

Porsche differential housing shaped with PCD

Despite maintaining a high level of expenditure on development, Dr. Ing. h.c. Porsche AG, Stuttgart achieved a 40% increase in pre-tax profits in the last financial year. Accordingly, the company's trading result before tax rose substantially, from € 592.4 million in the previous year to € 828.9 million.

Despite the difficult economic conditions in the financial year 2001/2002, the company sold 54,234 sports cars. While it is true that this corresponds to a fall of 0.6%, due to an improved product mix turnover rose by 9.4%.

Porsche is very confident of the trend in the current financial year. Not only because with the new Porsche range the Cayenne S and the Cayenne Turbo (Fig 1) a sporty off-road vehicle expands the product range, but also the demand for the Boxster and 911 series is still positive.

The 911 series is still Porsche's crowd puller. These cars are characterised by their light metal construction, including the engine. A light metal engine has advantages and disadvantages. On the negative side of weight advantages is the substantial expansion of the material at high working temperatures, which can however be minimised by the appropriate selection of the aluminium alloy.

The differential housing of this Porsche series is also manufactured from such an aluminium alloy, among others by the company Georg Fischer Mössner GmbH in Munich. Here, each year some 12,000 of these housings are manufactured, starting with the production of the workpiece material through to the machining of the components.

Reduction in tool-change times and reduced tool flow

The differential housing shown in Fig 2 is used in the Porsche models the 911 turbo and the 911 four-wheel drive vehicle. It is made of the aluminium alloy GD- AlSi_9Cu_3 , which can be machined relatively easily.

In the automotive industry the roughing of aluminium housings is in many cases carried out with tungsten carbide tools, and PCD tools are used only for finishing. But if factors such as machining speeds, longer tool lives and reduced tool flow are also taken into account, there are advantages in using PCD tools for roughing as well. This article by P. Bornschlegl and H. Simon.



Fig 1 The Porsche Cayenne Turbo

As well as the face milling of all the outside faces with quality requirements of $R_z = 10$ to $25 \mu\text{m}$, the complete machining process includes producing various threaded bores and seats. Here too the quality requirements are high. Machining qualities of Q8, H7, G6 and R6 are required in the bores, which must be produced in the diameter range from 6.2 to 228 mm, while in the seats surface qualities of $R_z = 10 \mu\text{m}$ and, in the case of the oil delivery bores values of $R_z = 6.3 \mu\text{m}$ in quality H6 must be adhered to in a reliable process.

The differential housings are machined in two set-ups. In the first set-up the workpiece is received with the edge uppermost on the gripping tabs of the oil cooler (three-point bearing), while the second set-up is carried out lying flat (four-point bearing). In order to satisfy the high demands on the machining quality,



Fig 2 Differential housing made of GD- AlSi_9Cu_3



Fig 3 Machining the bore in the first set-up



Fig 4 PCD boring bar as a combination tool with adjustable indexable inserts (for bore diameters of 76.2 mm and 82 mm)

in the first set-up, because of the precise reference characteristics of all the seats, a measuring stylus is used.

As well as adhering to the machining qualities in a reliable process, at the beginning of the project particular attention was paid to the shortest possible tool-change times and a low tool flow. Essentially, three measures were taken in order to reduce the times needed to change tools.

Machining (Fig 3) is carried out on a Honsberg Lamb Mach 1-500 A machining centre. This is a twin-spindle machine with a 24 kW drive system. The twin spindle is used in order to save on tool-change times. While one spindle is machining the workpiece, the other travels to the tool magazine to fetch the next tool. Furthermore, the same tools are available twice over at different places in the magazine, which can take up to 60 tools, so that due to the shorter paths tool-change takes place more quickly. The third measure for minimising tool-change times lies in the use of combination tools.

In order to minimise tool flow, in many of the machining operations PCD tools with removable indexable inserts of the same specification are used both for roughing and finishing.

PCD indexable inserts of the same specification for roughing and finishing

Typical examples are the combination tools shown in Fig 4 and Fig 5 (centre). A boring bar with four indexable PCD inserts of specification CCGT 09T304 and a PCD grain size of $10\ \mu\text{m}$ is used to rough the 43.7 mm and 81.3 mm diameter bores. This tool can also be fitted with a thread cutter at the end, enabling tool-change time to be reduced by 7 seconds.

In order to minimise tool flow, PCD inserts of the same specification as for roughing are also used in the finishing tool shown in Fig 4. This too is a combination tool for machining two bores (82 mm diameter, quality H7 and also 76.2 mm diameter, quality H7) and can also receive a thread cutter. In both tools the PCD inserts are supplied with coolant by separate coolant channels.

While with the roughing tool tolerances of less than 0.1 mm can easily be produced without the use of an adjustable insert seating, the tools for finishing are adjustable so that the indexable inserts can be adjusted to micron accuracy in the middle of the tolerance range. The insert is screwed onto the tool with a locking screw and tightened with a defined torque of 300 Ncm. The tool is then adjusted to the nominal size with an optical adjusting device. Further adjustment is not necessary.

Rotational speeds of $7,000^{-1}$ and feeds of 0.14 mm/rev are used for roughing these bores, and finishing is performed at rotational speeds of $6,000^{-1}$ and feeds of 0.21 mm/rev. The speeds used here, which are relatively low for PCD tools, ensure that the high requirements on the roundness of the H7 bores can be adhered to in a reliable process. Also, with an R_z of $8\ \mu\text{m}$ the surface quality achieved is considerably better than that required by the customer ($R_z = 10\ \mu\text{m}$).

No end to tool life in sight

But in this application conventional monoblock PCD tools also show their advantages compared with other tool materials. For example, the seating bore (diameter 25 mm, length 13 mm, quality H6, $R_z = 2.5\ \mu\text{m}$) for the oil cooler is produced directly with a two-edged PCD



Fig 5 PCD tools are used for both roughing and finishing

step counterboring tool of this type. The internal coolant channels of the tool emerge in the chip room and thereby ensure adequate cooling and lubrication during the boring process. At a speed of $2,750\ \text{min}^{-1}$ and a feed of 0.2 mm/rev, so far 6,000 bores have been produced with this tool and there is still no end in sight for tool life.

Summary

Unlike with many other applications, in the machining of the differential housing of the Porsche 911 turbo and the four-wheel drive model, PCD tools are used not only for finishing, but in some operations also for roughing. As well as considerable advantages in terms of tool life and machining speed, these have also resulted in cost savings due to a considerably reduced tool flow. Therefore, in roughing as well, the more expensive PCD tools are an economic alternative to other tool materials. ♦

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