Super Skiving Cutter
An Innovative Process Modification for Gear Skiving

TETSUJI MONDEN*1 TOSHIMASA KIKUCHI*1
KEISUKE YOSHIKAWA*1 NORITAKA FUJIMURA*2
ADRIANOS GEORGOUSSIS*3

In recent years, the skiving process has been attracting attention as an internal gear cutting method, and many gear cutting users in the automotive and construction machine industries have been adopting it as a cutting method for mass production.

The gear skiving process allows for high precision and high efficiency cutting. However, significant challenges, such as the high dynamic load on the tool during cutting and thus a shortened tool life, inhibit the large-scale industrialization of the process. To overcome these challenges, Mitsubishi Heavy Industries, Ltd. (MHI) conducted a comparison test between the super skiving cutter and the pinion skiving cutter used in the conventional skiving process and the test results are reported here. The test was conducted in cooperation with the WZL of RWTH Aachen University, Germany, as a third party organization.

1. Introduction

Internal gears are mainly used for planetary gear devices for automotive automatic transmissions and reducers of construction machines. The conventional internal gear cutting processes are mainly limited to gear shaper cutting using a pinion cutter and broaching using a broach cutter, and these cutting processes have both advantages and disadvantages in terms of productivity, processing accuracy, production cost, etc. In recent years, the development of a skiving process, as an alternative to the conventional processes, which allows high precision and high efficiency cutting, has been promoted along with the increase in machine rigidity/performance and the progress in tool material/coating technologies. However, the industrialization of the process on a large scale is being inhibited by a shortened tool life.

As shown in **Figure 1**, in the skiving process, a crossed axes angle is formed, and so the effective rake angle of the tool becomes negative during cutting. As a result, the cutting sharpness of the tool is reduced, the cutting resistance is increased and the load on the tool cutting edge is increased, causing a rise in tool wear and chipping on the cutting edge of the tool. MHI developed a proprietary super skiving cutting tool with the objective of improving the cutting conditions and increase the tool life, thus enabling a productive an economical process.

Figure 2 presents the appearances of the pinion skiving cutter (hereinafter, PSC) used for the conventional skiving process and the super skiving cutter (hereinafter SSC) developed by MHI. The SSC is a skiving tool consisting of multiple blades. Each blade represents a pinion skiving tool with a specific amount of cutting teeth. Thus, the cutting volume can be further distributed and the cutting load per tooth can be reduced.

*1 Engineering Headquarters, Mitsubishi Heavy Industries Machine Tool Co., Ltd.
*2 Chief Staff Manager, Engineering_Development_Department, Engineering_Headquarters, Mitsubishi Heavy Industries Machine Tool Co., Ltd.
*3 Research Associate, WZL of RWTH Aachen University

