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Engineering and Equipment

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A SPARK-GAP TOOL-SETTING SYSTEM

C. Asmanes

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the ATOMIC ENERGY COMMISSION under U. S. GOVERNMENT Contract W-7405 eng 26

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ABSTRACT

An automatic tool-setting system has proven satisfactory for most machine tools requiring a high degree of accuracy in establishing tool position. The system utilizes a spark, between a probe or tool-setting station and the cutting edge of the tool, to establish a point as a repeatable gap for tool positioning. The system permits the machining of parts to very close tolerances on a production basis.

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SUMMARY

Development of the Spark-Gap Tool-Setting System has provided a versatile tool-setting device. The electronic circuitry has proven to be reliable over long periods and is little affected by temperature or primary voltage changes.

The tool-station design is not limited by the size and availability of existing hardware and requires no moving parts which can be damaged by being accidentally struck by the tool or affected by temperature and coolants.

Attaching the sensor to the fixture allows spindle-growth effects from part to part to be compensated for automatically.

In addition to the advantages realized from accurate tool setting, the spark-gap instrument may have potential application to the inspection of parts.

INTRODUCTION

From technological advances in metal fabrication and improvements in automating the machining of precision components, the need continually arises for more precise methods of establishing the position of the cutting tool of numerically controlled machines, relative to the part being machined. The advances in precision machine tool design have exceeded the capability of the operator to measure the part and offset the tool each time a part is machined. Variables such as tool pressure, variations in material, and machine backlash are usually corrected by the operator after measuring the first few parts during the setup. This size must be established before uniform parts can be cut within the limits of the machine's accuracy.

A desirable system for machining would allow the tool position to be established automatically, directly from the fixture holding the part, thus eliminating the need to measure the part and offset the tool. Such a system would also eliminate the variables on machines having spindle-growth problems since the tool reference would follow the change in part position. In addition, the position error possibility, when the part fixture is mounted to the spindle nose or face plate, would be considerably reduced.

A system has been developed that has proven satisfactory for most machine tools requiring a high degree of accuracy in automatically establishing the tool position. This system, known as the Noncontact Spark-Gap Tool-Setting System, may be used on machines having a tool station, such as is shown on a numerically controlled machine in Figures 1 and 2, or on conventional machines where the sensor may be attached magnetically to the fixture holding the part (Figure 3).

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Figure 1. SPARK-GAP TOOL-SETTING SYSTEM ON A NUMERICALLY CONTROLLED MACHINE.

Figure 2. BASIC COMPONENTS OF A NUMERICALLY CONTROLLED TURNING MACHINE.

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Figure 3. SPARK-GAP TOOL-SETTING SYSTEM ON A CONVENTIONAL TURNING MACHINE.

THE SPARK-GAP SYSTEM

DESCRIPTION

The spark-gap system consists essentially of a power supply and a tool station or sensor. The present power supply, as outlined in Figure 4, has a regulated output of 1,200 volts with a current capacity of 20 microamperes. The precision of the instrument electronics is better than 0.1%. This value was obtained by applying a known signal to the input and observing the output. An amplified stage has a meter that indicates the tool position on a zero center scale to ± 0.5 mil, with a total range of gap width of five mils.

Functionally, the system utilizes a spark that is established between a probe or tool-setting station and the cutting edge of the tool. This spark-gap resistance, which changes with distance, allows a point to be established as a repeatable gap for tool positioning. This gap can be established by having either the sensor head or tool insulated for one side of the circuit. A gap of 2.5 mils is generally used for tool setting.

The power supply has a second amplifier that is used as a buffer stage for automatic tool setting on tape-controlled machines. The material used for the fabrication of the sensor head is usually tungsten carbide because it is less likely to be damaged if it is accidentally struck by the tool. The tool stations are designed to move if they are accidentally struck by the tool or tool holder, thus avoiding damage to either the tool or tool station.

Shown in Figure 5 are two of the several types of tool stations that have been designed for particular applications. Figure 6 shows a cross section of the pedestal-type tool station using a one-inch precision carbide ball as the sensor. The magnetic-base type may be attached directly to a part holding fixture, as shown in Figure 3.

