TESTING CERAMICS INSERTS AT IRREGULAR INTERRUPTED CUT ON MATERIAL 14MoV6

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\textbf{Abstract:}
This article deals with the test of removable ceramic cutting inserts during machining with an irregular interrupted cut. Tests were performed on a lathe, with a preparation which simulated an interrupted cut for us. By changing the number of slats mounted in the preparation, it simulated a regular or irregular interrupted cut for us. When it had four slats, it was a regular interrupted cut, whereas the remaining three variants were already irregular cuts. This paper examined whether it would have an irregular interrupted cutting effect on the insert and possibly how it would change the life of the inserts during an irregular interrupted cut (a variable delay between shocks).

\section{Introduction}

Nowadays there is the continuous development of machined materials. Therefore, it is also necessary to develop and to improve cutting materials too. These should resist high temperatures and forces during machining. Apart from selecting the right material, there is also a need in practice to select the appropriate cutting parameters recommended by the manufacturer for the cutting material. During the development of new cutting materials, these materials also are to be tested. One of the tests may be a measure of resistance to this material at the interrupted cut, especially if it is for new hard but fragile materials, such as ceramics [9, 11].

\section{Experimental investigation}

\subsection{2.1 Preparation for the tests}

For the tests there was chosen the testing method of longitudinal turning called “cylinder with paddles”.

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During an interrupted cut, the insert is stressed by mechanical and thermal shock. From a theoretical perspective, thermal shocks should have a little more negative effect on the cutting edge than the mechanical shocks. Tests can prove that by maintaining a constant temperature or preheating, the resistance of the cutting edge to shocks is increased [7, 8].

To examine deeply the influence of mechanical and thermal shock, the testing methodology was modified so as to compare regular interrupted cutting (4 clamped slats) and interrupted irregular cut (3, 2 or 1 clamped slats). This special preparation (see Fig. 1) consists of a cylinder with grooves in which we can clamp slats at a number from 1 - 4 (see Fig. 2) according to which we can provide the effect of the different time delays between shocks. This can also have an impact on the resistance to thermal shocks. The criterion for the termination of the test is destruction of the cutting edge or degradation of surface roughness.
The simulator is set up from the body of the simulator (1), slat (2), exchangeable washer (3), clamping wedge (4) and safety ring (5).

**Figure 1. Sketch of simulator [5].**

**Figure 2. Scheme of preparation with 1 - 4 clamped slats [5].**

### 2.2 Machined material

On the slats, 14MoV6-3 steel was used. It is alloyed Mo-V steel resistant to high temperature and creep, which excels in high toughness resistance at temperature of about 580°C. The microstructure is greatly affected by heat treatment.

**Table 1. Mechanical properties of 14MoV6-3 steel [1]**

<table>
<thead>
<tr>
<th>Mechanical properties</th>
<th>Rp 0.2 [MPa]</th>
<th>Rm [MPa]</th>
<th>A5 [%]</th>
<th>Hardness [HB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>14MoV6-3 min</td>
<td>320</td>
<td>460 - 610</td>
<td>20</td>
<td>197</td>
</tr>
</tbody>
</table>

### 2.3 Cutting parameters

The ceramic cutting inserts were tested under the following cutting parameters:
- cutting speed \( v_c = 204 \text{ m} \cdot \text{min}^{-1} \),
- feed 1 \( f_1 = 0.20 \text{ mm} \),
- feed 2 \( f_2 = 0.32 \text{ mm} \),
- cutting depth \( a_p = 1 \text{ mm} \),
- preparation diameter \( d = 260 \text{ mm} \).

Due to different numbers of clamped slats for the preparation, a maximal spindle speed of \( n = 250 \text{ min}^{-1} \) was chosen, corresponding to \( v_c = 204 \text{ m} \cdot \text{min}^{-1} \). By exceeding this RPM, very strong vibrations and the shaking of the machine were caused, even though the machine was properly anchored to the ground.

### 2.4 Cutting tool

The inserts were clamped to the tool holder CSRNR 25x25 M12-K. This is the tool holder for the square ceramic inserts (see Fig. 3).

**Figure 3. Tool holder CSRNR 25 x 25 and insert ISCAR IN23 [1].**

The selected tool holder has the following geometry:
- rake angle \( \gamma_0 = -6^\circ \),
- clearance angle \( \alpha_0 = 6^\circ \),
- cutting edge angle \( \kappa_r = 75^\circ \),
- cutting edge inclination \( \lambda_r = -6^\circ \),
- included angle \( \varepsilon_r = 90^\circ \) [2].

