DYNAMICALLY INVESTIGATION ON THE PROCESS OF THE BACKWARD- AND DOWN-MILLING

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Abstract

In our project we investigated the parameters of force and surface roughness on the CNC working centre at different speeds and feed rates at backward- and down-milling.

Similar to same cutting experiments made earlier the CNC working centre, the characteristics, see above, were investigated at vacuum and rigid clamping too. National Instruments measuring system and LabView operating and evaluating programs were used at force measurement.

The first project results were very interesting, we could see the main statutory, but there are effects, which need more tests.

The heart of matter examining surface roughness it is clearly typical, that comparing rigid and vacuum clamping the rigid clamping productive of better surface either in the function of tool speed or feed speed.

Key words: *Force, force sensor, cutting speed, milling, roughness.*

INTRODUCTION

The mechanics of the cutting examines/analyses the interaction between the tool and the chip with the instruments of the mechanics. We take into consideration the mechanical properties of the material, if necessary the anisotropy, the viscoelastic and plastic properties as well. We look for connections between the forces and the shifts/dislocations (deformations), and the final goal is the determination of the cutting-force depending on the properties of the material and the toll. Our aim is as well that we explain the so far only observed phenomena with scientific instruments.

We confirm the theoretical results with experimental data. Where necessary, we give work-charts for the faster determination's aim of the wanted parameters.

In our present measuring series researched poorly so far, the parameters of backward- and down-milling were investigated at different parameters especially for the arose force relations and the surface roughness found as result.

THEORETICAL CONSIDERATIONS

The mechanics of the cutting

Force- and tension -relations

Certain assumptions have to be made by the beginning of theoretical derivations usually. Our most important initial assumption concerns on the chip's shape in this case. We suppose that the chip shears/deforms on the knife's surface on an R radius. A series of practical observation confirms this assumption. E.g. the shaving gets off from the tool's front surface in a closely rolled state at B-direction cutting. The rolled state remains after cutting as well (after balancing) because the chip's depressed belt fluidizes plastically and this means permanent deformation.

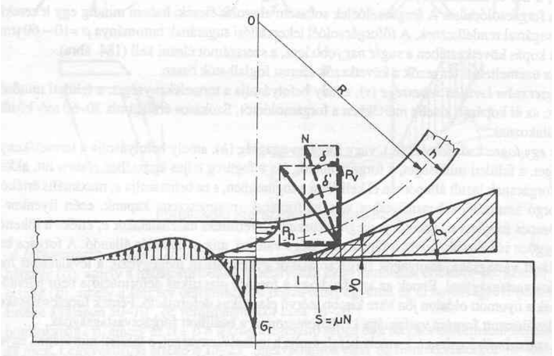

Fig. 1 Force and stress conditions during cutting

Figure 1 shows force and stress conditions during cutting. An N normal force has an effect on the end face of the tool, which can be divided into its components (horizontal, vertical). While the cutting slips on the end face of the tool, S=μN friction force is generated, which can also be divided into its components. If we sum up the components, the resultant force bends forward toward the direction of displacement and the angle between vertical will be [2]:

$$P_h = N \cdot \sin\delta + \mu \cdot N \cdot \cos\delta$$
$$P_v = N \cdot \cos\delta + \mu \cdot N \cdot \sin\delta$$

From derivations, vertical and horizontal clipping components of force can be known [2]:

$$P_v = \frac{1}{f(\mu,\delta)} \cdot \frac{E \cdot b}{50} \cdot \left(\frac{h}{R}\right)^2 \cdot h$$

The horizontal force component is the cutting force, which can be computed from the following equation [2]:

where:

$s \cong 2\rho$ - cutting edge thickness,

σ_{ny} - compression strength of the material

The specific horizontal cutting force is [2]:

$$P_h = 2\rho \cdot \sigma_{ny} + \frac{\tan\delta'}{f(\mu,\delta)} \cdot \frac{E \cdot b}{50} \cdot \left(\frac{h}{R}\right)^2 \cdot h$$

We drew the inner tension-distributions in the figure. The inner tension-distribution ensue from the inflection is asymmetric because the pressure-strength is roughly half of the tensile-strength. The pressure-tension is near constant on the depressed side where the material's impressment achieves the strength.

