BETTER BROACHING OPERATIONS

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PREFACE

Broaching as a metalcutting process was used as early as 1850, when it was called "drifting." The first broaches were push broaches—short heavy tools that were used to cut keyways in pulleys and gears—and were driven through the workpiece by a hand hammer. Almost all broaching at this time was internal—the broach being pulled or pushed through the workpiece. The development of the internal pull broach and power press greatly increased the scope of broaching. The first external or surface broaching machine was patented in 1882, but surface broaching did not become important as a metalcutting process until the 1920s.

Early broaching machines used a rack and gear drive, and were light, belt-driven units. In 1901, a screw-type broaching machine eliminated chatter and established new standards of accuracy not attainable by other machining methods. As a result of the machine developments in the early 1900s, square holes with close tolerances were broached in transmission gears and by 1910, further development of the screw-type machine made it possible to broach multiple splines in gears. An advancement in spiral spline broaching came with the ball bearing thrust puller which allowed the broaching tool to rotate while being pulled through the workpiece.

The introduction of hydraulic broaching machines reduced manufacturing costs, bringing broaching within reach of a large part of the metalcutting industry. Surface broaching became prominent as the automotive industry adopted mass production techniques requiring large numbers of identical parts.

During the 1930s, hydraulic, fully automatic internal and external broaching machines and rotary type continuous surface broaching machines were in use. With the new broaching techniques, came improvements in broach holders and fixtures. Modern broaching fixtures may be mechanical, hydraulic or pneumatic in principle, and equipped with automatic clamping for continuous cycle indexing.

The manufacture of broach cutting tools has greatly changed in the past 10 years. Grinding wheels with cubic boron nitride (Borazon) grit are finding more applications. Some of the grinding applications include the back-off angle, form grinding and outside diameter grinding.

Wire electrical discharge machines (EDM) are now being used to produce pot broach cutting tools. Broaches that are used to manufacture sector gears may be made by wire EDM. This process also is being applied to produce some of the pot (tool holder) components.

Digital readouts and Computer Numerical Control (CNC) are being applied in the grinding process to produce broach cutting tools. In addition, some manufacturers are now using CNC lathes and mills to produce broaches. Many of the broach manufacturers now design broach cutting tools and establish the manufacturing setup dimensions with computers.

Today's broaching machines are generally equipped with programmable controllers even though the number of inputs and outputs is frequently low. Many companies now specify hydraulic units designed for high water-base systems. The electrical and hydraulic systems are now drawn with the assistance of computer-aided design units. Along with the lower cost programmable controller systems, more automation and automatic inspection devises are now being applied to broaching machines. This includes dedicated and standard robots to inspect, orient, load and unload parts. Current machines may provide for inspection and sorting of parts performed by either traditional mechanical systems or with numerically controlled vision systems. There have also been some recent applications of automatic tool changers to broaching machines.

The reader will find many of these concepts and applications on the pages of this book. It is hoped that the book will be a source of ideas and increased broaching productivity.

I wish to thank all of the companies, organizations, publishers, and authors who gave permission to have their articles reprinted in this volume. Thanks also to the Publications/Marketing Division staff at SME for their assistance in the research and development required in making this book possible.

Edward W. Kokmeyer
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CHAPTER 1

BROACH CUTTING TOOL ENGINEERING

Presented at the SME 1974 International Engineering Conference, April 1974

Relationship Between Thermoelectric Compensation and Tool Life

By C.H. Kahng
Michigan Technological University

ABSTRACT

After an extensive review of foreign literature, it was found that thermoelectric compensation improves tool life from 30 to 400%, not only for turning operations, but also drilling, milling, boring, broaching, etc.

In order to evidence his findings, the author of this paper studied the characteristics of the thermoelectric circuit and designed an external current supply device. Using this device tool wear investigations were conducted and it was concluded that there is a distinct effect of thermoelectric compensation on tool wear. However, the substantial advantages of the compensation on reduction of tool wear would be applicable only to limited machine tool structures, work-tool systems and operating conditions.

INTRODUCTION

When two dissimilar metals are joined together at two separate points, a complete electric circuit is formed and if there exists a temperature gradient between the two junctions (i.e., one junction is hotter than the other), current flows around the circuit. This is called the Seebeck effect after its discoverer, T. J. Seebeck, a German physicist, who discovered it more than 150 years ago. This principle has been used to determine average temperatures generated at the contact zone between the tool and workpiece under various conditions and is known as Gottwein's method (Fig. 1).

Since the cutting temperature is a most important parameter of cutting tool wear, much research work has been done using this technique.

Opitz [1] felt that there exists a relationship between thermoelectric current and tool wear. In order to compensate for the produced thermoelectric voltage, e.m.f., the machine-workpiece-tool system was insulated and from an external source the same amount of power as produced by the thermoelectric current was supplied back to the circuit. The tool life was increased by 200% when turning steel with a carbide tool. Later, Hehenkamp [2] concluded that compensation improved tool life remarkably. Recently, Ellis and Barrow [3] analyzed the compensation of the thermoelectric current based on Kirchoff's theory and obtained positive results.

In Russia, many extensive studies in this area have been reported. The thermoelectric compensation can be applied not only to turning, but also drilling, boring and milling. Avakov and Ryzhkin [4] reported that drilling alloy steel in an open-loop thermoelectric circuit increased drill life by 50 to 100% compared with that of conventional drilling.

As a result of comparative tests in millinג, it was reported by Bobrovskii [5] that milling cutter life increased by 30 ~ 150% when the thermocurrent circuit is disconnected. However, some investigators [6,7] found there was no change in tool wear by either electrically insulating the cutting tool from the machine tool or by application of a back emf. Therefore, the author of this paper felt it would be significant to investigate the thermoelectric phenomena and the effect on the cutting tool performance to further clarify this matter.

1. Characteristics of the Thermoelectric Circuit

Thermocouple circuits forming thermoelectric generators in the tool-work interface are very complicated.

A typical tool-work interface electrical equivalent is shown in Fig. 2. E_1 will be formed where the wire is attached to the workpiece, E_4 depends on the type of toolholder used. The flank face generator E_2, and crater face generator E_3, will develop voltages dependent on the temperature at these points.

This is important when the entire machine thermoelectric circuit is considered. A typical circuit is shown in Fig. 3. Headstock and tailstock resistances for different machine conditions have been reported by researchers [3], which indicate that due to these high resistances, the current flow is small.

According to Bobrovskii [8], the machine resistance can be substantial and can vary within wide limits. The resistance of the headstock, R_H, and tailstock, R_X, are dependent upon the type of machine tool structure, the material, design, technical state and number of bearings in the e.m.f. circuit and also the number of gear pairs in engagement; the type of lubricant, the thickness of oil film, the temperature of the oil and, consequently, the operation time and the stopping time of the machine, the cutting speed, depth of cut and feed rate, the dimensions and mass of the workpiece and other factors. Even on one machine these factors can vary within wide limits. For the above reason, considerable differences are observed in the results when identical parts are machined with identical tools on identical machines in the same shop.

The resistances of LeBlond, Regal lathe, model 15C5, 5 HP, used for the investigation was measured and it was found that the maximum resistances were 15 ohm in the headstock and 10 ohm in the tailstock. The open circuit thermogenerator voltages were obtained for several different conditions. Two different kinds of cutting tools were used: SPG-422 K6 Tungsten carbide insert and KSBL-C style toolholder, both from Kennametal and a HSS ½" square tool using