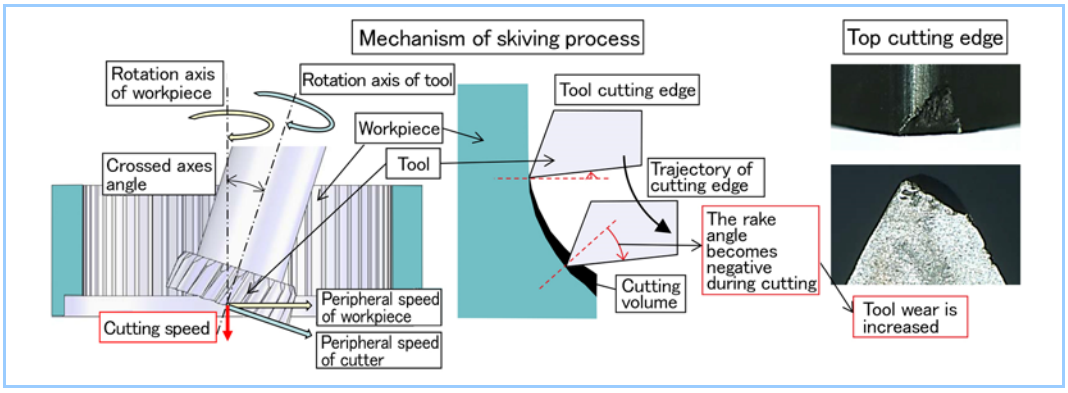

Figure 1　Effective rake angle in skiving process

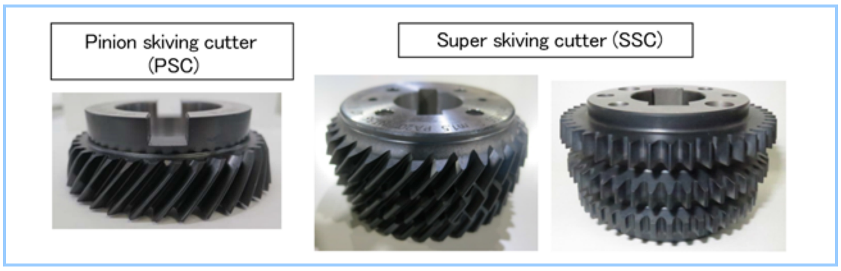

Figure 2　Appearances of PSC and SSC

In addition, **Figure 3** displays the general internal gear manufacturing process. SSC was developed, from the beginning, targeting workpieces falling under Figure 3-(1) and mainly used by domestic automotive manufacturers. In this case, the workpiece hardness is HB230 (≈HRC20) or less, which is relatively easy to cut. **Figure 4** gives the results of continuous cutting in which each PSC and SSC tool was used to cut a workpiece with HB200 falling under Figure 3-(1), until the tool wear amount reaches 250μm. This test was conducted under the same cycle time (hereinafter C/T). The results indicated that the number of workpieces processed by SSC was about 6 times larger than that by PSC. Some users, however, require a skiving process for a workpiece material with a hardness of HRC45 or less as can be seen in Figure 3-(2), which is something that overseas users often require. Therefore, in this test, we requested the cooperation of WZL of RWTH Aachen University in Germany as a third party organization and evaluated the performance of SSC for a workpiece material with a high hardness.

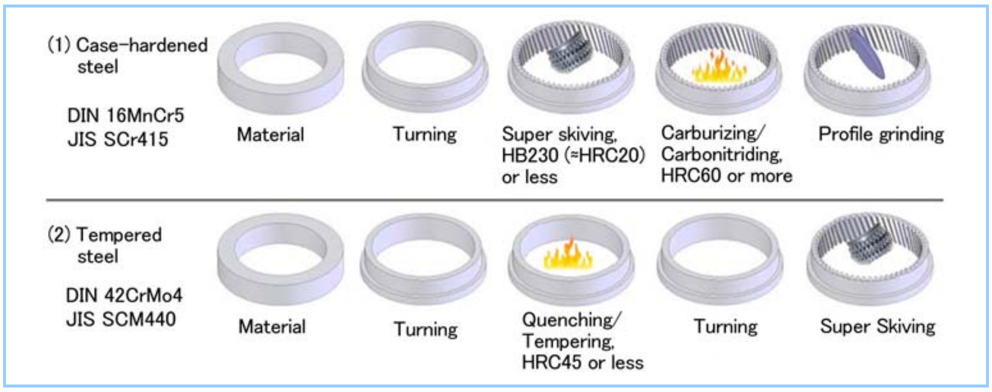

Figure 3　Manufacturing process of internal gear

Specifications of workpiece

Material	SCM415 (HB200)
Module	1.5
Number of teeth	70
Helix angle	20° LH
C/T	60 s

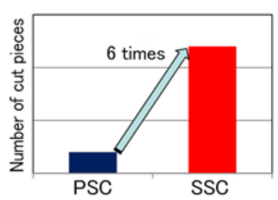

Figure 4　Comparison of performance between PSC and SSC (Workpiece material: SCM415)

2. Features of super skiving cutter

2.1 Development concept of super skiving cutter

For a skiving cutter, which has the problem of a shortened tool life, we needed to realize improved productivity and increased tool life in continuous cutting using multiple blades in a manner similar to hobbing. Therefore, in order to provide a tool with multiple blades, we developed a tool with an increased thickness compared with that of the conventional PSC. As shown in **Figure 5**, in the skiving process, a crossed axes angle is formed. If a tool with an increased thickness is used with the crossed axes angle being formed, interference occurs between the tool and the workpiece. To avoid this interference, the tool must be barrel-shaped. Based on the barrel shape, the multiple-blade tool was realized. As depicted in **Figure 6**, SSC is formed with the finishing blade at the maximum outside diameter of the barrel shape and the rough blades set based on the finishing blade.