A typical tool path for automatic tool setting is shown in Figure 7. Initially, the tool is prepositioned by the operator near the ball sensor on the center line of the axis programmed for automatic tool setting (X or Y). The tool will stop at a point 2.5 mils from the surface of the ball within ± 0.1 mil at the X or Y position when the output signal actuates the control circuit for the tool-setting function.

The tool will be positioned automatically on the X and Y axis relative to the part. Programmed cutting of the part will start and stop from Position A (Figure 7), allowing for tool changes and the repeat of the cycle. A similar

procedure is used to set the tool manually on a fixed tool station or a sensor attached to the fixture.

PROBLEMS IN DEVELOPING THE SYSTEM

Tool Stations

Obtaining proper insulation and capacitance were two of the major problems encountered during the development of the tool station. Several materials were tried as insulators: micarta, epoxy, Teflon, and glass. Most plastics soon developed electrical leakage due to their exposure to coolants which created an unstable condition, or they were not rigid enough. Glass proved to be the best insulator for this application because it is mechanically stable and easily cleaned if leakage develops.

An attempt was made to develop a dynamic tool-setting system using an insulated ring attached to the fixture, but this work was discontinued due to the erratic results caused by a capacitance effect that resulted from the large surface area exposed to the high voltage.

The tool stations were redesigned to eliminate this problem by reducing the surface area of the tool pickup, by increasing the insulation of the tool sensor to ground, and by including a one-megohm resistor in the lead that connects the sensor to the power supply. The resistor was attached close to the sensor to reduce the capacitance effect of the lead going to the power supply.

Power Supply

The original power supply was unregulated and drift did occur due to small primary voltage changes or temperature variations. The present system has a regulated power supply that has been checked over long periods with no significant drift recorded from reference zero. Primary voltage can be varied from 70 to 140 volts with no change in the zero reading. Temperature changes of ± 5 degrees make no noticeable change in the zero reading. There was no problem due to humidity because the system is used in a controlled humidity area.

Tool Tips

Another problem encountered was a deposit on some tool tips which caused an unstable condition in the spark gap. Cleaning was tried but it was found that these materials were insoluble in degreasing agents and could not be easily removed. Later, it was determined that it was easier to degrease

Figure 4. COMPONENTS OF THE POWER SUPPLY FOR THE SPARK-GAP TOOL SETTER.

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Figure 5. POWER SUPPLY AND TWO TYPES OF TOOL STATIONS.

Figure 6. PEDESTAL-TYPE TOOL STATION. (Wiring not Shown)

Figure 7. TYPICAL TOOL PATH FOR AUTOMATIC TOOL SETTING.

the tools using perchloroethylene and then coating the tip with a thin film (0.1 mil) of colloidal graphite, a conductive material. This graphite film provides a stable condition and also allows the use of tools which are made from such nonconductive materials as ceramics, sapphire, and diamond. The tool-preparation procedure includes the following steps:

1. Clean the tool with perchloroethylene.
2. Dry the tool by placing it in a block with the tip up.
3. Coat the tip with a colloidal graphite lubricant by lightly touching the tip with the brush.
4. Before using, allow a few minutes for the coating to dry. Caution: Do not handle or wipe the tool tips after coating. If handling occurs, the procedure must be repeated.

TESTS

Several tests were conducted to evaluate the accuracy and versatility of this system for machining both by manual and automatic means. Though primarily developed for use as a tool-setting device, it was also tested as an inspection tool using the system as a null-point sensor. Three methods were investigated to evaluate the accuracy of the machine using the spark-gap system. Operation of this system on two tape-controlled machines for several months on an automatic tool-setting cycle has proven it to be reliable and maintenance free.

Pedestal-Type Tool-Setting Station

The data shown in Figure 8 pertain to the length and diameter of nine brass parts machined on a tape-controlled turning machine by the use of an automatic cycle going from the tool-setting station to the part, as shown in Figure 1. No adjustments were made to the tool setting after the initial settings. A new tool was used to machine each part and three inspections were performed on each part to minimize the inspection uncertainty. No attempt was made to evaluate the accuracy of the device.

