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STRAIN GAUGE TOOL PROBE FOR NC LATHES *

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ABSTRACT
The main role of tool probes in NC machine tools. The probes used now in industry and their drawbacks. The original concept of a tool probe using full strain gauge bridges for orientation of tool edges in four directions: +X, -X, +Z, -Z and for direct tool wear measurement.

1. INTRODUCTION

The rapid development of all areas of manufacturing technology and the aim to reduce costs, increase precision and to shorten production time are enforcing the use of modern production technology. Dimensional parameters are the most commonly encountered quality characteristics of workpieces. Conventional machine tools are gradually being replaced in production plants by modern manufacturing systems, components of which, in the case of machining, are CNC machines. Main new CNC machines operate several different tools.

To increase dimensions accuracy of components manufactured in CNC lathes we must use tool setting systems to know how the tools are located on the machine. Using traditional techniques, tool setting is time consuming and can be prone to human error. A touch probe system is an inspection equipment that allows a machine tool to perform geometrical measurements inside its working area, but besides tool tip coordinate identification, we must have information about tool wear.

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From all elements of manufacturing systems cutting edges wear is the fastest. In case of total wear we must replace a worn out tool with a sharp one. Cutting edge wear starts from first moment when touching the working material. Tool wear may be gradually, in case mechanical, chemical or temperature activity in turning process and we call them **natural wear**. In some cases tool wear is sudden – when we have forces above the yield point and we call them catastrophic tool breakage (KSO).

2. INDUSTRIAL TOOL SETTING SYSTEMS

When clamping a new tool on the machine or after the replacement of a worn out tool with a sharp one we must have information about orientation of tool edge. During writing the part program, the path of the tool tip is described by an assumed system co-ordinates, without knowing how the tools will be located in the machine. The corrective coordinates are defined during the orientation of the tool tip by the tool probe, and are then entered for every tool in the tool table stored in the machine control unit. While interpreting, the machine controller adjusts the points of the edge path by the values read from tool table.

Figure 1 presents use of a standard touch trigger probe system for determination of X co-ordinate of the tool edge.

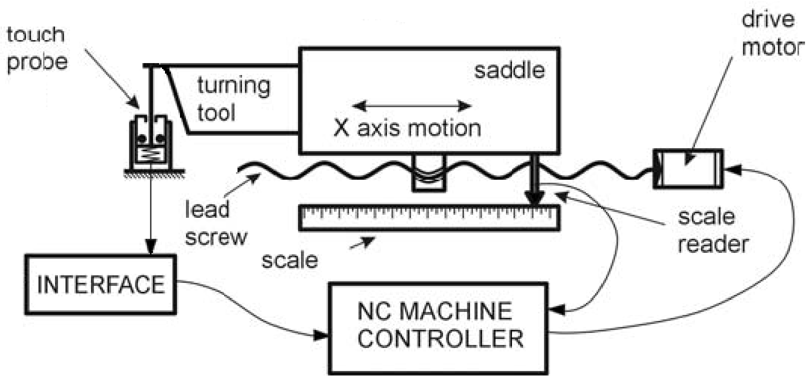

Fig. 1. The use of a standard touch trigger probe system for determination of X co-ordinate of the tool edge [1].

When tool tip touches probe stylus, the contact sensors in its result are opened, the value of the coordinate of the location of the saddle, which is read from the machine measuring system, is automatically entered into the register of the control unit reflecting the number of the measured tool and then the saddle motion is switched off. These probes only need to signalize that contact between tool tip and probe stylus was occurred.

Standard tool setting system used touch-trigger probes. The most known is RP3 probing system (Figure 2) designed by Renishaw [2, 3].

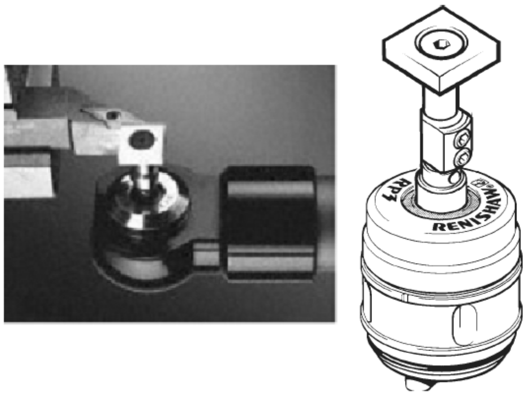

Fig. 2. Renishaw RP3 probe [3].

The sensing of contact between workpiece and the probe is done by electric switches, witch strongly determine the repeatability and accuracy of probing.