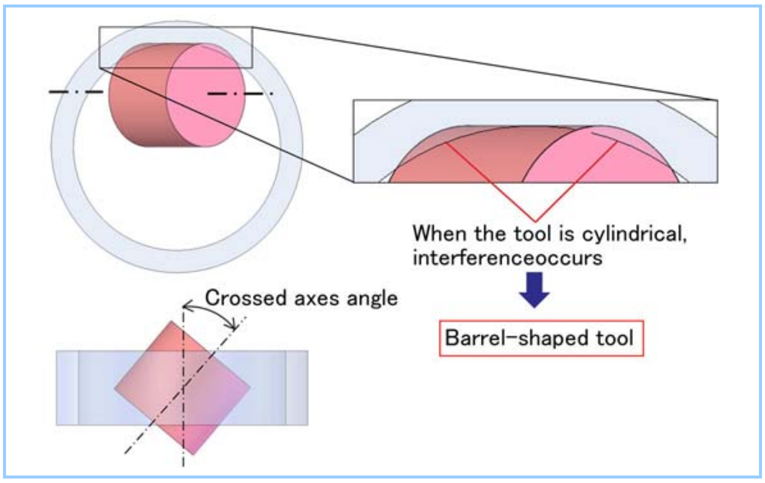

Figure 5 Shape of SSC (1)

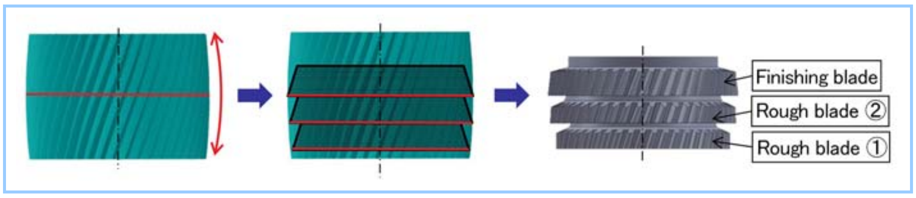

Figure 6 Shape of SSC (2)

2.2 Advantages of super skiving cutter

As illustrated in **Figure 7**, the advantages of SSC are as follows:

- PSC cuts the tooth space of a workpiece using the same finishing blade (Figure 7 presents the case of cutting in 3 passes), while SSC has three cutter blades (rough blade ①, rough blade ②, finishing blade) so that it can cut the tooth space of a workpiece in one pass using different cutter blades. The cutting load on one cutter blade of SSC was reduced to one third of PSC, and SSC achieved a longer tool life.
- The two rough blades are independent from the finishing blade. The precision of the workpiece depends on the tooth profile of the finishing blade, and the tooth profile of the rough blades can be changed freely. The tooth profile of the rough blades can be adjusted according to the state of wear of each blade or the shapes of chips, and a further increase in tool life can be expected. In addition, depending on the state of wear, different tool materials may be used for the finishing blade and the rough blades.

