile formed by back of the mill will be lesser concave after compensation, but deviation $STRt_p$ will not be zero.

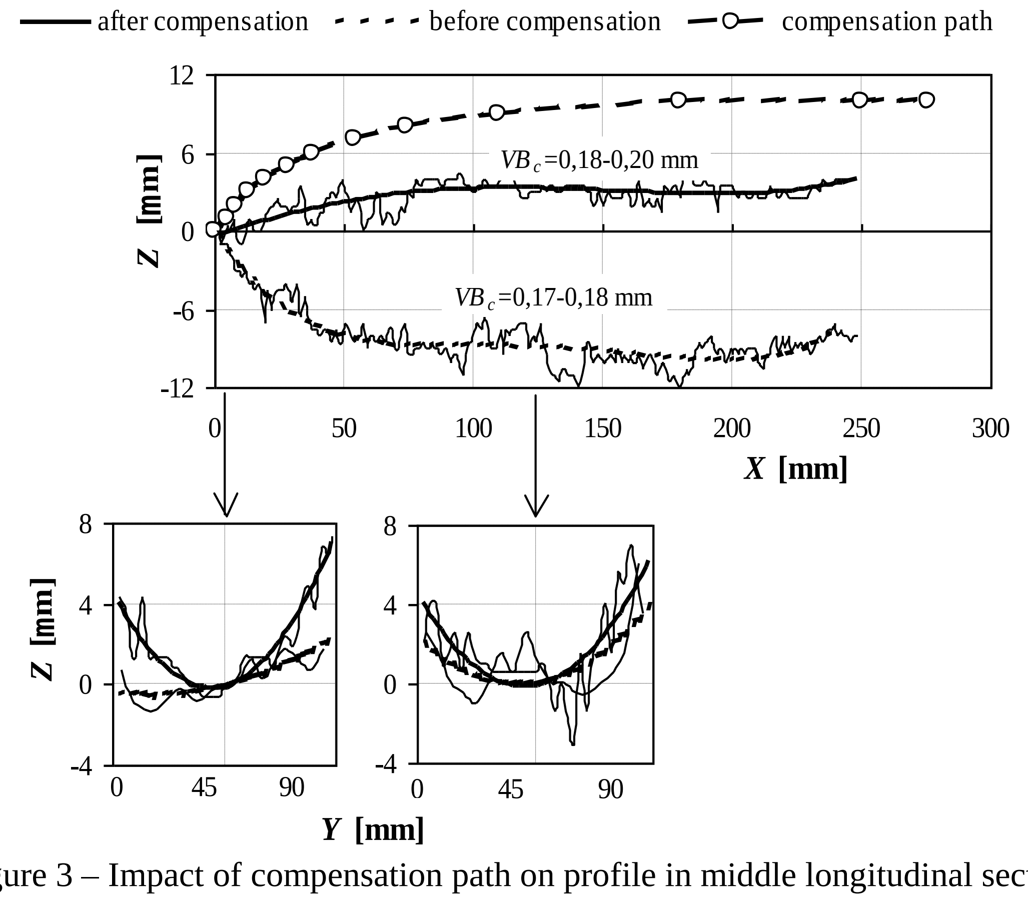

Figure 3 – Impact of compensation path on profile in middle longitudinal section and profiles various transverse sections (basis on [8])

