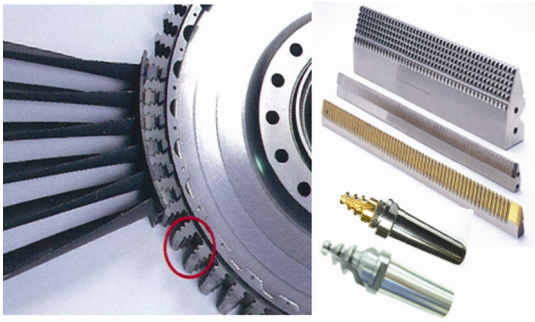
Precision Cutting Tools for Turbine Blade Grooves of Power Systems and Aircraft Engines



Sales Department
Machine Tool

The MHI Machine Tool Division is one of the few machine tool manufacturers that deal with both tools and machines. We have offered our products to a wide range of areas including the automotive and construction machine industries, and have received high evaluations. MHI is one of the best power system and aircraft engine manufacturers in the world. The Machine Tool Division has been supporting the in-house manufacturing of power systems and aircraft engines for more than twenty years, and has accumulated abundant experience, technologies, and expertise regarding machine work. In addition, in March 2012 we acquired Federal Broach and Machine Company based in United States, one of the global broach and broaching machine manufacturers. We intend to attain a higher level of technology through cooperation with this acquired company.

This document describes a broach and a side entry cutter that are accurate cutting tools for machining blade grooves of a turbine rotor and a turbine disk, which are key components of power systems and aircraft engines.

1. Broach

A broach is a rod shaped precision cutting tool consisting of many cutting teeth – the dimensions of which increase gradually – that is intended to be set on a broaching machine to form a workpiece. The features of the broach are high productivity and stable cutting accuracy. In particular, turbine blade grooves of power systems and aircraft engines have complicated shapes and require high levels of cutting accuracy and surface finish quality due to their harsh use environment.

1.1 Specifications of workpiece

We have experience in various forms of broaching, using both teeth profiles of fir tree shapes and dovetail shapes, a wide range of groove depth, groove width and skew angles and a broad array of workpiece materials from hot-resisting steel to difficult to machine materials such as Inconel.

1.2 Features

(1) Optimum design generated by unique cutting technologies and expertise

Based on the abundant results as described above, we have developed our unique cutting technologies and expertise and established the optimum design. For example, we have attained efficient and accurate machining through determination of the cuts per tooth and the broaching method, as well as the rake, relief, back angles, etc., suitable for the accuracy required for the part to be cut, in addition to the chip pocket suitable for handling chips.

(2) Use of unique high performance, high speed steels and coating technologies

We have established longer tool life and machining accuracy by taking advantage of unique materials and coating technologies obtained through our division's high speed gear cutting technology at a speed of 300 m/min or faster and past cutting experiences of difficult to machine materials. **Figure 1** shows one example of improvement of tool life.

(3) Outstanding tooth profile accuracy and creation of sharp edges

We have attained high quality cutting with a thinner damaged layer through the use of our technologies: a tooth profile grinding technology that realizes precision dimensions and

shapes with an accuracy of a few micrometers and enables high quality finish of tooth surface, and a unique sharpening technology that reduces burrs and chipping and enables a sharp edge finish. (**Figure 2**)

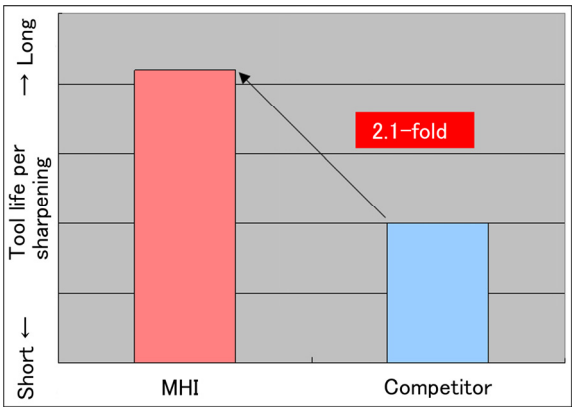


Figure 1 Example of tool life improvement due to unique design and optimization of tool material

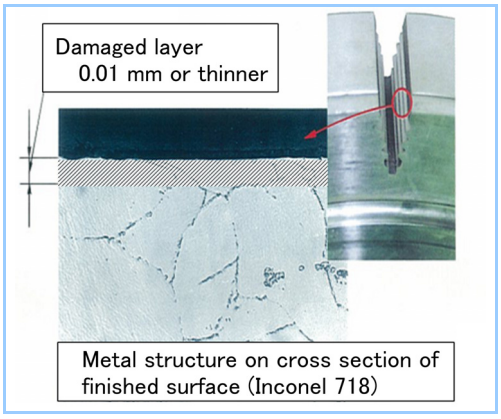


Figure 2 Superb surface finish quality achieved by high quality cutting

1.3 Overall support of broaching including broaching machine, broach sharpening machine, etc.

Our chain type broaching machine (**Figure 3**), which has block shaped rotating tool holders and enables single-pass machining of turbine blade grooves from rough cutting to finish cutting, is well received by customers for its ability to contribute significantly to productivity. In addition, we provide our unique NC control wet broach sharpening machine for re-sharpening operation, which grinds and removes the worn portion of used cutting edges for reuse. We offer overall support of customer broaching operations including the usage of a cutter.