The consequence of the asymmetric stress distribution is that the neutral axis shifts toward the tensile side. The additional significant displacement of the neutral axis is caused by the

horizontal component of the cutting force that expand pressure of axis direction to the chip like a bent beam, so that it increases the width of pressure zone loaded up to plasticity.
The inflections of chip in the horizontal plane in front of the cutting edge result in load. To know about it in functional aspect is very important, because it can cause pre-splitting of the material in unfavourable case.
The acting forces to the cutting edge and rake can be seen in Fig. 2.

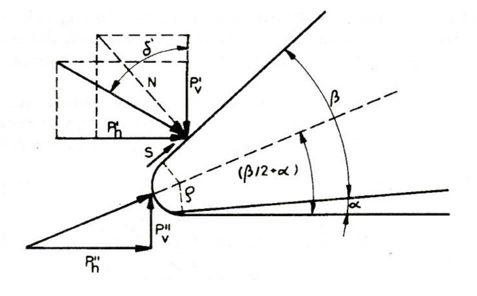

Fig. 2 The acting forces to the cutting edge and rake

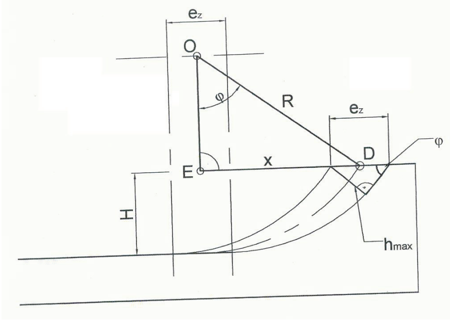

Fig. 3 The kinematic condition of cutting tool

The kinematic condition of milling and planning tools can be seen in Fig. 3. The edge of tool in proportion to the material makes a cycloid path.

The value of feed rate per tooth:

$$e_z = \frac{e}{n \cdot z}$$

about:

e_z - feed rate per tooth
e - feed rate
n - revolution of tool
z - number of cutting edge

The maximal chip thickness: $h_{\max} = e_z \cdot \sin\varphi$

The φ clamping angle of cutting – that can be seen in the Fig. 4. – connection of the H/R function.

The middle chip thickness: $$e_{zköz} = \frac{e_z \cdot H}{\varphi \cdot R} = \frac{e_z}{1{,}425}\sqrt{\frac{H}{R}}$$

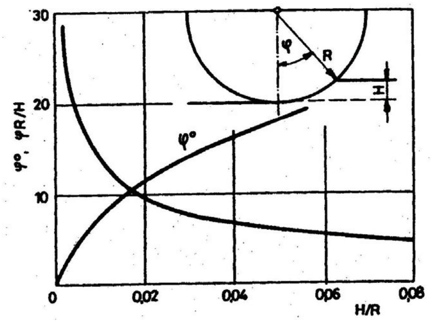

Fig. 4 The relative length's arc length of cutting, in the function of depth of cut

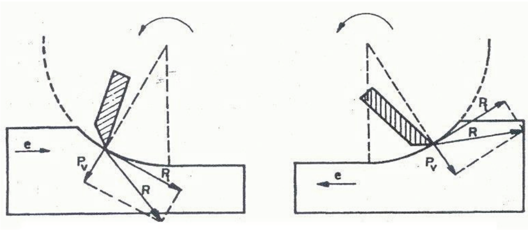

Fig. 5 Down- and backward-milling force conditions

Cutting can be backward and down orientated correlating to direction of feed. Between the two kinds of cutting there is more difference in many aspects. At down-milling the horizontal component of cutting force shows into the direction of feed, so the work piece can be fooled under the tool at not good clamping. That is why it can't be used to manual feed.

