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Simultaneous machining of a material combination with an internally and externally cooled cutting insert

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Abstract

This paper discusses the machining of cylinder running faces of aluminum engine blocks with reinforced, arc-sprayed cylinder walls. Such special material combinations and, therefore, processing conditions are common in the automotive sector, where the load-oriented material use induces a significant reduction of fuel consumption. The machining of such a material combination comes along with several challenges including notch wear on the main cutting edge as a result of the arc-sprayed cylinder walls or a built-up edge formation on the main cutting edge because of the aluminum. Promising approaches by means of an internally and externally cooled cutting insert are presented in this paper and compared to common external cooling.

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Keywords: material combination; simultaneous machining; internal and external cooled cutting insert; notch wear; flank wear; built-up edge

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1. Introduction

When machining cylinder running faces of modern engine blocks - a material combination consisting of casted Al-alloys (EN AC-46000, 80 HV) and wire-arc-sprayed cylinder walls (DIN EN 10016-2, 850 HV) - a number of distinctive material - related effects occur, which hamper the straightforward implementation of the machining processes. These effects mainly derive from the varying chipping behavior of the specific material combination because of different material parameters. Particular the highly unequal hardness results in different cutting forces and different wear on the appropriate cutting areas like built up edge at the cutting area of the aluminum engine block and notch wear at the cutting area of the wire-arc-sprayed cylinder wall (as a result of mechanical and thermal overload [1]).

Assembly parts are divided in pseudo hybrids and real hybrids (figure 1, left side). For pseudo hybrids, the support structure is made of one material and the non-support structure of another. Assembly parts with a support structure of different materials are called real hybrids [2]. If a component is made of two or more materials, it can be distinguished between composite materials and material combinations (figure 1, right side). Composite materials are macroscopically homogenous whereas material combinations are a connection between two or more macroscopically different materials.

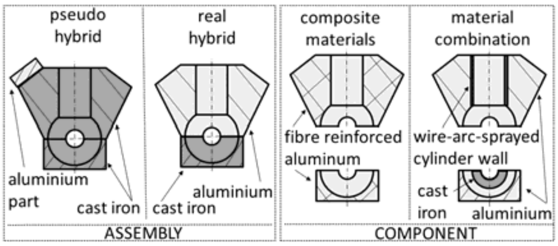

Fig. 1: Definition of assembly and component.

With respect to the position of the different materials relative to the feed vector, the machining of material combinations can be divided in serial, parallel and simultaneous machining. Figure 2 depicts exemplarily these

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different types of machining. In the case of serial machining, the machining process can be optimized for each single material if the process is divided into two different operations with two different tools. Parallel machining results in both materials being machined alternately in one single rotation of a tool, so the process cannot be optimized for each individual material [2]. Machining of the wire-arc-sprayed cylinder wall is a combination of serial and parallel machining, a simultaneous machining of a material combination. The position of the two materials relative to the feed vector indicates a parallel machining, however, the process could be optimized for each material by splitting it in two machining steps with two different tool diameters. Regarding timely efficiency, the wire-arc-sprayed cylinder wall is principally machined in a single, simultaneous machining step.

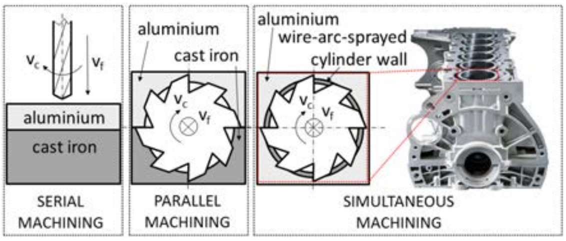

Fig. 2: Definiton of serial, parallel and simultaneous machining.

This paper presents some findings on the influence of different coolant supply solutions in the machining of wire-arc-sprayed cylinder running faces - a simultaneous machining of a real hybrid material combination.

2. Internal and external coolant supply

Besides conventional external cooling strategies like flood cooling new strategies such as atmospheric-pressure plasma jet [3], solid lubrications [4] and cryogenic cooling [5] are described in the literature. Additionally there are some different internal cooling strategies well known concerning the cutting fluid itself and the kind of delivery. The latter can be defined by open loop [6] or closed loop [7] systems. Figure 3 gives a schematic overview of the state of the art in cooling strategies considering the impact of the cooling fluid/solid on the cutting insert.

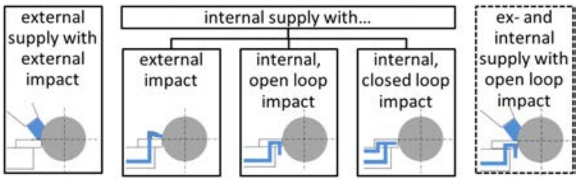

Fig. 3: Schematic overview of state of the art cooling strategies and new developed system with internal and external delivery (dashed line)

The major obstacle for the application of internal cooling systems is the acceptance in the industry. The results are promising but there are several unsolved problems such as chip removal (being currently done by the cutting fluid at high pressure cooling) or the millions of liters of cutting fluid which must be costly disposed of as special waste when switching to another cooling fluid.

Because of these challenges a new system was developed. The newly developed system is depicted on the right hand side of figure 3. In the modified cooling strategy, the cutting edge is cooled both, internally and externally, with cutting fluid. For cutting experiments, flow-optimized cooling channels were machined by EDM in cemented carbide cutting inserts (insert code: TCMT 16T308) with Ti-Al-N coatings. A tool holder was adapted with additional holes for supplying the internal inlet and outlet of the cutting insert by cutting fluid. The second outlet channel is used for supplying the external cooling of the cutting process (figure 4). The flow channel geometry in the cutting insert has been designed by the use of FEM simulations in order to perform stability investigations and to scale the size and position of the flow channel. The final design lies at the closest area only 0,5 mm beneath the rake face surface and the cooling channel has a minimum distance to the cutting edge of 0,8 mm.

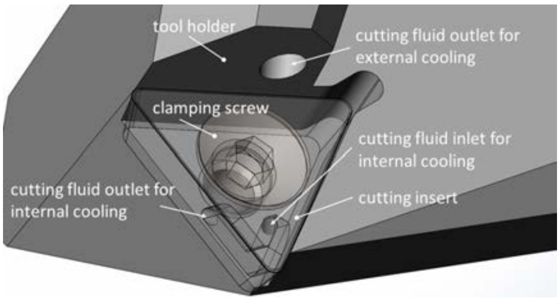

Fig. 4: Tool holder with assembled EDM machined cutting insert.

3. Model based investigations

Before starting experimental tests, a model-based investigation of the temperature distribution as well as the influence of the internal cutting fluid flow has been conducted. The tool holder with the EDM machined cutting insert (figure 4) and the process parameters shown in table 1 are used for simulations and experimental investigations.

Table 1. Process parameters.

Process parameters	value	unity
Revolution speed (n)	500	1/min
Diameter (D)	85,2	mm
Cutting speed (v_c)	134	m/min
Feed (f)	0,2	mm/rev
Cutting depth (a_p)	0,9	mm
Cutting depth aluminium	0,6	mm
Cutting depth cylinder wall	0,3	mm

To show the dependency of the temperature increase from the inlet to outlet of the EDM machined channel (figure 4) to the internal flow rate, a simulation with ANSYS Fluent was carried out using a laminar model for viscosity. The mesh had a skew under 0.6 and an orthogonal quality over 0.4 at the relevant parts of the cutting insert like the cross section of the cutting edge or the EDM machined channel. Hence, a very good mesh quality was obtained and appropriate results can be assumed. For calculating the heat transfer Q (formula 2) at the