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STRAIN GAUGE TOOL PROBE FOR NC LATHES

Keywords

Tool probe, tool wear, tool wear measurement, strain gauge tool probe, NC lathes.

Abstract

This paper shows the original probe which is protected by patent pending, and original method which is developed for direct wear measurement at the tip of the cutting edge in turning. The measurement is made automatically on a NC lathe by means of a special probe, which enables at the same time, to determine the X, Z co-ordinate of the edge. The modified probe has 4 strain gauges connected to full-bridge sensor. The sensor is placed on a flat surface which is mounted under angle 45 degree in relation to measurement direction. This probe has a possibility of 4-axis measurement, in X^-, X^+, Z^-, Z^+ direction of tool movement using only one full-bridge sensor. The results of laboratory tests show great promise in a number of industrial applications.

Introduction

The rapid development in all areas of manufacturing technology is aimed at shortening production time, reducing costs and increasing accuracy. Today's market is enforcing the use of modern production technology. In the case of machining, conventional machine tools are gradually being replaced in production by NC machine tools. The NC machine tools allow using machining with automatic control even for small batch production, increasing both machining efficiency and workpiece accuracy.

To achieve dimensional accuracy of a workpiece after machining on a NC lathe the tools should be located relevant to the workpiece according to the NC program – the proper tool setting is needed. A traditional technique used for a tool setting is by touching the known surface of the workpiece with the tool edge and registering the actual position of the tool in the NC controller. The process is time consuming and can be prone to human error. Because of these drawbacks, in a typical case in which several tools are needed, only one of them is located in this manner, and, for the setting of the rest of them, a tool probe is used. A tool probe is now typical equipment for every NC lathe. The common use of tool probes created the idea of a special tool probe, which could be used, not only for tool setting, but also, at the same time, for direct measurement of tool wear. The original double-touch tool probe has been developed for this purpose.

Among all the elements of machining systems, the cutting edges are the most prone to wear. When the tool is worn out, it should be replaced by a sharp one. Cutting edge wear starts from first moment of cutting. It is natural wear caused by mechanical, chemical or temperature phenomena in the turning process. In some cases, tool wear is sudden – when the cutting forces are above the allowed level the cutting is destroyed. It is so called Catastrophic Tool Failure (CTF).

1. Industrial tool setting systems

When a new tool is added to the machine tool or after the replacement of a worn out tool with a sharp one, the information on the location of the tool edge should be sent to the NC controller. During writing the NC program, the path of the tool tip is described in the coordinates of the machine tool with assumed a location of the tools. The actual coordinates of the tools may be different than the coordinates assumed during programming. The actual coordinates should be defined during the tool setting and entered for every tool into the tool table stored in the machine tool controller. During machining, the NC controller adjusts the coordinates of the edge path in the NC program by the values read from the tool table.

Fig. 1 presents the use of a standard, touch-trigger probe system for determination of the X coordinate of the tool edge.

When a tool tip touches the probe stylus, the contacts of the probe open and the value of the coordinate of the location of the saddle is read from the machine tool coordinate system. The measured value is automatically entered into the register of the NC controller. The probe needs only to signal the touch of the tool tip to the probe stylus.

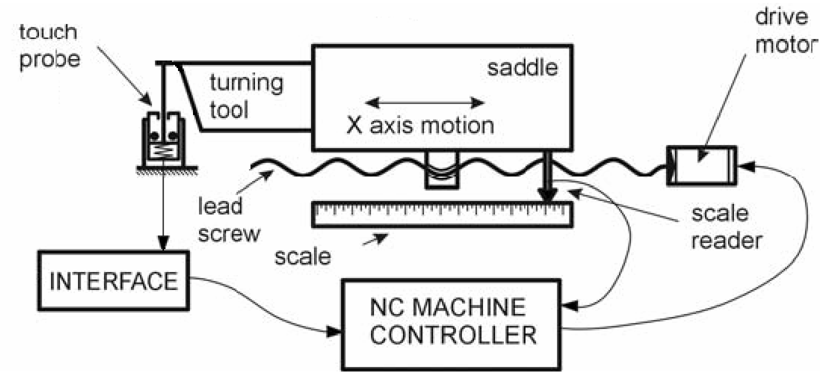

Fig. 1. The use of a standard touch trigger probe system for the determination of the X coordinate of the tool edge [1]

The standard tool setting system uses a touch-trigger probe. The best known is the tool probe RP3 designed by Renishaw (Fig. 2) [2, 3].