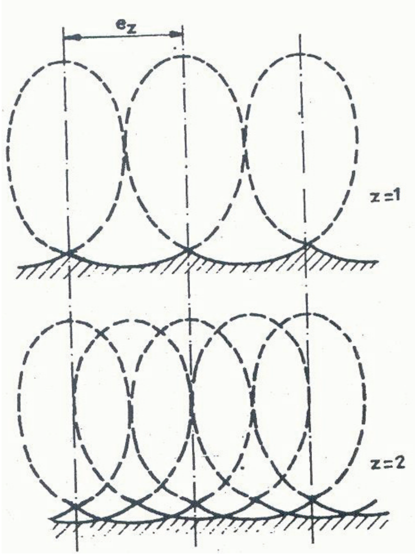

Fig. 6 Waved surface formed by plane and milling knife

At backward-milling the horizontal component of cutting force is opposite to direction of feed.

Down- milling makes smoother surface, because the cutting edge always induce on the material. At backward-milling the edge induces final tension on the material too, which can cause fiber ripping. But the big cutting velocity through force of inertia allow usually of requited surface quality at backward-milling, too. In this project we would like to study these statements more particular.

The operations of planning and milling accompany the wavy surface through the cycloid path (Figure 6.). The waviness is described by wave depth, which is defined by the diameter, tooth number and revolution number of the tool and by the feed speed of the material.

The wave depth can be given in the function of the tool diameter (D), the tooth feed (ez), the revolution number (n) and the numbers of cutting edge (z) with the following formula:

$$t_1 = \frac{e^2}{4Dn^2z^2}$$

The wave depth at 0,03 – 0,3 μm is good surface, but the wave depth at 0,3 – 1,2 μm means middle good surface quality.

THEORETICAL BACKGROUND OF THE MEASUREMENT

Force meters

The piezo electric tools used for dynamic effects differ from the vibration meters in a way that there is no seismic mass but we charge directly the crystal in an appropriately built housing. The resulted charge's amount depends only on the dynamic effect. The PCB piezo electric three dimensional force measuring sensor used during our measurements can measure dynamic and quasi-stationary force values at the same time along the coordinate system's three (orthogonal) directions (Fx, Fy, Fz). [1]

EXPERIMENTAL METHODS

We connect the vibration- and force measuring sensors stated in the previous chapter to NI 9233 - type data collecting cards, which collects and organize data. The data collecting card

is built in into a NI cDAQ card slot, which transmits data through an USB port toward the computer. The computer processes data with the help of appropriate software (LabVIEW).
Some characteristic values:
Sampling: 5 million samples/ second/ card
Sample puffer's size: 2047 samples

VIRTUAL INSTRUMENTATION

Measurements based on personal computer can be realized with products offered by the National Instruments. The virtual instrument is such a program, which models a physical instrument's exterior and mechanism. The National Instruments, LabVIEW is a graphically programmable development environment, with which measuring-, process controlling applications can be made.

In our case we would like to represent dynamic effort as a function of time. On the virtual instruments, the horizontal time axe has been set between 0-0,2 seconds, the force axe has been set between -3000 - 3000 N. The measuring system is adapted for the implementation of various measurements and during it we can measure the dynamic impacts arising during cutting.

The exercises of the measurement are the following:

In the case of vacuum- and rigid clamping, measurement and comparison of originated the forces.

THE WORKING TOOL

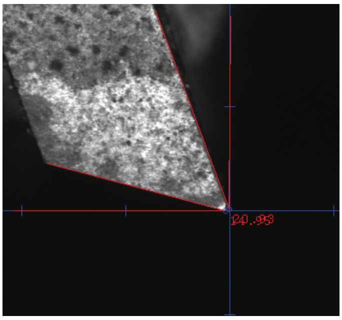

Fig. 7 The cutting edge

For the cutting, we have used straight edged removable hard metal tipped cutter. We measured the tool with optical tool measuring microscope type Zoller Smartcheck.

The measured tool dates:

Bevel angle: 64,12°

Rake angle / clearance angle: 20,93°/14,96°

Max. revolution number: 18000 revolution/min

PARAMETERS OF MEASUREMENT

We have done the force measurement in the case of a 20 mm beech wood panel on one side. It is common among the measurements that we have done conventional milling along X in every case. In the case of comparison investigation, we have done the milling with 6000, 8000, 10000, 12000 revolutions by cutting depths (1.0 mm) with four different feeding (5.0, 7.0, 10.0, 12.0 m/min).

