

AUTOMATIC SETUP FOR TRIGGERING FORCE TESTING OF TOUCH-TRIGGER PROBES

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Abstract – The automatic setup for touch-trigger probes' triggering force was developed as a modification of the setup for testing of the probes' triggering radius using the moving master artefact method. In this paper, construction of the setup, its principle of operation and its uncertainty's estimation are presented, as well as exemplary results – characteristics of the triggering force of 2 probes for CNC machine tools: OMP40-2 3-point kinematic probe and IRP32.00-MINI 1-point kinematic probe.

Keywords: triggering force, touch-trigger probes

1. INTRODUCTION

Touch-trigger probes are widely used in coordinate metrology, not only on coordinate measuring machines, but also on CNC machine tools [1-3]. In both cases their accuracy is seriously connected with their triggering force variation [4-7]. Moreover, the triggering force can cause deflections of flexible elements. Those deflections additionally decrease the measurement accuracy. That's why the need for testing the triggering force of touch trigger probes exists.

The popular method of the probes' triggering force testing is using a Renishaw gram gauge [5, 8]. This method is simple, but it cannot be automated. A novel setup for testing of the triggering force was therefore proposed to overcome this limitation.

2. SETUP FOR TRIGGERING FORCE TESTING

2.1. Method of triggering force testing

The developed device is based on a previous setup for probes' triggering radius testing [9]. The operating idea scheme is shown in Fig. 1. The tested probe (1) is fixed. Its stylus tip (2) is placed in the centre of the inner hemisphere master artefact (3). The master artefact is mounted to the 3-axis force sensor (4) which is placed on the 3-axis piezostage (5). The control unit (6) generates signals controlling the piezostage's position and acquires signals from the force sensor and from the piezostage's displacement sensors.

To perform a measurement, the piezostage moves in a given direction. The master artefact's surface contacts with the stylus tip and the probe gets triggered. Signals from the force sensor and from the probe are synchronised, so it's possible to find a value of the force in every of the 3

directions in point of triggering. Basing on these values, total triggering force's value is calculated.

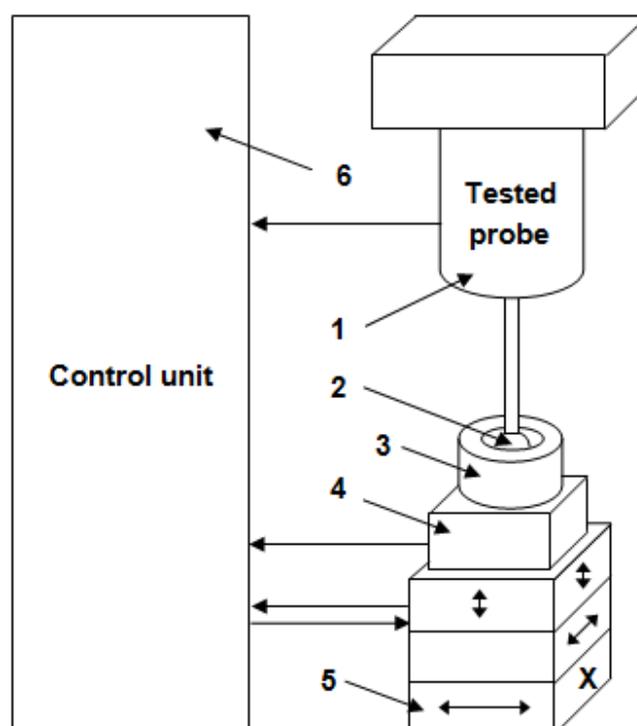


Fig. 1. Scheme of setup for triggering force testing.

2.2. Practical implementation of the method

The mechanical part of the developed setup is presented in Fig. 2. The tested probe is mounted in a vertical, linear guide (7), while Physik Instrumente P-615.3CD NanoCube piezostage is mounted on horizontal, XY, screw-driven stage (8). This system allows to roughly preset the stylus tip near the centre of the inner hemisphere master artefact. The fine setting is done using piezostage.

All components of the setup are fixed together using a lightweight, fully portable, modular frame (9).