Figure 8. LENGTH AND DIAMETER DEVIATIONS FROM NINE PARTS MACHINED ON A TAPE-CONTROLLED TURNING MACHINE.

Analysis of these data indicate that for machining lengths, the system is capable of repeating to ± 0.22 mil. The average length of the nine test parts was 3.83817 inches. For machining diameters, the system is capable of repeating to ± 0.21 mil. However, there is a significant relationship between time and the diameters of the parts. The diameters of the parts being evaluated became smaller at the rate of 32 microinches per part. The average diameter of the nine test parts was 3.93729 inches.

Magnetic-Base Tool-Setting Station

A conventional ten-inch lathe was used to obtain the data given in Figure 9. The material was free-machining brass. To minimize the effects of spindle

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An error appears on Page 15 of the subject document under the topic "Electrically Insulated Tool Holder", second paragraph, line 7, the value " ± 0.1 microinch" should read " ± 100 microinches".

H. F. Ballenger
H. F. Ballenger

Figure 9. LENGTH DEVIATIONS FROM TEN PARTS MACHINED ON A CONVENTIONAL LATHE.

growth, the tool-setting probe was attached by the magnetic base to the workpiece holding fixture, as shown in Figure 3. The carriage was used to position the tool to the probe as directed by the meter on the instrument.

The part and tools were replaced and the process repeated for each part. When set, the carriage was locked to the bedways and the cross slide set in motion. A facing cut was taken on the brass at a depth of 10 mils and a feed of 5 mils/rev.

Each test piece was then inspected for thickness; the results are presented in Figure 9.

Electrically Insulated Tool Holder

Another method for cutting parts from a tool-reference position on the fixture was conducted using an electrically insulated tool holder. The purpose of this test was to reduce the errors of spindle growth and operator error in measuring the part during the cutting operations.

In order to evaluate this method, a fixture having a tool-reference position on the fixture was used on another tape-controlled machine. A tape was programmed to establish a tool-setting reference from the fixture to the part. An aluminum blank was mounted on the fixture and was then cut with no attempt to measure it during the cutting operation. The part was measured using a sweep gage and the standard gage normally used for measuring this type of part, and both measurements established that the part was cut to within ± 0.1 microinch of dimensions.

ADVANTAGES OF THE SPARK-GAP SYSTEM

The Spark-Gap Tool-Setting System is a highly versatile instrument for general shop use. Advantages of this system include the following:

1. For automatic tool settings, the operator's degree of skill is not included in the accuracy of the tool-setting operation.
2. The operator can monitor the tool approach on a meter and establish the tool position manually or automatically.
3. One probe may be used for tool positioning on either the fixed tool station or on the part holding fixture.
4. The tool does not contact a feeler gage or probe head which, in some cases, could chip the fine edge of the tool.
5. The sensor head is rugged and not easily damaged if accidentally struck by the tool or exposed to coolants.
6. The size of the sensor may be small where space or weight is a limiting factor.
7. The cost of a unit is low compared to equipment giving comparable results.

The spark-gap system may have potential in the inspection of parts. Using a probe designed for use with a null-point system, precision measurements can be made on X, Y, and Z directions without the need of a precision spindle to rotate the sensor head which, in this case, would be a carbide ball of a known size and an established spark gap to the part. One test using this method was run on an inspection machine to evaluate the possibility of using the spark-gap tool-setting system for the noncontact inspection of parts. The results indicated that the accuracy of measuring a standard gage was within 50 microinches; the repeatability was within ± 20 microinches.

Another advantage is the ability to measure from a nonrotating probe in the X, Y, or Z axis, eliminating this variable. A probe may also be attached to the tool-holding fixture to be used for checking the runout of fixtures or parts on the machine. This application would be ideal for deep holes where it is difficult to reach with conventional gages.

ACKNOWLEDGEMENTS

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