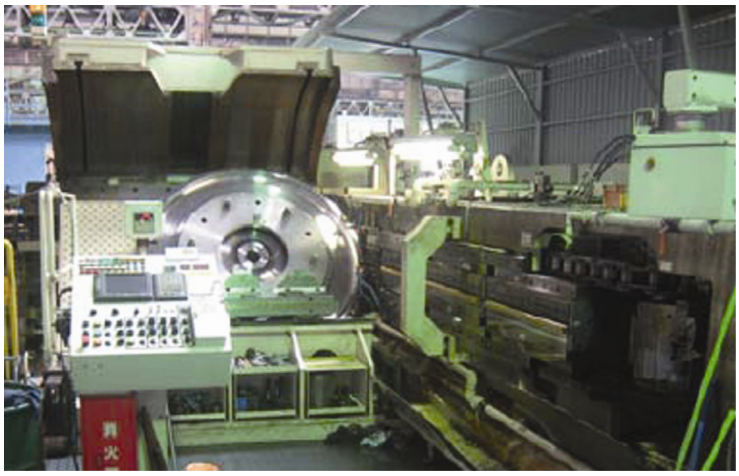


Figure 3 Chain type broaching machine

2. Side entry cutter

A side entry cutter is a formed milling cutter that is used for cutting blade grooves that cannot be broached. Typically a side entry cutter includes fir tree shapes and dovetail shapes as shown in **Figure 4** and is sometimes named a fir tree cutter after the shape of its cutting teeth.

2.1 Features

(1) Achievement of accurate tooth profile

Typically, the tooth profile accuracy of a side entry cutter is maintained by superposing the cutter's tooth profile projected by a projector on the form drawing. In this procedure, an image magnified several tens of times is projected for measurement. In our division, tooth profile is magnified up to two hundred fold from a three-dimensional view and is measured entirely and automatically using three fixed CCD cameras. This correctly evaluates the cutting teeth accuracy of a cutter and enables accuracy compensation in increments of micrometers, resulting in the establishment of accurate tooth profile maintenance.

Figure 4 Shape of side entry cutter
The left cutter is fir tree shaped and the right cutter is dovetail shaped

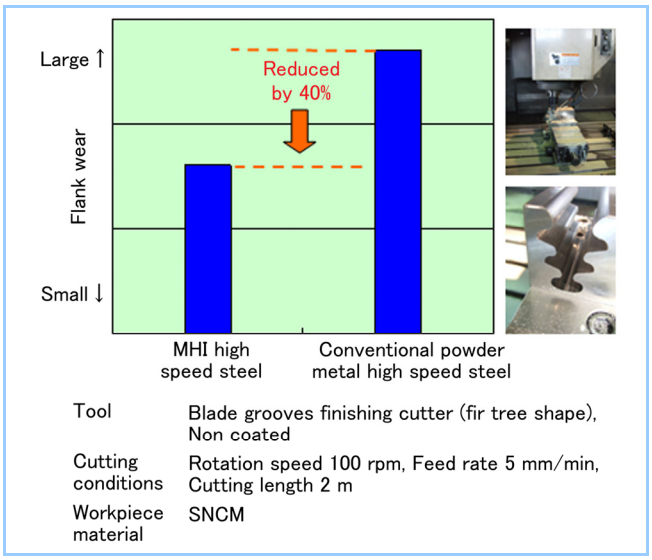


Figure 5 Example of cutting with MHI high speed steel
Comparison of tool wear through a cutting test in which simulated turbine rotor blade grooves were cut

(2) Use of tool material with superb wear resistance and toughness

In our division, high speed steel with both superb wear resistance and toughness is used as the cutter material. This material includes a lot of finely and evenly dispersed vanadium carbide, which is a hard granular substance, to significantly improve wear resistance and toughness in comparison with conventional high speed steel. As a result, longer tool life and more efficient cutting can be expected.

Figure 5 compares after-groove-cutting wear of a cutter made of high speed steel used in our division with that made of conventional powder metal high speed steel. The wear of the cutter made of high speed steel used in our division is 40% smaller than that made of conventional powder metal high speed steel.

2.2 Side entry blade groove machine

We also manufacture a side entry blade groove machine that can simultaneously cut up to four grooves, and have established a framework for supporting tools and a machine integrally.

3. Future prospects

Currently we are developing broaches for the manufacture of new type gas turbines in the Power Systems Division. Together with the Engineering Headquarters and Manufacturing Technology Center of our division, we provide overall support including responding to the need for further improvement of productivity, etc.

In order to accelerate global development in the power system and aircraft engine industries, we are going to establish, for both technology and marketing, a trilateral system consisting of Japanese, American and Indian bases through cooperation with Federal Broach and Machine Company, which we acquired in March 2012, and MHI-IPT in India, which was founded as an overseas production base for tools.