Two different types of inserts were selected from the production of two worldwide companies. ISCAR IS8 - Nitride silicon ceramics (Si₃N₄) used for medium-duty turning and milling operations. Inserts can be used for an interrupted cut on cast iron and nickel-based alloys and super alloys. Recommended cutting parameters - cutting speed \( v_c = 400 \div 1 \text{ 200 m} \cdot \text{min}^{-1} \), feed \( f = 0.1 \div 1 \text{ mm} [3]. \)
ISCAR IN23 - Black oxide ceramics (Al₂O₃-TiC) used for machining of gray and nodular cast iron and hardened steels in medium to finishing cutting conditions. This is a little harder ceramic material [2].

SAINT-GOBAIN D210 - Mixed oxide ceramics (Al₂O₃, ZrO₂, and Co) - apart from hardness and wear resistance at high temperatures, it excels also in a little higher toughness. It is suitable for machining of graphite iron with lamellar graphite, graphite, spherical graphite, cast iron and malleable cast iron, structural, tempered and high speed steels during a light interrupted cut [1].

SAINT-GOBAIN D460 - Nitride ceramics (Si₃N₄ based) - exhibits very high toughness, high hardness and enables conventional machining with an interrupted cut and can be used with a coolant. This kind of ceramics is especially suitable for machining of all kinds of cast iron [1].

2.5 Lathe used

For the testing of ceramic inserts during an interrupted cutting, a TOS SN 55-7 lathe made in Czechoslovakia was used.

The main technical parameters of the machine:
- Maximal RPM \( n_{\text{max}} \) = 1440 min⁻¹
- Power of main electric motor - 7.5 kW
- Maximal cutting diameter - 550 mm.

3 Results

During the tests we observed the number of shocks that would last until the insert was broken off or until the surface roughness of the tested slats was worsened. After stopping a running measurement, we measured the cutting length. The results were recorded into the table and the length was calculated on the number of shocks on the inserts using the formula below. In the tables below, the average value of the three measurements is written.

\[ R = \frac{x l}{f}, \]

where, \( R \)......the number of shocks [-],
\( x \)......the number of slats in the preparation [-],
\( l \)......the cutting length [mm],
\( f \)......the feed [mm].

3.1 ISCAR IS8

Table 2 shows that the insert ISCAR IS8 has the best mechanical shock resistance (Fig. 4 and 5) with the feed \( f = 0.2 \) mm and the maximum number clamped. Accordingly, the insert ideally operates during a regular interrupted cut [4].

Table 2. Values recorded with the IS8 insert [1]

<table>
<thead>
<tr>
<th>Feed f [mm]</th>
<th>No. of slats [-]</th>
<th>Length l [mm]</th>
<th>Number of shocks R [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1 276</td>
<td>25 513</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1 315</td>
<td>19 725</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1 305</td>
<td>13 053</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1 026</td>
<td>5 132</td>
<td></td>
</tr>
<tr>
<td>0.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1 045</td>
<td>13 063</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1 153</td>
<td>10 806</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>879</td>
<td>5 496</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1 088</td>
<td>3 401</td>
<td></td>
</tr>
</tbody>
</table>

In general, we can say that ISCAR IS8 insert used for the material 14MoV6-3 exhibited very low resistance to mechanical shocks.

Figure 4. Wear of insert IS8 \( f = 0.2 \) mm (left), \( f = 0.32 \) mm; 4 slates [1].

Figure 5. Wear of insert IS8 \( f = 0.2 \) mm (left), \( f = 0.32 \) mm; 1 slats [1].

Fig. 6 shows that by decreasing a measurable time delay between shocks, the resistance of the IS8 insert to the interrupted cut is increased (the best resistance were achieved with the maximum number of clamped slats in the preparation). The insert
exhibits better properties with the lower feed. An increase in measured values appears to be very constant.

Figure 6. Dependence on number of shocks according to the number of IS8 insert.

3.2 ISCAR IN23

Table 3 shows that the ISCAR IN23 insert has the best mechanical shock resistance with a feed $f = 0.2$ mm and with four clamped slats (Fig. 7 and 8). Therefore, the insert ideally operates during a regular interrupted cut.

Table 3. Values recorded with the IN23 insert

<table>
<thead>
<tr>
<th>Feed $f$ [mm]</th>
<th>No. of slats [-]</th>
<th>Length $l$ [mm]</th>
<th>Number of shocks $R$ [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>4</td>
<td>4126</td>
<td>82 520</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2453</td>
<td>36 800</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3200</td>
<td>32 003</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4565</td>
<td>22 827</td>
</tr>
<tr>
<td>0.32</td>
<td>4</td>
<td>786</td>
<td>9 821</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>645</td>
<td>6 050</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>826</td>
<td>5 165</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1353</td>
<td>4 227</td>
</tr>
</tbody>
</table>

In general, we can say that ISCAR IN23 insert used Ad, and the material 14MoV6-3 exhibited very high resistance to mechanical shocks.

Figure 7. Wear of insert IN23 $f = 0.2$ mm (left), $f = 0.32$ mm; 4 slats [1].

Figure 8. Wear of insert IN23 $f = 0.2$ mm (left), $f = 0.32$ mm; 1 plate [1].