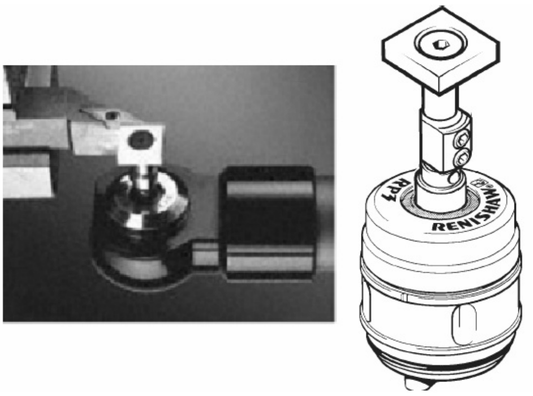

Fig. 2. Renishaw RP3 probe [3]

The contact between the tool edge and the probe stylus is signalled by electric switches. The accuracy of the switches determines the repeatability and the accuracy of probing.

The original touch-trigger probe also called ”kinematic resistive probe” (Fig. 3), works with a set of three cylindrical pegs attached to the stylus. Each of them rests on two balls that give six points of support altogether for the six degrees of freedom of the stylus. They also create an electric circuit built out of contacts between pegs and balls. The contacts are closed when the stylus is in its neutral position. When the stylus touches, the tool tip the pressure on one of the support points is reduced and that changes the resistance of the electric circuit. The contact between stylus and tool tip is signalled when a certain threshold value of resistance is exceeded.

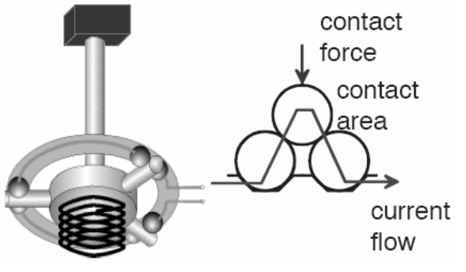

Fig. 3. Touch-trigger probe [4]

2. Industrial tool monitoring systems

The direct measurement of tool wear during cutting is impossible. There are many types of tool in-process monitoring systems (Fig. 4), based on the

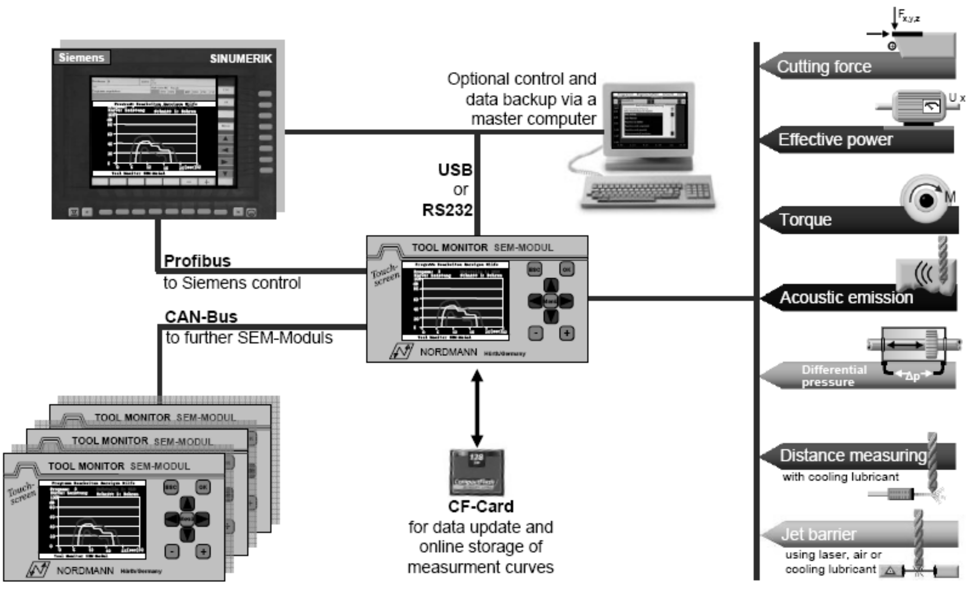

Fig. 4. Tool monitoring systems (Nordmann) [5]

measurement of physical values somehow related to the tool wear. The monitoring systems are using one or several of the following values:
- cutting forces,
- effective power,
- torque,
- acoustic emission,
- differential pressure,
- distance measuring with cooling lubricant,
- jet barrier using laser, air or cooling lubricant.