RESULTS

Given that we used straight-edge tool, we didn't examine the role of vertical force.

Specific force on the process of down- and backward-milling in the function of cutting speed.

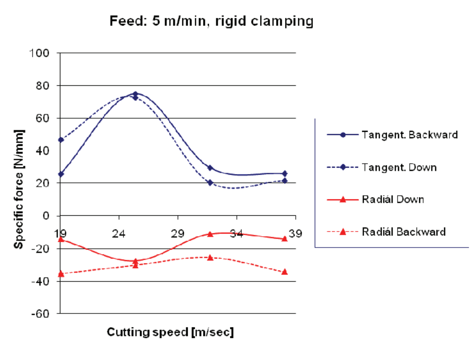

Fig. 8 Rigid clamping

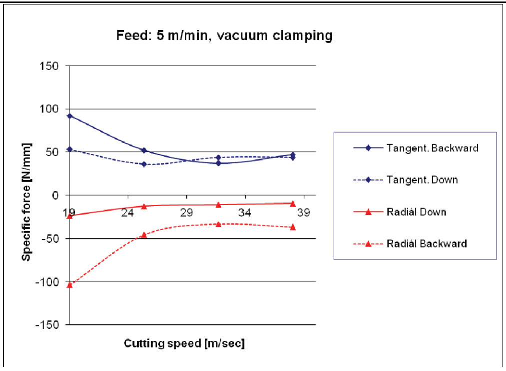

Fig. 9 Vacuum clamping

The tangential components of specific cutting force take on nearly the same values at backward- and down-milling. But at a reached maximum value increasing the velocity it begins to decrease at rigid climbing (Fig. 8.).

The tangential component of specific cutting force take on nearly the same values at backward- and down-milling and at vacuum clamping it is described by gradual decreasing (Fig. 9.).

The down-milling's radial force component is nearly half compared to backward-milling, there were examined at different cutting speeds.

It is usually true, that at vacuum clamping mostly bigger force components come out on the process of the backward- and down-milling.

Specific force on the process of down- and backward-milling in the function of feed speed.

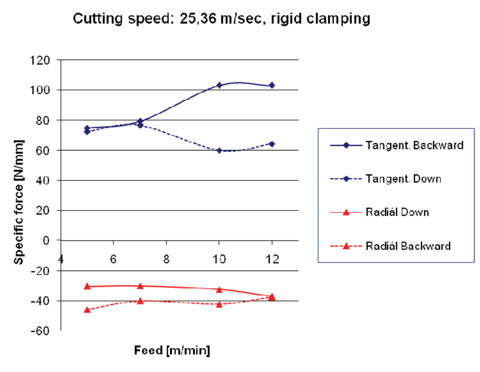

Fig. 10 Rigid clamping

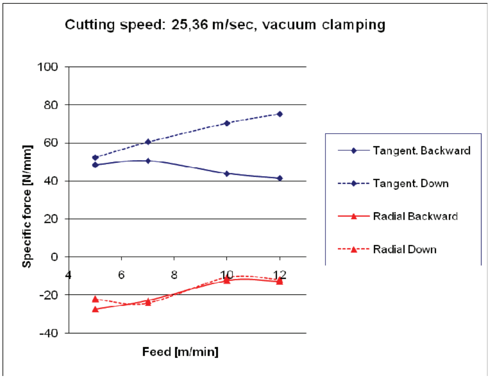

Fig. 11 Vacuum clamping

The tangential component of specific cutting force take on diverse values at bigger feed. In the process of backward-milling there are considerably higher values (Fig. 10., 11.).

The radial component of force by increasing the feed speed gives nearly the same values in the process of the backward- and down-milling.

We can usually say that at vacuum and rigid clamping examining radial forces in the process of the backward- and down-milling the force values are nearly the same. Opposite that at tangential forces at vacuum clamping the values of the backward-milling are sulostantially lower than the down-milling by the increasing the feed speed.

