Cutting Materials

The optimum carbide for rough milling of titanium

Despite the heavy wear load, the need for cutting tools for machining titanium is on the rise. Researchers and practitioners analysed how a roughing cutter should be designed to achieve optimum production results.

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→ Due to the predominating segmented chip formation, the chemical reactivity and the lower thermal conductivity of titanium, machining of titanium alloys is considered especially challenging [1]. In the field of industry this becomes clear based on a low productivity limited by the tool wear. The reason for the high degree of tool wear is the heavy thermomechanical tool loading which causes greatly differing tensions in the cutting wedge. This can be shown impressively with the example of an FEM chip formation simulation (Figure 1).

The need for tools for machining titanium continues to grow

The temperatures and the effective tensions are shown for two cutting speeds $v_{c1}$ and $v_{c2}$ over the arc length of the cutting edge rounding. It is apparent that the tool temperatures while machining titanium are considerably higher than when machining aluminium and steel, as is also known from the relevant literature [1 to 3]. The poor thermal conductivity of titanium is, among other things, responsible for extremely high, locally differing tensions in the cutting wedge, which can result in local chipping. Adhesion to the cutting edge is another frequently occurring type of wear when machining titanium. Despite the high tool costs resulting from the heavy wearing during machining, the need for cutting tools continues to grow. This is mainly due to the newer aircraft generations with a high share of CFRP structures in which titanium is used as a composite partner [4]. However, titanium is also increasingly used in other industrial sectors, for example in

1 The results of an FEM simulation on the tension behaviour during machining (planing) of aluminium, steel and titanium. Parameters: $v_{c1}$ 60 m/min, $v_{c2}$ 180 m/min, h 0.10 mm, b 1 mm, $r_{a}$ 50 µm. The increased local tensions for titanium can be recognised (Figure: IFW, No/75895)
The process situation partially determines the carbide suitability

The vertical milling machine is more pliable and due to a lack of inside cooling has a poorer chip transport or a poorer lubricating effect than the modern high-performance machining centre. As a result, the probability is higher for the vertical milling machine that sudden cutting edge chipping will occur, e.g., due to chip jamming. It is apparent that local chipping for the tougher substrates is considerably less critical than for the harder substrates. If chipping is avoided by a good chip transport and suitable dynamic properties of the machine tool, harder substrates should be given preference with which primarily abrasive flank wear occurs.
However, the hardness of the substrate cannot be increased arbitrarily, as an increasing hardness also results in a reduced toughness. Ultra fine-grained carbides have a different ratio between hardness and toughness compared to submicron grades. This reduces the chances of titanium alloys for milling. When using ultra fine-grained carbides, shell-shaped chipping can occur at irregular intervals, as shown in Figure 3 at the left, which result in a rapid failure of the tool. This effect increasingly occurs with high tooth feeds $f_t$, as the mechanically loading of the milling tool is mainly intensified by the increased chip cross section. For example, the productivity $Q_m$ could be held constant by increasing the cutting speed with simultaneous reduction of the tooth feed, however an increased adhesion tendency caused by chemical effects became apparent in the examinations. This in turn resulted in a faster tool failure. A high feed strategy is therefore preferable.

**High feed strategy preferred**

The choice of the suitable carbide is therefore dependent on a large number of factors. An example of this is the influence of the machine tool. With modern high-performance machining centres, the toughness of the substrate should be chosen just high enough that chipping on the milling tool is avoided. If smaller, local chipping on the cutting edge, e.g. due to poor chip transport, cannot be prevented, tough substrates are more suitable.

In addition to the carbide, the coating, the tool geometry, the cooling lubricant feed and the adjustment variables were also optimised in the multilateral project. With an increase in the metal removal rate to 150 percent of the initial value, it was possible to increase the tool life by 217 percent. The maximum metal removal rate was achieved with the milling tool of the final development stage and is 196 percent. And that with only a minor tool life reduction of 23 percent compared to the reference tool [6]. Figure 4 shows various forms of realization of an advanced milling tool designed according to the project results. In practice, the best suited of these can then be chosen depending on the preference of the process target figure.