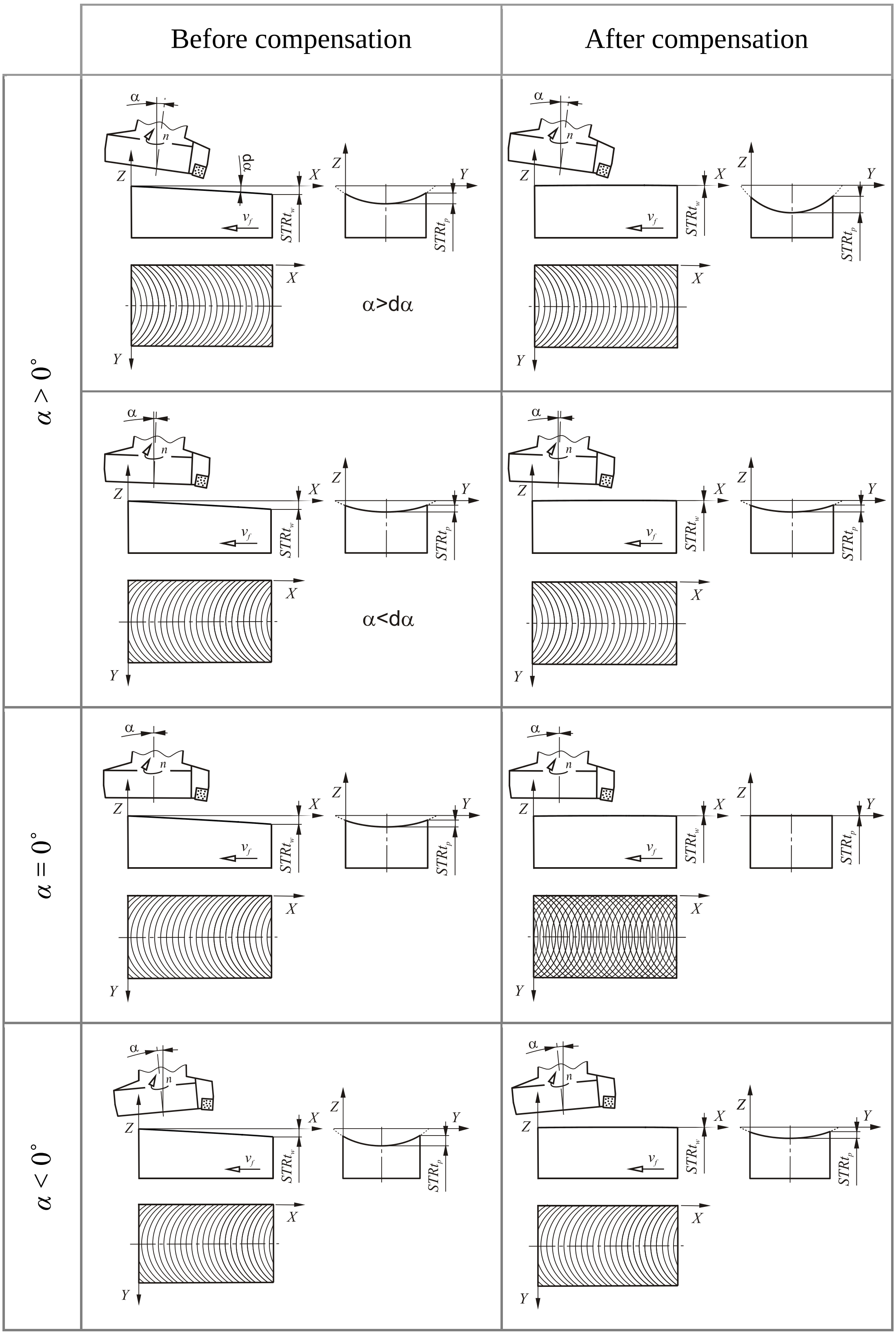

Figure 4 – Machined surfaces before and after compensation for various angles α of face mill axis tilt

CONCLUSIONS

Diversification of deviations in various sections is mainly result of geometric-kinematic action of face mill. In longitudinal section intersecting axis of face mill deviation $STRt_w$ has the highest value. Profile in longitudinal section (beeing real path of face mill) is misalignment, what has impact on diversification of deviation $STRt_p$ measured in various transverse sections.

It is possible to minimize deviations in all longitudinal sections by correction of mill path relative to workpiece. Compensation path has impact on deviations in transverse sections and the impact is higher during milling of wider surface. Efficiency of machined surface flatness improvement by this type of compensation depends on value and sign of face mill tilt angle α as well as shape of compensated longitudinal profile. Only for tilt of face mill axis by angle $\alpha = 0^\circ$ both $STRt_w$ and $STRt_p$ deviations can be minimized after compensation.

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