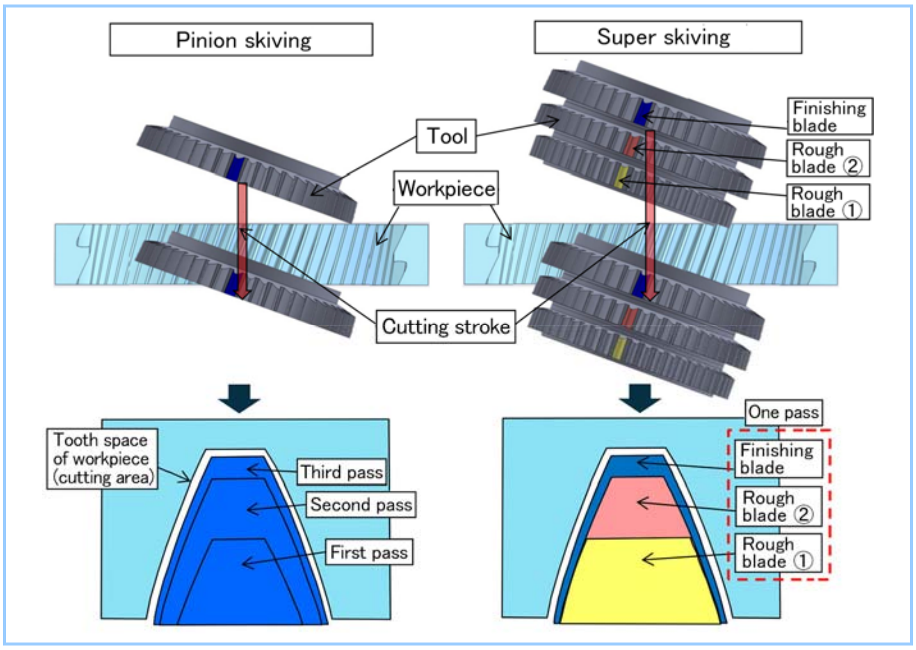

Figure 7 Cutter blades of tool used in cutting area

3. Test results

3.1 Test specifications

The workpiece, tool, and cutting conditions used in this test are shown in Table 1. In the test, a cutter with only six teeth was used to reduce the number of workpieces needed. With the use of this cutter, the machining of 9 workpieces can be made equivalent to the machining of one workpiece. The number of cuts under the given cutting conditions is a result of the cutting amount of one cutter blade being the same, rather than the C/T being the same. That is, when the number of cuts of the cutter blade is 13, PSC uses one cutter blade (only the finishing blade) in one cutting stroke and the total number of cutting strokes corresponds to 13 passes (cut with one cutter blade x 13 passes = 13 cuts). SSC uses three cutter blades (rough blade ①, rough blade ②, finishing blade) in one cutting stroke. In the final cutting stroke, however, only the finishing blade is used for the purpose of increased precision. Therefore, the total number of cutting strokes corresponds to 5 passes (cut with three cutter blades x 4 passes + cut with one cutter blade x one pass = 13 cuts). In this case, the C/T of SSC is shortened by about 40%. The cycle times of PSC and SSC do not simply correspond to the number of passes, because the cutters have different thicknesses and their cutting strokes are different, as can be seen in Figure 7.

Under these conditions, the tool life for PSC and SSC was evaluated with the following comparison items:

- Influence of workpiece hardness: Comparison between HRC30-35 and HRC35-40
- Influence of cutter material: Comparison between powder high-speed steel and carbide

For the test, the MSS300 Skiving Machine developed by MHI was used.

Table 1 Specifications of test pieces

Specifications of workpiece		
Module	1.25	mm
Number of teeth	85	
Pressure angle	20	deg
Helix angle	20 (RH)	deg
Material	1.7225 (42CrMo4)	
Hardness	30-35 35-40	HRC

Specifications of tool	
Type	PSC SSC
Number of teeth	6 (equivalent to 54)*1
Helix angle	SPUR
Materials	Powder high-speed steel, carbide

Cutting conditions		
Cutting speed	120	m/min
Feed speed	0.1～0.2	mm/rev
Number of cuts by cutter blade	13	times*2

*1 The test cutter with evenly spaced 6 teeth was made by reducing the teeth from a 54-teeth cutter.

*2 In PSC, the number of cutting strokes is 13 passes (In one stroke, one cutter blade cuts (once).)
In SSC, the number of cutting strokes is 5 passes (In one stroke, three cutter blades cut (three times), but in the final stroke, only one finishing blade cuts (once).)

3.2 Test results

Figure 8 gives the results of the cutting of workpieces with different hardnesses, HRC30-35 and HRC35-40, by the powder high-speed steel cutter. The upper graphs show the changes in tool wear. When the limit wear amount is 250μm, the tool life of SSC is 2.3 times longer than that of PSC for the workpiece hardness of HRC30-35, and the tool life of SSC is 1.4 times longer for HRC35-40. The lower the workpiece hardness is, the larger the performance difference between PSC and SSC becomes. The lower graphs illustrate the pressure angle deviation of the workpieces. Compared with PSC, SSC maintains almost the same pressure angle deviation in any wear amount.

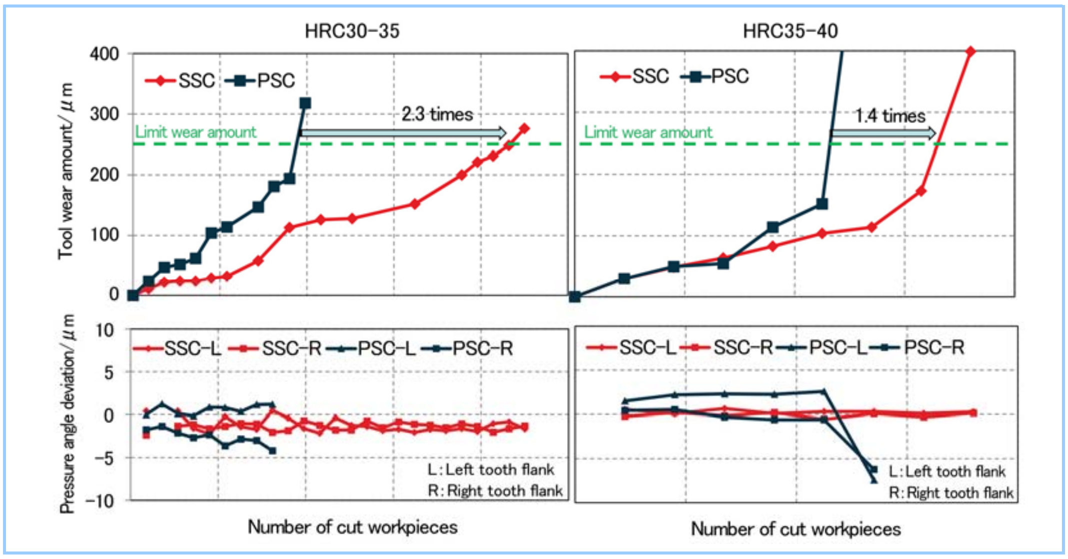

Figure 8 Comparison of performance between PSC and SSC (Workpiece hardness difference)

