

# High Performance Broaching

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## 1. Introduction

Today's broaching process has spread widely as a highly precise, mass production processing method of automobile parts and industrial machine parts.

Especially the development of precision parts in the automobile and industrial industry, new broaching advancements has been supported from the high productivity.

A broach performs a very small cut of about 0.01 to 0.10mm and has a complicated form. A sharp edge tooth is required; it has been manufactured by HSS or HSS-Co. So far, this broaching process needs a lot of cutting oil in order to maintain a high surface finish of the work piece and long tool life.

Saving the environment is getting more and more important for corporate activities. The broaching process by MQL was developed by us to meet the requirements to make the factory more environmentally safe and decrease the consumption of cutting oil.(fig.1)

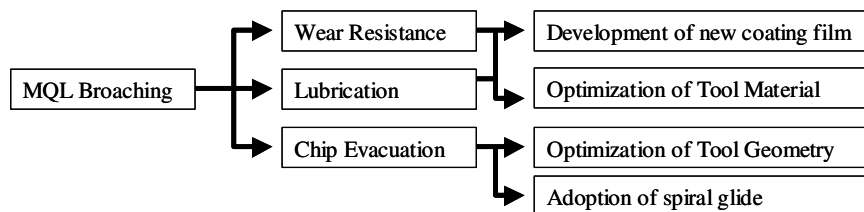


Fig.1 Development Target

We have developed a powder metal HSS broach with TiAlN coating as well as a high-speed broaching machine, this combination of environmentally friendly machining is 10 times more than efficient than the current broaching process.

This paper introduces about MQL efficient broaching process.

## 2. Principles and feature of broaching process

A broach is a tool shown in Fig.2, of which height or outside diameter grows gradually and continuously from the front tooth to the end tooth.

The cut depth per one tooth is approximately 0.05mm in case of steel broaching, namely very small cutting is executed.

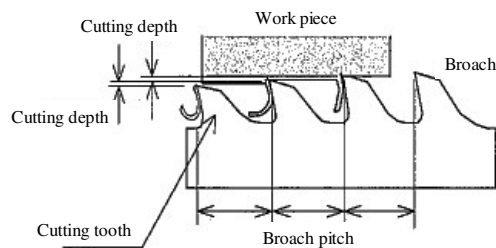


Fig.2 Principle of broaching process

The features of broaching process are as follows.

- ① Even if the parts have a complicated form, they are possible when the form is same in the broaching direction.
- ② Usually, as broaching process finishes in a one path, broaching time is short.
- ③ Broaching accuracy is stable and high compatibility parts are made.
- ④ Broached surface can be reached within Ry8 to 10  $\mu$  m.
- ⑤ There are many cutting edges compared with milling cutters, and since the cutting volume on one tooth is small, the tool life is 5 or more times longer.
- ⑥ Machining is very easy and any special skill is not required

The demand for high efficiency broaching process is high, it is a fact that improvement in broaching speeds and coating technology is becoming indispensable when advocating ecological cutting without oil.

### 3. Broaching with MQL (Minimum Quantity Lubrication)

Although MQL process was developed in Europe, its technology has spread widely in Japan right now.

We developed MQL broaching from the following viewpoints:

#### (1) Tool material

The adhesion intensity of coating related to the carbide grain size and distribution, so that, high V & Co contained powder HSS was adopted.

As this high V & Co improves the heat-resistance remarkably, high alloyed powder HSS is suitable for a MQL broach.

#### (2) Surface treatment

Using a Nachi-Fujikoshi patented, multi-layered TiAlN coating of which features are high heat-resistance, high oxidation-resistance, and excellent heat conductivity, no coolant or cutting oil is needed.

#### (3) Tooth geometry

According to our simulated tests, the rake face angle, back-off angle and uniform taper (cutting depth per one tooth) were optimized.