The Kraftsensor K3D60 strain-gauge sensor is used as force sensor. Its range equals ± 10 N, so it's possible to test the CNC machine tool probes of much higher triggering force that of the probes for CMMs.

The control unit is built on the base of the National Instruments NI USB-6259 BNC data acquisition card. Signals from the force sensor are sent to this card by the

multichannel amplifier. NanoCube works in a closed loop with the Physik Instrumente E-500 modular controller with the E-509 and the E-802 modules.

The triggering signal from the probe is received by a dedicated, wireless interface receiver. It is transferred to the data acquisition card via additional electronic devices.

All the components of the setup are fully portable and can be transported by one person, so it's possible to test the probes in customer's place of choice.

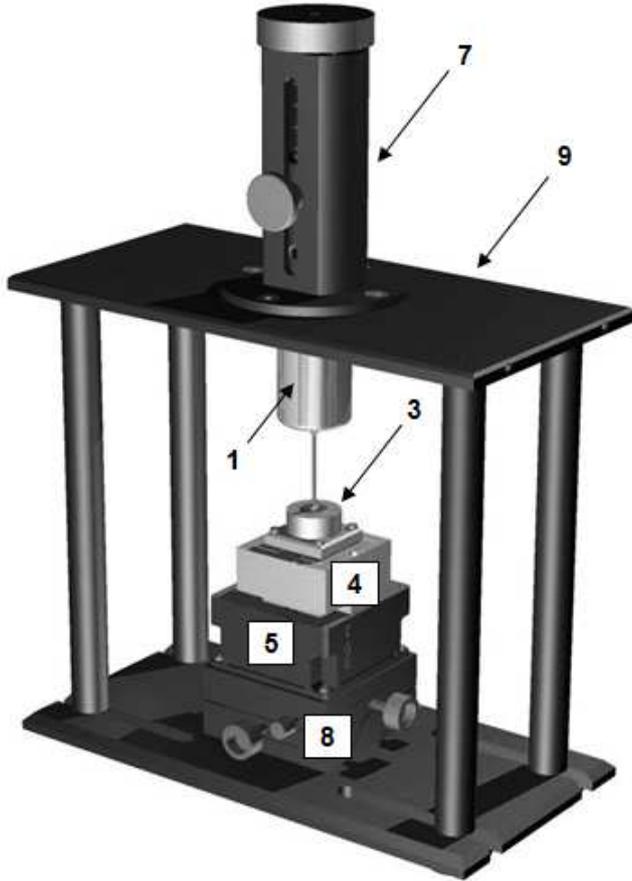


Fig. 2. View of the setup for triggering force testing.

2.3. Setup's calibration and uncertainty estimation

The 3-axis force sensor calibration was performed with a force sensor of greater precision, the Mecmesin Advanced Force Gauge with a range equal to ± 10 N in X and Y (horizontal) axes and using M1 class weights in Z (vertical) axis. For every set force 1000 measurements of voltage given by the force sensor were done. Then, for every axis the regression equation was determined and the obtained voltage values were changed into measured force values. Results of calibration for the X, Y and Z axes are shown, respectively, in Fig. 3, Fig. 4 and Fig. 5.

For X axis the largest absolute value of measured force deviation $\Delta F_{TX} = 0.11$ N, for Y axis $\Delta F_{TY} = 0.10$ N and for Z axis $\Delta F_{TZ} = 0.17$ N. Because statistical tests showed that obtained deviation values do not come from normal distribution, it was assumed that the distribution is rectangular. In that case the standard uncertainty of force measurement in the i axis is given by:

$$u(F_{Ti}) = \frac{\Delta F_{Ti}}{\sqrt{3}}. \quad (1)$$

Standard uncertainty of a single total force measurement $u(F_T)$ can be estimated by:

$$u(F_T) = \sqrt{u(F_{TX})^2 + u(F_{TY})^2 + u(F_{TZ})^2} \quad (2)$$

and its value equals 0,13 N.

If measurement is performed multiple times for every direction, uncertainty can be calculated from:

$$u(\overline{F_T}) = \frac{u(F_T)}{\sqrt{n}}, \quad (3)$$

where n is a quantity of measurement repetitions.