The original touch-trigger probe also called „kinematic resistive Probe" (Figure 3), works with a set of three cylindrical pegs attached to the stylus. Each of them rests on two separated electric contacts that gives altogether six points of constraint for the six degrees of freedom of the stylus. An electric circuit is built out of these contacts, which is closed, when the stylus is in its neutral position. When the stylus touches the tool tip a further constraint point is added and so the pressure on one of the original constraint points is reduced, which changes the resistance of the electric circuit. The contact between stylus and tool tip is signaled when a certain threshold value of resistance is exceeded.

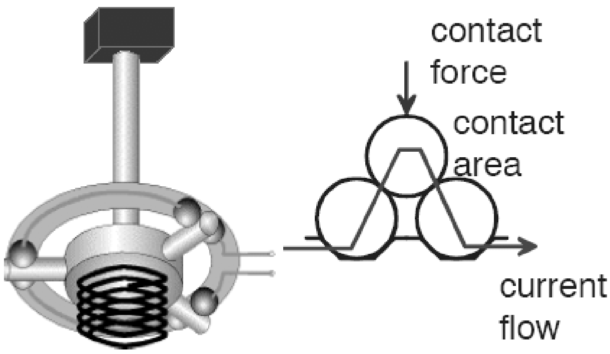

Fig. 3. Touch-trigger probe [4].

3. INDUSTRIAL TOOL MONITORING SYSTEMS

KSO must be detected very fast and after that we must provide necessary changes in turning process. That means that automation of turning process needs automatic detect and properly react in case of KSO. Method and range of this monitoring depend on process type. We have many industrial systems which can detect KSO.

Natural wear is difficult to measure, but we don't need fast reaction from monitoring systems – the reason are continuous changes of tool wear value.

We have many industrial types of tool monitoring systems (Figure 4.), we measure:

- cutting forces
- effective power
- torque
- acoustic emission
- differential pressure
- distance measuring with cooling lubricant
- jet barrier using laser, air or cooling lubricant

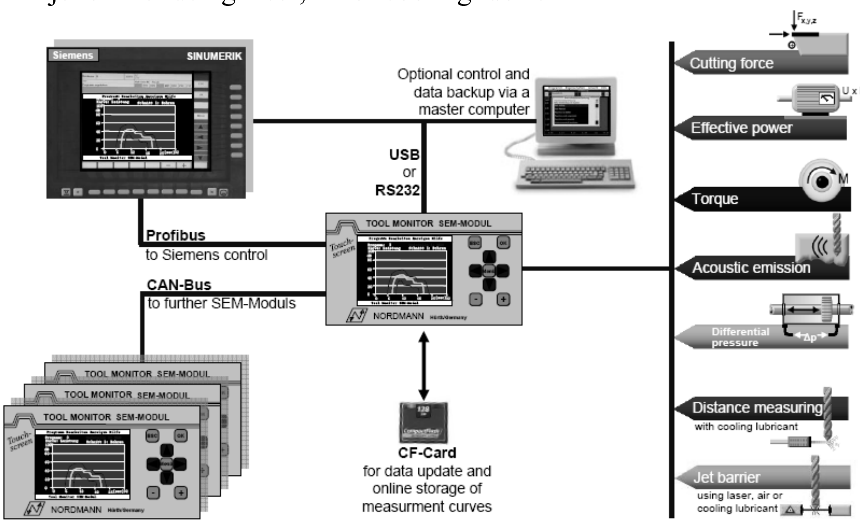

Fig. 4. Tool monitoring systems (Nordmann). [5]

We can mark out two types of monitoring in-process: monitoring and post-process tool monitoring.

POST-PROCESS TOOL MONITORING

Post-process tool monitoring is tantamount to geometry control of the tool cutting edge before or after the chip producing process with feelers, light barriers, or similar devices.

Pro:

- Sometimes high certainty of detection of breakage
- Typically easier usage

Contra:

- Measurement can lengthen the production time
- Machine is only stopped after tool breakage, i.e. possible damage to the work piece or the machine or the tool holder as a result of the forces incurred
- Not all testing methods are free of wear

IN-PROCESS TOOL MONITORING

Indirect control during the metal cutting process of effective power, cutting force, or acoustic emission.

Pro:

- The measurement does not extend the production time
- Machine is stopped at the moment of tool breakage
- No additional installations (e.g. control switch) are necessary near the tool
- Loss-free sensors.

Contra:

- Does not offer 100% guarantee of detection for all tool breakage
- Sometimes the breakage is only detected when the next work piece is cut, e.g. in the case of thread cutting control with effective power and breakage at the moment of reversal of spin direction.