#### (4) Gullet geometry

Although ring type broaches are common because of ease of manufacture, the spiral glide gullet broach was developed to achieve better chip evacuation and cutting resistance reduction.

#### (5) Cutting oil

For ecological machining, plant oil or synthetic ester oil which is excellent in natural decomposition is recommended.

## 4. Performance

### 4.1 MQL broaching under conventional speed

The conventional broaching speed is generally from 5 to 10 m/min, the comparison relief wear (VB wear) by MQL broaching with TiAlN coated powder HSS broach and conventional chlorine oil broaching with conventional M35 broach is shown in Fig3.

This result suggests that MQL broaching is possible under the current machine and speed, if the broach is optimized for that purpose.

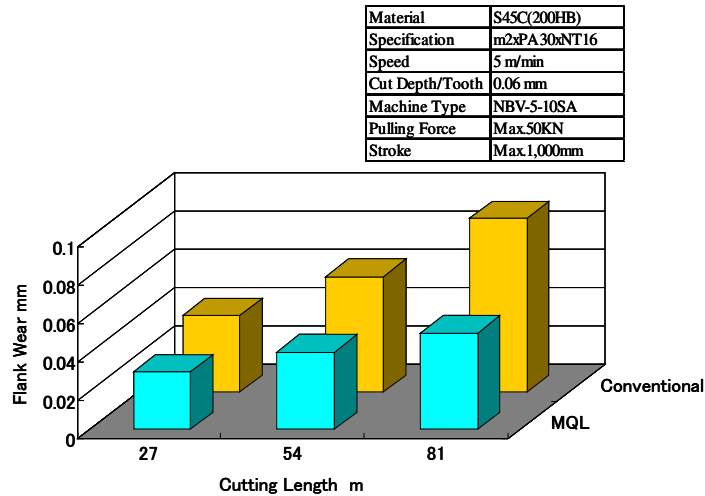


Fig3. Wear comparison of MQL and Conventional

For example, in this test, we cut carbon steel S45C (200HB) up to 81m cutting length with 1.5cc/h x 4 nozzles and compared the relief wear (VB).

Operation cases under conventional speed MQL broaching in some actual production lines are shown in a table1.

Table 1 Operation Case

Work Piece	Outline	Machine	Speed MQL oil type	Chip Discharge
Carbon steel Key-way PM- HSS TiN		Tool Transfer 3ton-pulling 800mm stroke	6m/min Plant oil	Roller Flushing Chip conveyor
Carbon steel Inv-Spline PM-HSS TiAIN		Tool Transfer 5ton-pulling 1,000mm stroke	5m/min Synthetic oil	Brush Vaccum
Cr-Alloy Inv-Spline HSS-Co TiN		Work Transfer 5ton-puwshing 1,000mm stroke	5m/min Plant oil	Brush Flushing Chip conveyor
Cr-Mo alloy Inv-Spline HSS-Co TiN		Tool Transfer 5ton-pulling 800mm stroke	3m/min Plant oil	Brush Flushing Chip conveyor
Cr-Mo Alloy Key-way PM-HSS TiAIN		Tool Transfer 5ton-pulling 1,000mm stroke	5m/min Plant oil	Brush Vaccum

#### 4.2 MQL broach under high speed

According to cutting theory, the relation of distribution between cutting speed and heat generation is shown in Fig.4.

Generated heat under high speed broaching is almost always transferred to chips and away from work piece.

Using this feature, we developed a high speed MQL broaching machine in order to achieve high productivity and longer tool life without sacrificing ecology.