2.1. Post-process tool monitoring

Post-process tool monitoring is used mostly for detecting the tool breakage in machining of holes. The tool breakage is detected by feelers, light barriers, or similar devices either before or after machining.

Pro:
- quite high certainty of breakage detection,
- easy use for tools used in hole machining.

Contra:
- measurement can lengthen the production time,
- the 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.

2.2. In-process tool monitoring

Indirect monitoring during the metal cutting process can be in-process through the measurement of effective power, cutting force, or acoustic emission.

Pro:
- the measurement does not extend the production time,
- the machine is stopped at the moment of tool breakage,
- no additional installations are necessary near the tool,
- wear-free sensors.

Contra:
- does not offer 100% guarantee of the detection of 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 measurement.

These methods mainly detect the moment of the tool breakage. For monitoring natural tool wear there are attempts to use the measurement of these physical parameters and calculate the state of wear based on these data. Unfortunately, the mathematical description used for the purpose also depends on many other unknown process variables. In-process monitoring of the natural tool wear can be effective only in some cases of mass production.

It seems that CTF needs in-process monitoring. It must be detected very fast and when detected the turning process should be stopped immediately. That means that it should be continuously monitored during turning. Methods and ranges of this kind of monitoring depend on the type of process. There are many industrial systems that can detect CTF in turning.

Natural wear is difficult to measure, but there is no need for continuous monitoring and fast reaction. Monitoring of natural tool wear can be activated from time to time, following the increasing value of the tool wear.

3. Original strain gauge probes for direct tool wear measurement and for tool setting

3.1. The probe for tool setting

A new tool probe has been developed at the Warsaw University of Technology for tool setting on NC lathes [6]. The main part of the probe is a round bar that is flattened out in the middle. The surfaces of the flattened part of the bar are oriented under the angle of 45˚ respectively to X and Z axes of NC lathe (Fig. 5). Four strain gauges are glued to 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 tool tip coordinate identification in four directions of tool movement (-X, +X, -Z, +Z) using only one full bridge sensor. A stylus with a crash protection device is connected to the bar.

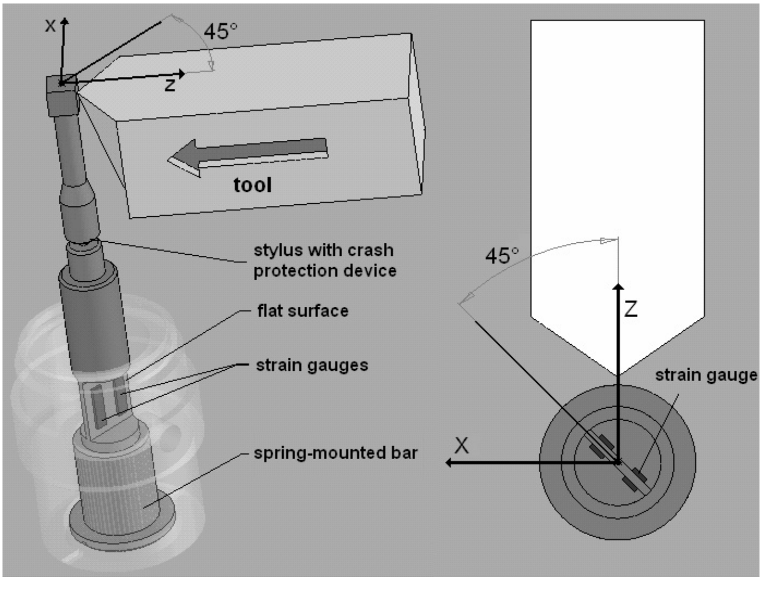

Fig. 5. The original idea of the probe [7]

When a tool tip touches the probe stylus it deforms the flat part of the bar. The maximum value of deformation is always kept below yield point defined by the material properties.