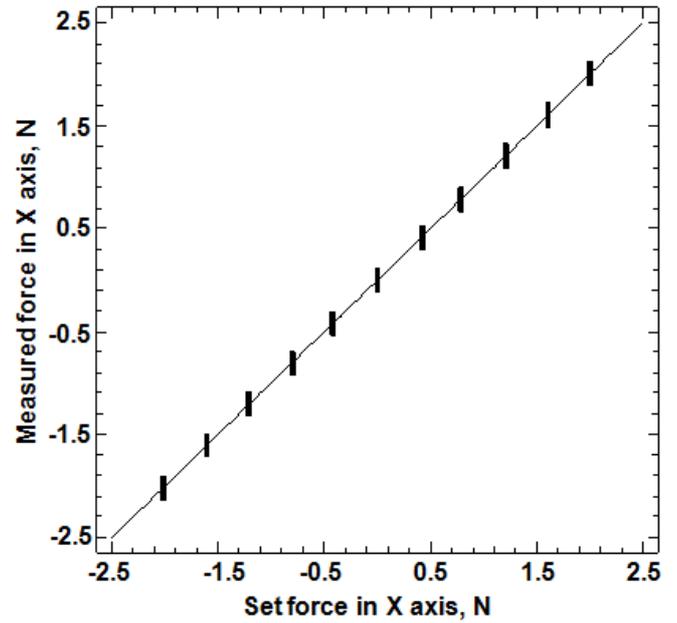


Fig. 3. Calibration results for the X axis.

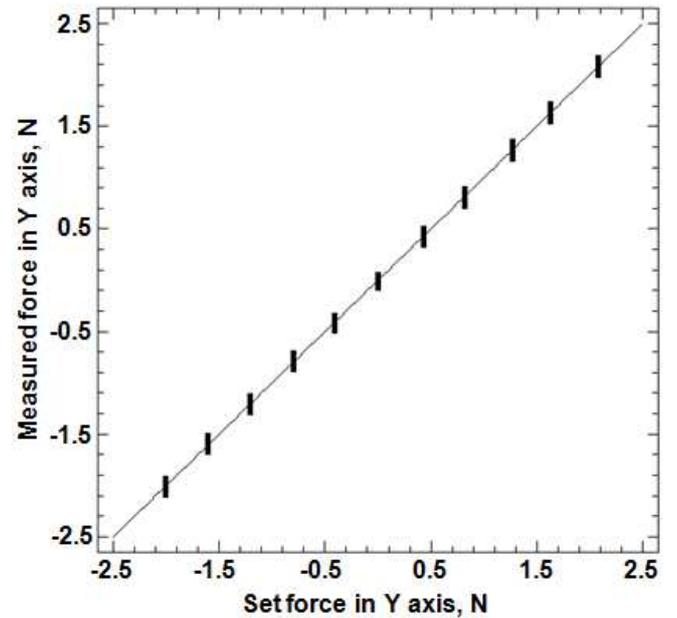


Fig. 4. Calibration results for the Y axis.

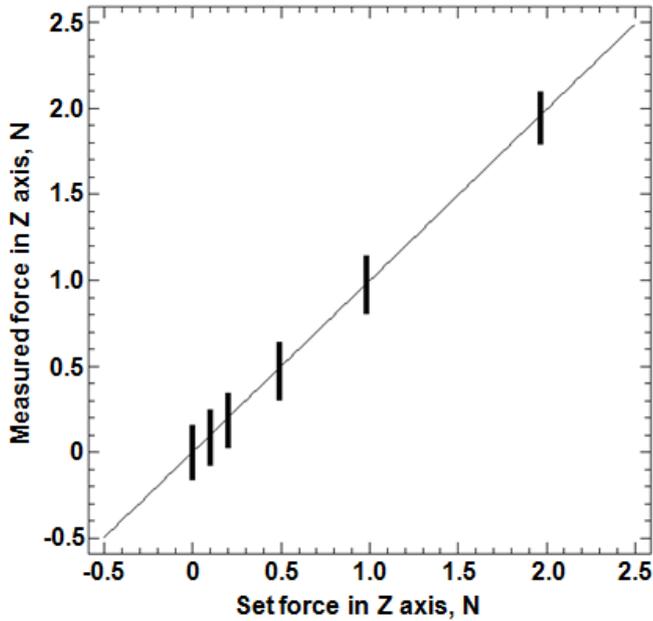


Fig. 5. Calibration results for the Z axis.