All above industrial systems are not provide direct natural tool wear measurement. These methods mainly detect moment of the tool breakage or measure physical process parameters and based on these data, calculate natural tool wear. Mathematical description must include many process variables (e.g. heat expansion), consequently method based on mathematical models may have many errors even in self mathematical model which is only approximation of real process.

4. ORIGINAL PROBES FOR DIRECT TOOL WEAR MEASUREMENT AND FOR TOOL SETTING DESIGNED IN WARSAW UNIVERSITY OF TECHNOLOGY - STRAIN GAUGE PROBE

A. PROBE FOR TOOL SETTING

This is a new probe for identification of a tool tip co-ordinates on an NC lathes and for tool setting [6]. The main part of this probe is a round bar. Stylus with crash protection device is connected with bar. The bar has two parallel flat surfaces on a part of its length. They are oriented under angle 45˚ in respect to X and Z axes of NC lathe (Figure 5).

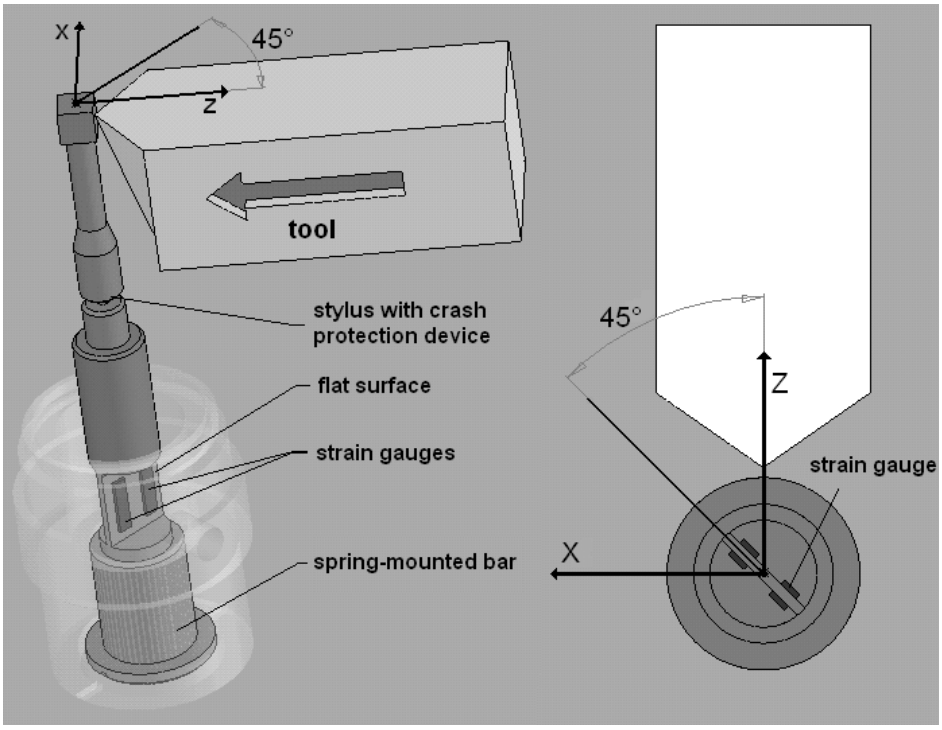

Fig. 5. Original measurement conception [7].

Four strain gauges are glued on those flat surfaces (two of them are placed on the one side and the two other on the opposite side), the strain gauges are connected in a full bridge with all active gauges. This original design allows the possibility of tool tip co-ordinate identification in four directions of tool movement (-X, +X, -Z, +Z NC lathe axes) using only one full bridge sensor.

When tool tip touches the probe stylus and moves forward, it deforms the flat and flexible part of bar. The maximum value of deformation must be kept below yield point defined by material properties.

An actual value of analog electrical signal from strain gauges is compared continuously with a defined level of signal. When compared signals are equal, the comparator sends a signal to a NC machine controller to read value of the co-ordinate of location of the saddle from linear scale. The probe accuracy is placed in repeatability of generating this signal by comparator. Acceptable repeatability must be near 1μm.

B. PROBE FOR MEASURING TOOL WEAR

Next probe is designed for both tool co-ordinate identification and tool wear evaluation in turning (Figure 7). The newest conception gives a possibility measuring the natural wear at the tool tip in the same time as identification of the tool co-ordinates. It is significant that both measuring components of the probe meet directly on the cutting plate. This allowed for elimination of errors e.g. unequal heat expansion of the seat and this plate.