The analogue value of the electrical signal from the strain gauges is compared continuously to a defined test level of the signal. When the signal from the strain gauges is equal to the test value, a one-bit signal is sent to a NC machine controller to be read from the linear scale value of the co-ordinate of the location of the saddle. The probe accuracy is based on the repeatability of the comparator generating this one-bit signal. The achieved repeatability is about 1µm.

3.2. The double-touch probe for tool setting and wear measurement

A more sophisticated double-touch probe was designed for both tool co-ordinate identification and tool wear evaluation (Fig. 6). The probe provides the possibility of measuring the natural wear at the tool tip at the same time as the identification of the tool coordinates. It is important that, in wear assessment, the probe makes a distant measurement relative to the tool point located very close to the cutting edge. This allows the elimination of errors caused by temperature changes and unequal heat expansion, for example.

The double-touch tool probe has a flexible sleeve around the bar. Strain gauges are mounted both on the flexible sleeve and on the flat part of the bar (Fig. 7). The worn part of the tool tip touches the plate mounted on the bar and the signal is sent to the NC controller for the registration of the coordinate. But in this case, the tool is not stopped until the unworn part of the tool tip touches the second plate mounted on the sleeve. After stopping, there are two signals from two full strain bridges. The difference between the signals is important.

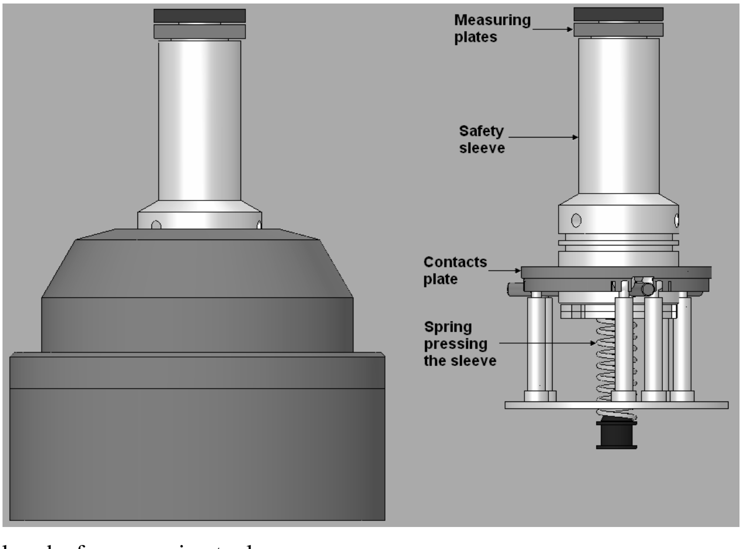

Fig. 6. Tool probe for measuring tool wear

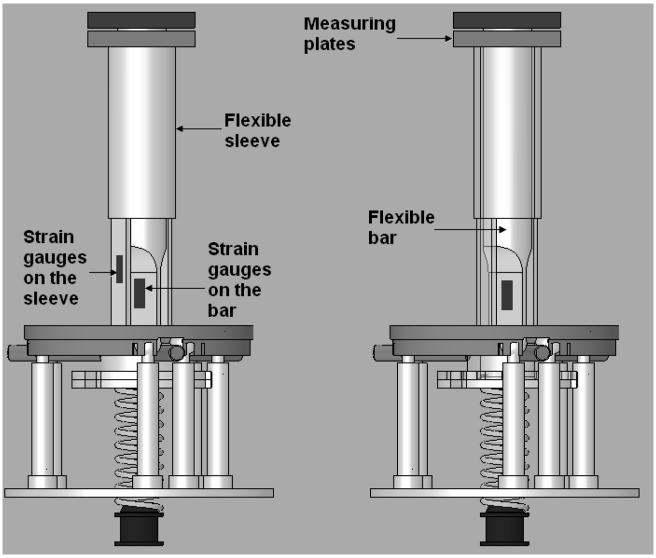

Fig. 7. Probe design

The difference in the signals measured on the new insert is used as a reference, during measurements, after machining the obtained value is subtracted from the reference one and gives the current value of the cutting edge wear (KE) (Fig. 8).