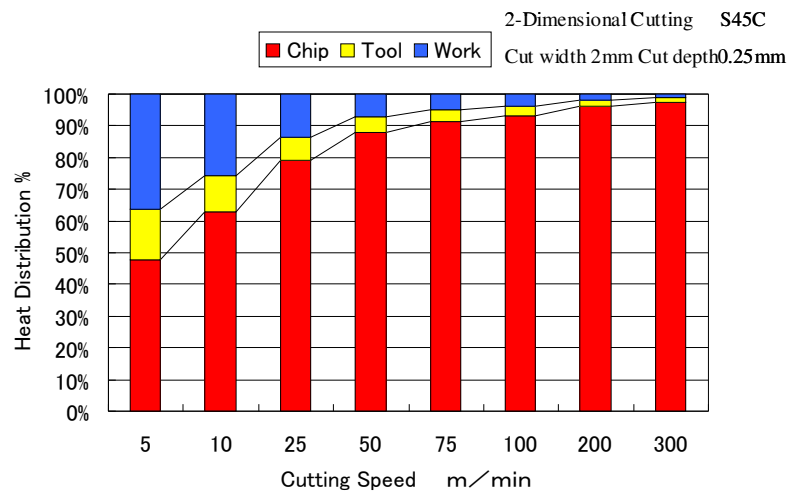


Fig.4 Heat Distribution by the Cutting Speed

The developed broach machine reaches a maximum speed of 80m/min, which covers the max. cutting temperature where TiAlN coated powder metal HSS broach can resist.

Fig.5 shows the progress of relief wear (VB) in high-speed MQL broaching, conventional speed MQL broaching and conventional oil broaching.

In comparison with the conventional oil broaching, the relief wear by high speed MQL broaching was 1/3, furthermore, in comparison with conventional speed MQL broaching,

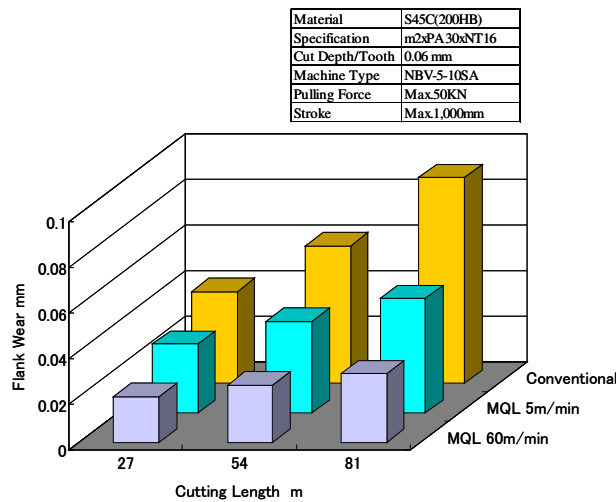


Fig.5 Difference of Flank Wear by each cutting Speed

the relief wear (VB) was 1/2.

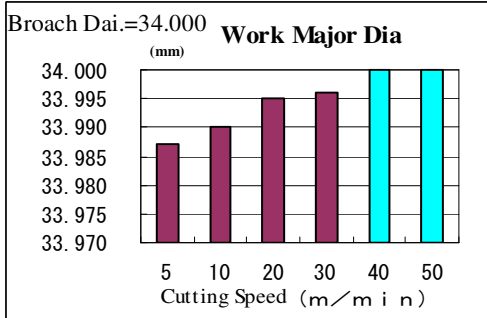
As shown in Fig.4, the generated heat is transferred to chips under high speed broaching, so that the damage of broach is decreased drastically.

Next, work accuracy was investigated under different cutting conditions.

The outer diameter of work piece corresponds to that of the broach when the cutting speed exceeds more than 40m/min as shown in Fig.6.

More than 90% of heat was transferred to chips and the half of the balance was transferred to a work piece, but that was negligible to heat up and deforming of the work piece.