From Fig. 9 it can be seen that with a decrease in delay between shocks, the resistance of the IN23 insert against the interrupted cut is increased (the best resistance values were achieved with a maximum number of clamped slats in the preparation). This increase is very obvious with a lower feed $f = 0.2$ mm, with a higher feed, this increase is not so (heavily) marked. With a higher feed, the number of slats has not a big impact on resistance. The better properties of the inserts are exhibited with the lower feed. With a higher feed, the resistance of the insert to mechanical shocks is rapidly decreased and we can state that the IN23 plate is not suitable for the machining of the material at a higher feed.

3.3 SAINT-GOBAIN D210

Table 4 shows that the SAINT-GOBAIN D210 insert has the best mechanical shock resistance (Fig. 10 and 11) with a feed $f = 0.2$ mm and with four clamped slats. Therefore, the insert ideally operates during a regular interrupted cut. With a little higher feed of $f = 0.32$ mm, the insert has the best resistance to mechanical shocks using four or two slats.
Table 4. Values recorded with insert D210

<table>
<thead>
<tr>
<th>Feed f [mm]</th>
<th>No. of slats [-]</th>
<th>Length l [mm]</th>
<th>Number of shocks R [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>4</td>
<td>1 887</td>
<td>37 733</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1 247</td>
<td>18 700</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1 423</td>
<td>14 233</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>700</td>
<td>3 500</td>
</tr>
<tr>
<td>0.32</td>
<td>4</td>
<td>763</td>
<td>9 542</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>290</td>
<td>2 719</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>820</td>
<td>5 125</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>533</td>
<td>1 667</td>
</tr>
</tbody>
</table>

In general, we can say that the SAINT-GOBAIN D210 insert used on the material 14MoV6-3 reached an average resistance to mechanical shocks at a lower feed. At a higher feed, the insert exhibited a low resistance to mechanical shocks.

Figure 10. Wear of insert D210 $f = 0.2$ mm (left), $f = 0.32$ mm; 4 slats [1].

Figure 11. Wear of insert D210 $f = 0.2$ mm (left), $f = 0.32$ mm; 1 slat [1].

Fig. 12 shows that with a measurable time decrease in delay between shocks, the resistance of the D210 insert to the interrupted cut is increased (the best resistance values were achieved with a maximum number of clamped slats in the preparation). The better properties of the insert were reached with a lower feed. The increase of resistance to mechanical shocks is more obvious at a lower feed $f = 0.20$ mm. At a higher feed $f = 0.32$ mm, the D210 insert negatively reacted to the irregular interrupted cut. It was more than a measurable time delay between the shocks, and the measured results were considerably affected by the character of the cut.

Figure 12. Dependence on number of shocks according to the number of insert D210.

3.4 SAINT-GOBAIN D460

Table 5 shows that the SAINT-GOBAIN D460 insert has the best mechanical shock resistance (Fig. 13 and 14) with a feed $f = 0.2$ mm and with four clamped slats. The insert, thus, ideally operates during a regular interrupted cut.

Table 5. Values recorded with the D460 insert

<table>
<thead>
<tr>
<th>Feed f [mm]</th>
<th>No. of slats [-]</th>
<th>Length l [mm]</th>
<th>Number of shocks R [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>4</td>
<td>3 177</td>
<td>63 533</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3 420</td>
<td>51 300</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2 800</td>
<td>28 000</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2 977</td>
<td>14 883</td>
</tr>
<tr>
<td>0.32</td>
<td>4</td>
<td>3 770</td>
<td>47 125</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4 315</td>
<td>40 453</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6 252</td>
<td>39 073</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>9 665</td>
<td>30 203</td>
</tr>
</tbody>
</table>

Figure 13. Wear of insert D460 $f = 0.2$ mm (left), $f = 0.32$ mm; 4 slats [1].
In general, we can say that the SAINT-GOBAIN D460 insert used on the material 14MoV6-3 exhibited a very high resistance to mechanical shocks for both feeds.

Fig. 15 shows that by decreasing a measurable time delay between shocks, the resistance of the D460 insert to the interrupted cut is increased (the best resistance values were achieved with a maximum number of clamped slats in the preparation). The insert exhibits better properties with a little lower feed, but only with a higher number of clamped slats in the preparation. With one clamped plate, the insert has better resistivity against mechanical shock with a higher feed \( f = 0.32 \) mm and more than \( f = 0.2 \) mm. In all other cases this phenomenon did not occur.

4 Conclusions

The best resistivity against mechanical shocks (see Fig. 16) was reached by the ISCAR IN23 insert (not for all types of shocks) and for a higher feed of \( f = 0.32 \) mm the SAINT-GOBAIN D460 insert has better properties (for all types of shock). Generally, we can say that the inserts have better resistivity against mechanical shocks with a maximum number of clamped slats.

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Katalog - Břitové desticky z rezne keramiky Disal Turnov.


