Additively Manufacturing an Indexable Insert

Jindřich Sýkora 1, Luboš Kroft 2

1 University of West Bohemia, i Družby 979/5, Plzeň, 31200, Czech Republic
2 Tymákov 387, 332 01 Tymákov, Czech Republic
sykora@rti.zcu.cz

Abstract. Considering the constant advances in additive manufacturing, it makes sense to use this approach when creating a cutting tool. Currently, a lot of the tools used in machining are in the form of indexable inserts. This minimizes the amount of material used and ensures a swift change when a tool is worn out. Indexable inserts are currently made by pressing and sintering which requires a large investment in specialized mould tooling for each insert shape. This paper investigates an additive approach to making indexable insert blanks. This manufacturing process does not require mould tooling and offers a large degree of freedom when it comes to making inserts of diverse shapes. In this work, the process of manufacturing CCMT inserts out of MS1 steel (X3NiCoMoTi 18-9-5) is investigated. MS1 is not an ideal material for a cutting tool, however, the findings can be translated to blanks additively manufactured out of tungsten carbide, cermets or ceramics.

1. Introduction
Additive manufacturing (AM) of metal parts is currently quite widely used in industrial applications. Using AM makes a lot of sense for parts with very complex shapes or parts that require complex internal cavities (e.g. injection moulds). The additive manufacturing process helps to minimize the material removal by machining as well as the need for complex fixtures. Moreover, it provides a solution for manufacturing otherwise impossible to make parts, for example internally cooled injection mould inserts [1], [2].

However, even with the rapid advances in additive manufacturing in recent years, conventional machining is still one of the most common methods used for part production. Therefore, the development of novel cutting tools is critical for the advancement of manufacturing as a whole. Arguably, one of the most important products in this industry is the indexable insert. It is the part of the tool that is responsible for the cutting action and is easily replaceable in the production environment. Tungsten carbide indexable inserts are the most common and they come in a variety of shapes and sizes. There are several ISO standardized types, but many more unconventional ones are used in milling, for example [3], [4].

The development of each of these unconventional inserts requires a mould in which the raw powder is pressed to create a blank of the desired shape. This is a very costly and time-demanding process that also limits geometrical freedom. In situations where the production volume of the inserts is not very large or when complex geometries or internal cavities are required, an additive approach to manufacturing could be more efficient. Prototyping a new indexable insert shape is one of the potential
applications. After heat treatment, the blank is in many cases finished by grinding, even when using conventional manufacturing methods.

The idea of creating insert blanks additively has become increasingly relevant as new approaches to additively manufacturing tungsten carbide are being developed and the properties of the parts are close to those of conventionally manufactured tungsten carbide [5], [6].

Therefore, this paper investigates a method of producing indexable inserts by AM. Inserts of the CCMT shape are used here because they are very common and can be easily tested using existing tool holders. In this case, inserts are made out of hardened MS1 tool steel (X3NiCoMoTi 18-9-5), which is not an ideal material for cutting tools. [7] The findings can, however, be utilised in the process of additively manufacturing tools out of tungsten carbide, ceramics or even PCD to a large degree. Alternatively, a tool steel insert can be used as a carrier for a carbide, CBN or PCD cutting edge. [8]

2. Additive manufacturing of insert blanks
Firstly, additive manufacturing of indexable insert blanks requires a CAD model – in most cases, an STL format is needed. The design of the insert was inspired by the CCMT 120404 indexable insert sold by Iscar ČR s.r.o. [9]. However, the flank faces, rake face, and the bottom face of the insert were offset to allow for finish grinding. The screw hole of the insert was left at the nominal shape.

Secondly, the print data was prepared in the Materialise Magics software and the parts were connected to the build platform using block and cone support structures (see Figure 1). Then, using EOS Print, the parts were laid out on the building platform according to the recommendations of the machine manufacturer.

Lastly, the build process is started. Most often the disadvantage of additive manufacturing is the length of the build time and the cost of the raw material. In the case of the inserts, these disadvantages are close to insignificant. A cutting insert (CCMT 1204 in this case) is usually a reasonably small part, therefore, the build process is quite quick. The total build time when 3D printing 10 inserts is 106 minutes, resulting in less than 11 minutes per insert. The amount of raw powder needed for each insert is 9 g including the support structures.