Model :NBV-5-10SA MQL:Bluebe Fat oil Volume :4cc/hx 4  
 nozzles Material :S45C Cutting length :30mm  
 Broach :34x30x4x4sp PM-HSS+TiAIN



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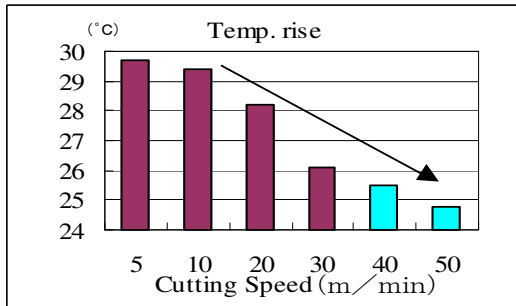


Fig.6 Relation between speed and accuracy(work major dia.) Fig.7 Relation between speed and temperature rise (work piece)

At the same time, temperature increase was investigated and in proportion to the broaching speed, temperature was decreased as shown in Fig.7.

In addition to the above mentioned advantage, high-speed broaching saves the power consumption by 1/4 shown in Fig.8 .

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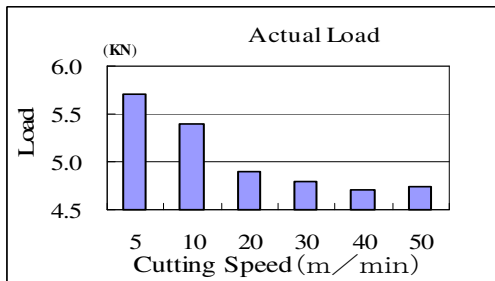
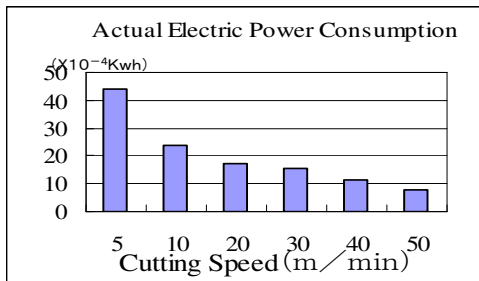


Fig.8 Relation between speed and power consumption

Taking those advantages into consideration, production cost reduction per a work piece by MQL high speed broaching is calculated 15% or more compared with the conventional broaching with oil and M35 broach.(Fig.9)

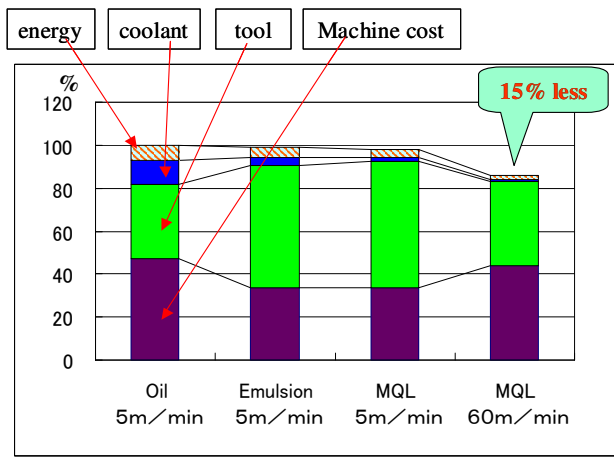


Fig.9 Cost reduction by MQL high speed broaching

### 4.3 Ideas to optimize MQL broaching

As cutting temperatures become high by MQL high-speed broaching, chips were easy to adhere in the broach gullet and difficult to evacuate automatically.

Taking advantage that a HSS tool can operate the form freely; we developed the spiral glide broach (multi threaded gullet) as shown in Fig10.