Figure 9 presents the results of the cutting of the HRC35-40 workpieces by the carbide cutter. As is the case with Figure 8, the upper graph shows the changes in tool wear. When the limit wear amount is 250μm, the tool life of SSC is 3 times longer than that of PSC, which substantially exceeds the 1.4-times increase in the results of the test using the powder high-speed steel cutter under the same conditions.

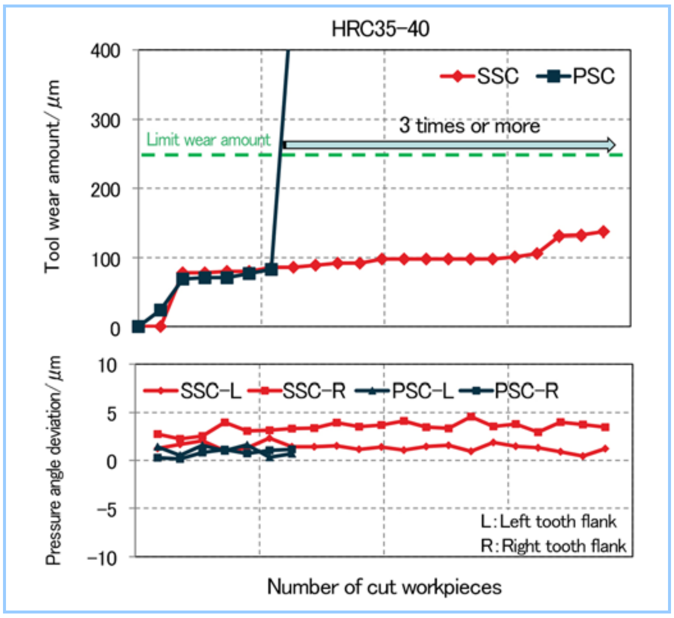

Figure 9 Comparison of performance between PSC and SSC (Cutter material: carbide)

4. Consideration

In this test, the results of the performance comparison between PSC and SSC showed the following:

(1) As can be seen in **Figure 10**, the difference in tool life between PSC and SSC depends on workpiece hardness.

(2) As shown in Figures 8 and 9, under the conditions where the workpiece hardness is high, HRC30-40, and the C/T is shortened by about 40%, the tool life of SSC can be 1.4 to 3 times or longer than that of PSC.

(3) As illustrated in Figure 4, under the conditions where the workpiece hardness is HB200 and the C/T is same, the tool life of SSC can be 6 times longer than that of PSC.

Accordingly, we think it is important to select appropriate tool materials and determine optimal cutting conditions according to workpiece hardness for SSC to deliver higher performance than PSC.

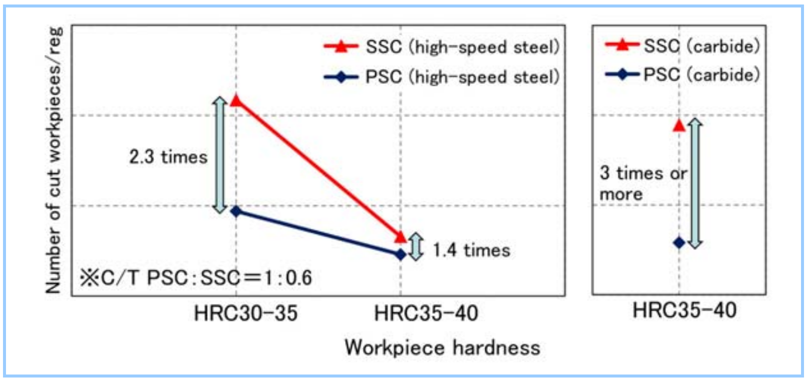

Figure 10 Comparison of performance between PSC and SSC

5. Conclusion

In this test, the superiority of SSC in a wide range of workpiece hardnesses including high hardness was verified. In the future, we will continuously develop SSC for further improved performance. In particular, we are going to optimize the cutting conditions, evaluate workpieces with different specifications and expand the verification scope. MHI has also developed and sells the ZI20A internal generating gear grinding machine for finishing, and we are making efforts to provide total and optimal proposals in the manufacturing process of internal gears from skiving to finishing grinding.

References

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