Standard measurement strategy for the developed setup assumes 10 measurements in every directions, so the standard uncertainty of mean total force measurement is

0.04 N and the extended uncertainty of force measurement for coverage factor $k = 2$ equals 0.08 N.

3. EXEMPLARY RESULTS

To verify the setup's performance 2 probes for machine tools were tested: Renishaw OMP40-2 3-point kinematic probe and m&h IRP32.00-MINI 1-point kinematic probe.

Characteristic of triggering force of the OMP40-2 probe is shown in Fig. 6, where α is angle defining probe's working direction in XY plane (plane perpendicular to probe's axis) and β is angle between probe's working direction and XY plane. The OMP40-2 triggering force characteristic for small β angles is distinctly 3-lobed. Moreover, the bigger the β angle is, the bigger the triggering force is. These phenomenon are consistent with the common knowledge about 3-point kinematic probes. Minimal value of this probe's triggering force $\min F_T = 0,75$ N, while its maximal value $\max F_T = 5.84$ N.

Characteristic of triggering force of the IRP32.00-MINI probe is shown in Fig. 7 and its sections are quasi-circular. As in the case of 3-point kinematic probe, the shape of the IRP32.00-MINI triggering force characteristic is consistent with the common knowledge about 1-point kinematic probes. Minimal value of this probe's triggering force $\min F_T = 1.33$ N, while its maximal value $\max F_T = 4.90$ N.

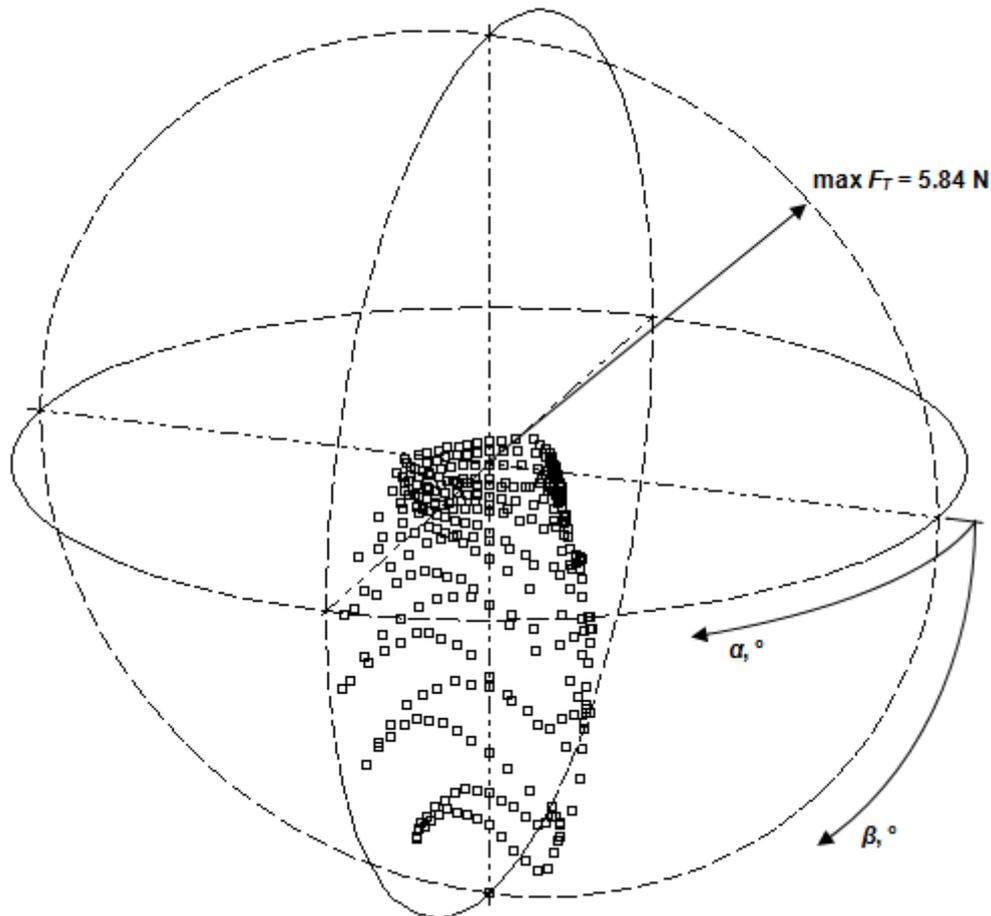


Fig. 6. Triggering force characteristic of the Renishaw OMP40-2 probe.