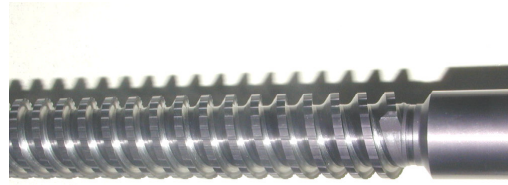
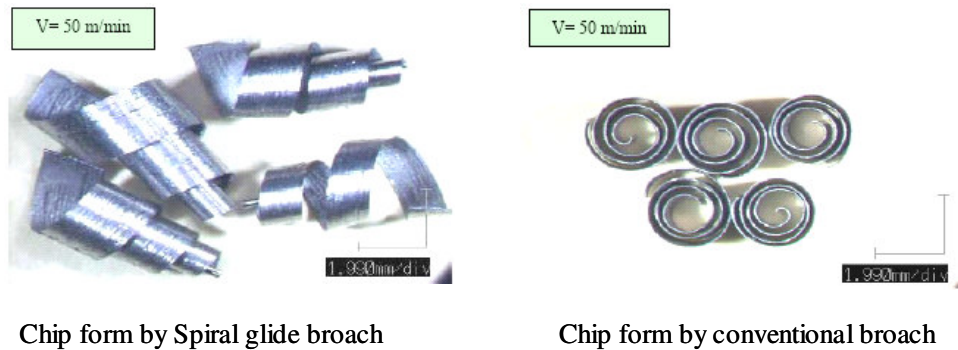


Fig.10 Spiral glide broach

A high alloyed powder HSS and TiAlN coating was developed and used.

When this spiral glide broach was used, as shown in Fig.11 , a completely different chip form was formed, like a helical spring, comparing that with the conventional ring type broach were discharged.



Chip form by Spiral glide broach

Chip form by conventional broach

Fig.11 Difference of chip form

This spring type chips were easily discharged from broach gullet. Furthermore, reduction of cutting power is confirmed by adoption of this spiral glide broach as shown in Fig.12..

For high-speed MQL broaching, spiral glide type is very effective and recommended.

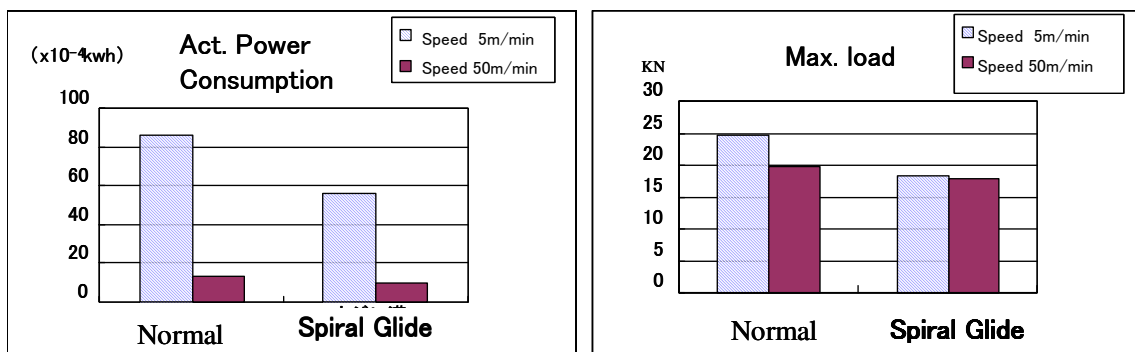


Fig.12 Difference of power consumption and Max. load

## 5. Conclusion

Broaching process is a method currently achieved by using HSS tools. It is confident that the broaching process will be continued to be used in automobile parts and other mass production parts as one of the most effective production techniques.

However, it is not an overstatement that this long time broaching method also faces a new turning point by the technology that we have developed.

High-speed, MQL broaching process with TiAlN coated and powder metal HSS broach has already been adopted in many Japanese manufacturing environments.

Furthermore, high speed broaching using carbide broaches is currently being tested and developed within our company. This process is applied to the finishing of hardened parts which could not be made by the conventional broaching speeds and feeds in order to substitute grinding.

Considering the cost savings and the efficiency of this broaching method, and also the goal to save our environment, Nachi-Fujikoshi is continuing to develop this new MQL broaching method as much as possible.

## References

- (1) Yasushi Nogawa; NACHI technical review, Vol57 No.1 ,2001, P28-32
- (2) Yoshiaki Matsumoto, Katsuyuki Shimasaku, NACHI technical review, Vol.57 No2, 2002,P47-51