Strain gauges are mounted on the flexible sleeve and on the flat part of the bar (Figure 8). Worn part of the tool tip touches the first plate mounted on the bar, in next step base part of the tip (not worn) touches the second plate mounted on the sleeve. We have signals from both full strain bridges.

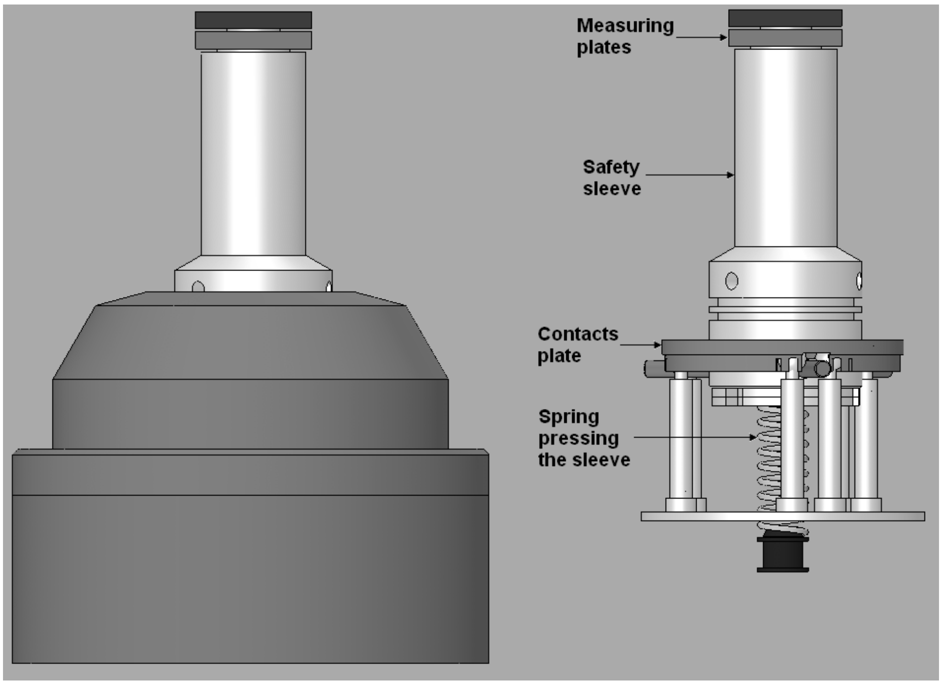

Fig. 7. Tool probe for measuring tool wear.

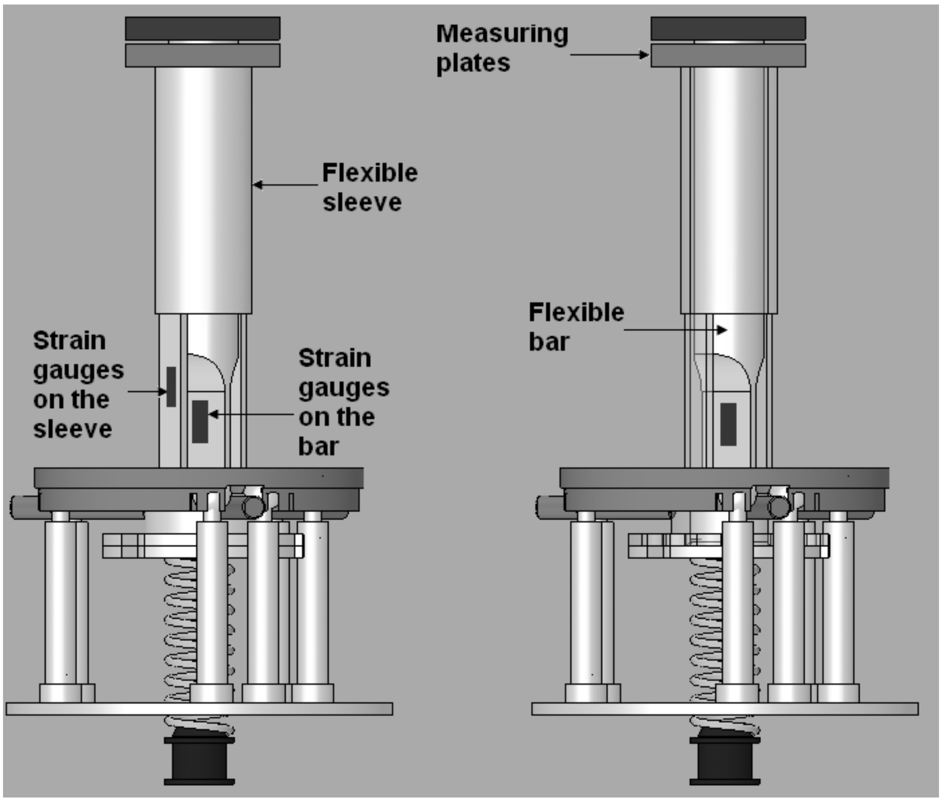

Fig. 8. Probe construction.