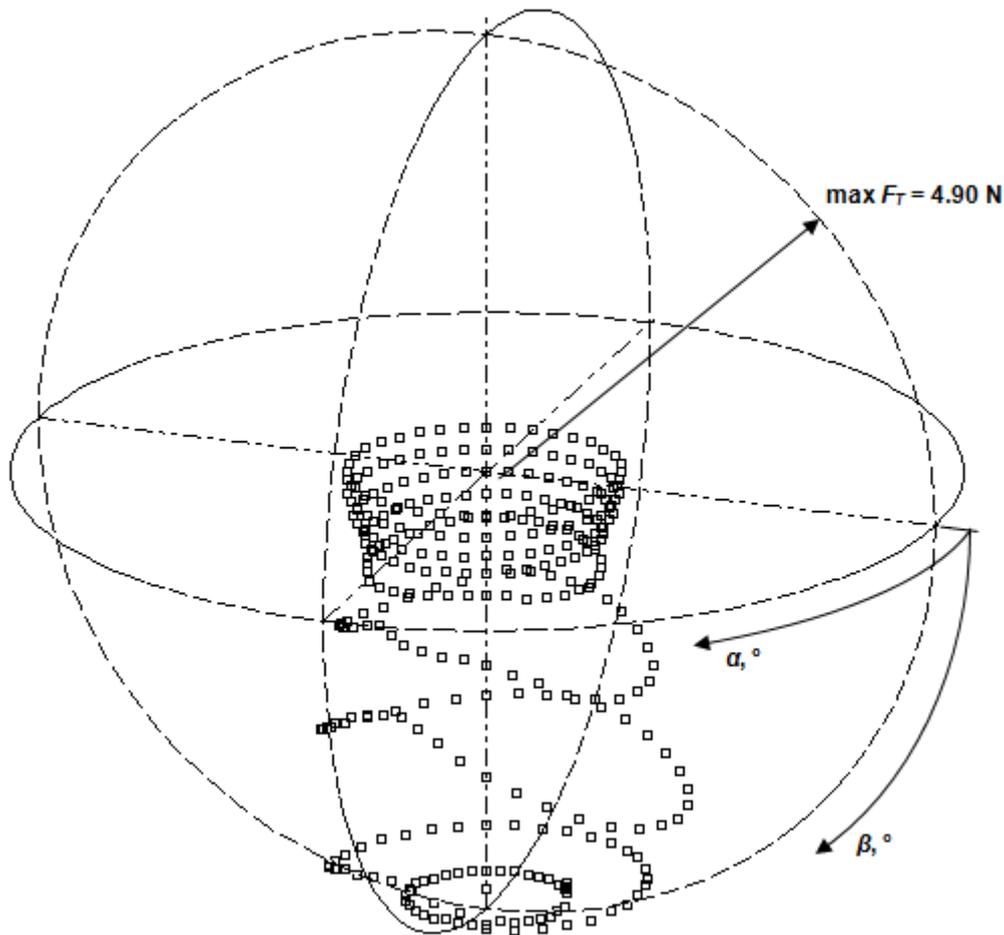


Fig. 6. Triggering force characteristic of the m&h IRP32.00-MINI probe.

4. CONCLUSIONS

The setup for testing of the touch trigger probes' triggering force was developed as a modification of the previous setup for testing the probes' triggering radius. The setup's extended uncertainty equals 0.08 N when repeating measurement 10 times in every direction. Measuring range of the setup is big enough to test the probes for the CNC machine tools.

To verify the setup's performance 2 different probes for machine tools were tested. Obtained characteristics confirm the setup's ability to test CNC machine tool probes.

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