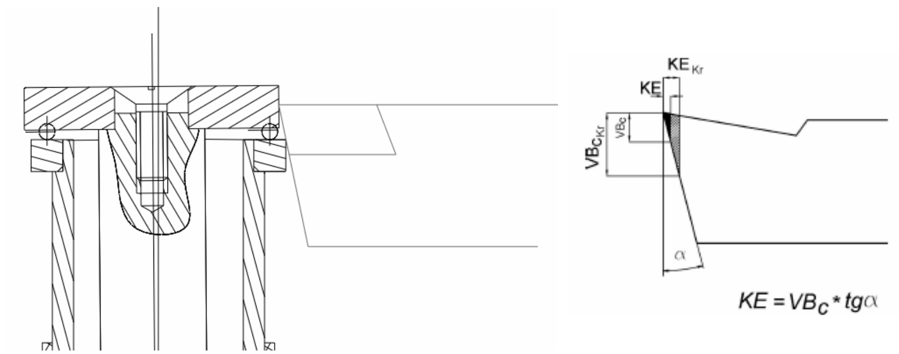

Fig. 8. KE calculation

For measurement deflections of the bar and the sleeve, the Siemens Siwarex U (Figure 9) weighing module is to be used. The Siwarex can accept two full strain bridges and can send signals to the machine NC controller. It is also possible to build a special control unit with the cooperation with a Polish company ZEPWN [8].

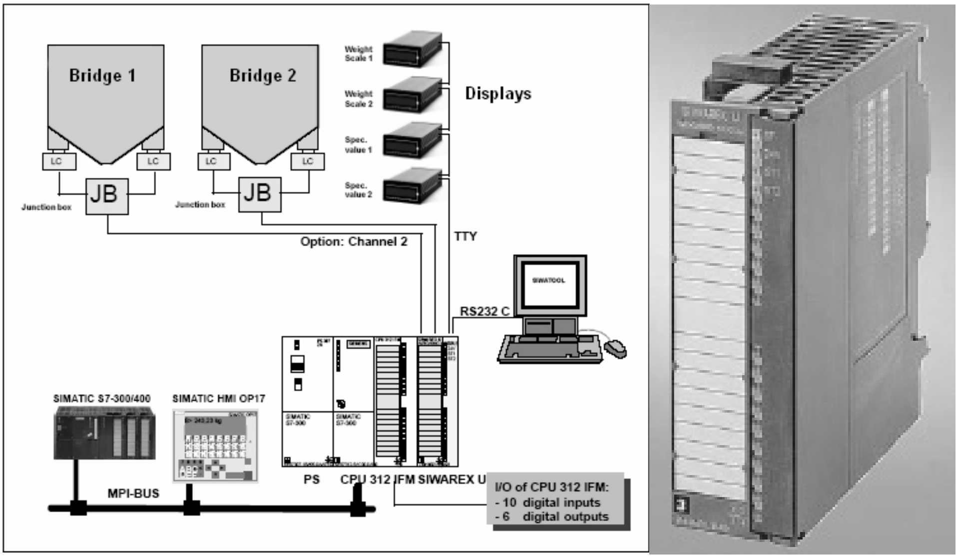

Fig. 9. Siemens Siwarex U – weighing module [9]

Conclusions

The first developed tool probe will be an alternate solution to a standard tool probe used on NC lathes. The results of tests demonstrate that a probe with a strain gauge sensor has better repeatability than a standard tool probe.

The double-touch tool probe seems to be suitable for both tool setting and for direct measurement of natural tool wear on NC lathes. From the point of view of application in industry, it is important that the double-touch tool probe can replace a standard tool probe presently used on NC lathes.

Acknowledgements

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Narzędziowa sonda tensometryczna

Słowa kluczowe

Sonda tensometryczna, sonda narzędziowa, naturalne zużycie ostrza, pomiar zużycia ostrza noża tokarskiego.

Streszczenie

W artykule przedstawiono rolę sond narzędziowych stosowanych na obrabiarkach NC. Ukazano obecne sposoby określania współrzędnych i zużycia ostrza. Przedstawiono koncepcję nowej sondy bazującej na mostkach tensometrycznych, która umożliwia podczas jednego cyklu pomiarowego określenie współrzędnych i bezpośredni pomiar zużycia ostrza noża tokarskiego na tokarkach NC przy czterech kierunkach ruchu narzędzia.