Surface roughness in the process of the backward- and down-milling in the function of the tool speed

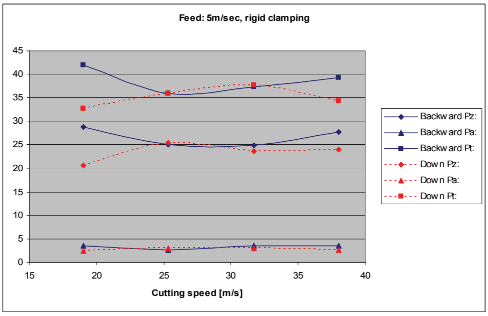

Fig. 12 Rigid clamping

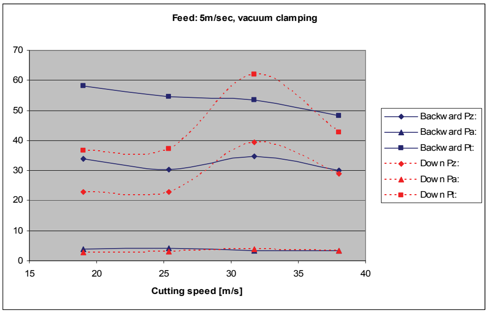

Fig. 13 Vacuum clamping

Surface roughness at rigid clamping in the process of the backward and down milling gives nearly the same values, it is described by 3 parameters, peak-to-valley height (Pz), average roughness (Pa), and maximum height of the profile (Pt) (Fig. 12.).

The surface roughness at rigid clamping in the process of the backward and down milling gives nearly the same values by average roughness (Pa) parameter, but peak-to-valley height (Pz) and maximum height of the profile (Pt) show diverse values (Fig. 13., 15.). It is clearly representative, that comparing rigid and vacuum clamping the rigid clamping generated better surface.

Surface roughness in the process of the backward- and down-milling in the function of the feed speed

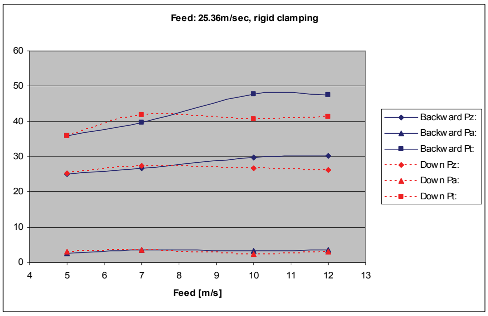

Fig. 14 Rigid clamping

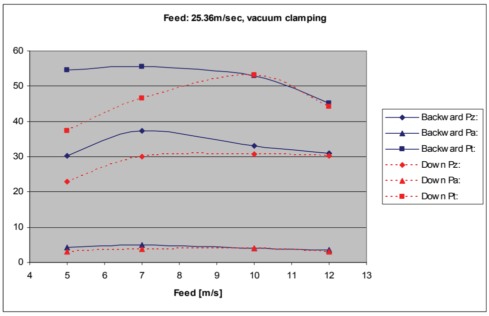

Fig. 15 Vacuum clamping

Surface roughness at rigid clamping in the process of the backward and down milling gives nearly the same values, it is described by 3 parameters, peak-to-valley height (Pz), average roughness (Pa), and maximum height of the profile (Pt) (Fig. 14.). To be sure, increasing feed the roughness deteriorates in same degree.

CONCLUSIONS

The first project results were very interesting, we could see the main statutory, but there are effects, which need more tests.

It is usually true, that at vacuum clamping mostly bigger force components come out on the process of the backward and down-milling in the function of tool speed.

We may relate the feeding velocity increased that at vacuum and rigid clamping examining radial forces on the process of the backward and down-milling the force values are nearly the same. Opposite this in case of tangential forces at vacuum clamping the values of backward-milling increasing feed speed are much lower than the values of down-milling. At rigid climbing it is inversion.

The heart of matter examining surface roughness it is clearly typical, that comparing rigid and vacuum clamping the rigid clamping productive of better surface either in the function of tool speed or feed speed.

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