Measurement of the new insert is used as a reference. During measurements after machining the obtained value is subtracted from the reference one and calculates current wear of the cutting edge (KE) (Figure 9).

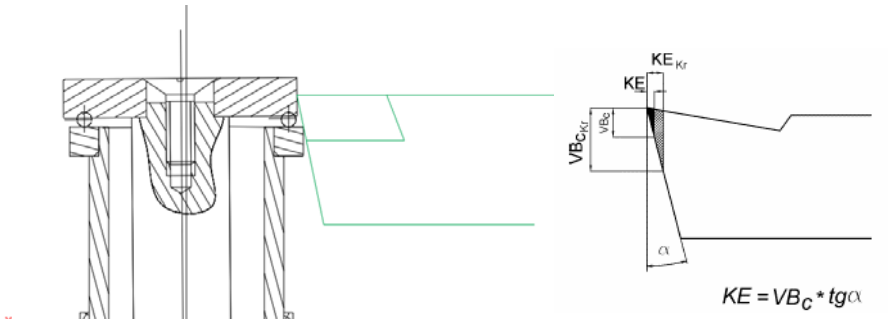

Fig. 9. KE calculation.

When tool moves and touches plate mounted on the bar and flexing the bar. Reaching defined level of signal from strain gauges mounted on the bar is signaled by sending digital signal to machine control unit to identify tool tip coordinate. We also have continuous analog signal from gauges and we can calculate this signal to the value of plate dislocation. When tool moves forward not worn part of the tool tip touches second plate mounted on the sleeve and flexing the sleeve. Reaching defined level of signal is signaled by sending digital signal to control unit to remember actual analog value from gauges mounted on the bar. This value (subtracted to the reference one) is the current tool wear value (KE).

We will try to use Siemens Siwarex U (Figure 10)- weighing module as a transducer. We can connect to them 2 full strain bridges and sending signals to machine control unit. We also consider building own control unit with cooperation with polish company ZEPWN [8].

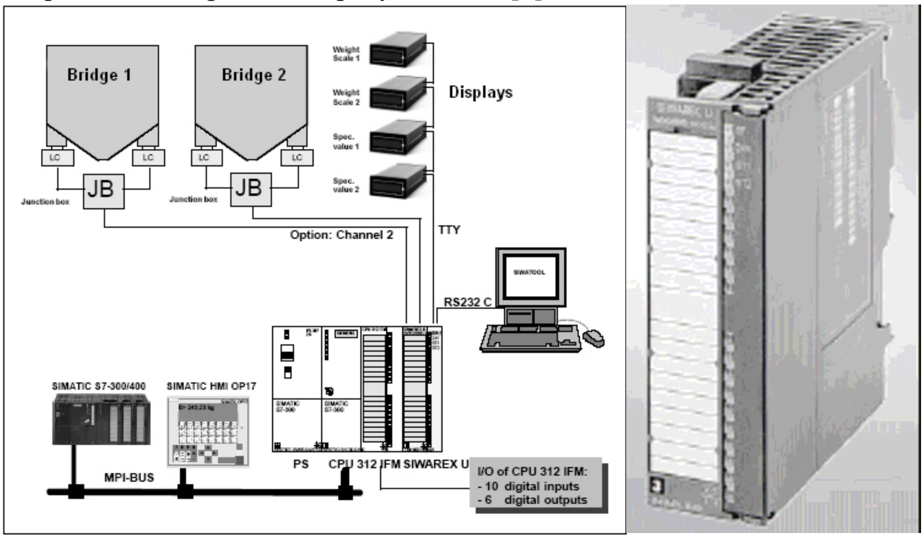

Fig. 10. Siemens Siwarex U – weighing module [9].

5. CONCLUSION

This probe will be an alternate solution in comparison with a standard tool probe. The strain gauges were never being used as a main part of a tool probe. The results of first tests demonstrate, that a probe with a strain gauge sensor based on presented original measurement conception, is suitable for both orientating the tool tip in the NC lathe co-ordinates and for tool wear measurement. After all tests we will try to adjust the probe for industrial application.

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