![Figure 1. Indexable insert with support structure – Prepared in Materialise Magics](image)

3. Preparation of blanks for finishing
After AM, the inserts need to be post-processed. The first step is heat treatment of the entire build platform to reduce the stress induced by the build process and to harden the parts. Next, the parts are cut off the build platform and the support structures are removed.
The rake face and bottom face is then finished using a surface grinder. The cutting insert we used has a flank face angle of 7°. This needs to be taken into account while surface grinding. The amount of the material ground off these faces needs to be such that the diameter of the inscribed circle on the bottom face is 12.14 mm and the final height is 4.76 mm. This is important for the set up in the fixture (see Figure 4) used for finishing the bolt hole. The remains of the additive manufacturing process is a 0.044 mm raised rim that appears on the topmost surface of the part (see Figure 2). This needs to be taken into account when surface grinding to ensure the part's accuracy. The height of this feature was measured on an Alicona IFM G4 microscope.

![Figure 2. Scan of the raised outline of the part taken on Alicona IFM G4](image)

The surface grinding of the blanks was done in the following way. All the parts were secured on a magnetic chuck on the rake face and the remains of the support structures were ground flat. Secondly, all the parts were flipped and the lip on the edge of the blank was ground down. Thirdly the parts were flipped again and the bottom surface was ground to the final dimension. The thickness of the insert at this stage was 5.06 mm. Lastly, parts were flipped on this freshly ground bottom face and the rake face was ground bringing the insert to the final thickness of 4.76 mm.

The next step was finishing the bolt hole. The precision achieved by additive manufacturing is not sufficient for this bore, because in this case, it determines the positional accuracy of the insert in the tool holder. Therefore, the surface of this bore needs to be machined. For this procedure, a special tungsten carbide taper mill was used. It has a 44° taper which matches the taper of the head of the precision bolt used for securing the insert to the tool holder. A fixture is used to clamp the insert blanks (see Figure 4). The bore finishing process consists of finding the centre of the existing bore with a workpiece contact probe and milling out a tapered section (see Figure 3) on which the bolt head will rest.

![Figure 3. Bolt hole finishing](image)
4. Grinding the inserts

The last step of the process is grinding the blank to its final dimensions and shape. For this final operation, which gives the insert its precise shape, a 5 axis Anca MX7 tool grinder is used. This grinder is designed to hold round bars with h6 precision. This meant that a clamping fixture for the inserts had to be designed and manufactured (see Figure 5). The fixture was produced to provide the highest concentricity of the M5 thread and the clamping cylinder. The insert is held in place by the precision bolt mentioned above. The tapered contact between the bolt and the insert together with the tolerances of the fixture determine the final precision and repeatability of the insert position. The tolerance of the insert position was smaller than 0.02 mm, measured on the Zoller Genius 3s.

The 5 axis toolpath was created using NX CAM and machine movements were set up in such a way that the tool stays at the top of the part, ensuring sufficient delivery of the cutting fluid. The grinding parameters used for the inserts made out of MS1 steel are shown in Table 1.

This setup allows for the flank face as well as the rake face to be ground. This provides a large degree of freedom and various shapes of inserts can be created. The final shape of the insert is dictated by the manufacturing NC program, which can be changed quite easily. Therefore, it is a convenient finishing procedure for prototyping. Various corner radiuses, flank angles or rake geometries can be easily created.

| Tool | SiC – DIA PRAHA 100x10x20 C49 80 K 9 V |
|------|---------------------------------------|
| Cutting speed | 25 m/s |
| Feed rate | 50 mm/min |
| RDOC | 0.1 mm |
| ADOC | 4.76 mm |
5. Conclusions

The use of additive manufacturing could make the process of manufacturing prototype or low volume cutting inserts more efficient by reducing the need for mould tooling. Moreover, it makes the whole process much more flexible. This study presents a usable methodology for creating an indexable insert with the aid of additive manufacturing. It clearly shows the essentials of the whole process, starting with the design requirements and ending with a functioning product. Due to the current equipment limitations at our facility, only the process of manufacturing an insert made of MS1 steel was investigated. Although further research needs to be done, the findings should translate by a large degree to manufacturing inserts out of carbide, cermet or other suitable cutting materials. The steel inserts could also be equipped with a brazed PCD or CBN cutting edge.

To conclude, this paper shows a clear framework for making an indexable insert using additive manufacturing. However, more research needs to be done not only with more suitable cutting materials but also in utilizing other advantages of AM, such as manufacturing internal cavities.

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