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Analysis of the drill base body fabricated with Additive Manufacturing technology

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Abstract
The paper presents the investigation results on the additive manufactured drill base body. Due to the technological and strength limitations, conventional drills with inner coolant ducts may not me smaller than 13 mm diameter. The investigated drills fabricated using a 3D laser printer have the geometry designed in the way not affecting its stifness and strength. Inner stress analysis proved the advantage of 3D-printed drills. The sintered material has very small porosity rate (below 1%) and very few discontinuities.

Keywords: 3D printing, 3D printing, inner stresses, drilling, material microstructure

1. Introduction

Additive Manufacturing (AM), commonly known as "three-dimensional (3D) printing," is a recently invented computer dependent technology that has proven its success as an option for production of parts in a wide application range, often the high complexity items, which could be very difficult or even impossible to be manufactured by other processes [1]. The absence of waste material, like chips resulting from machining, is also a great AM advantage in terms of saving energy, material, tooling and man power as well. It is considered more environmental friendly even though for most AM processes, 3D printers use more energy than that of comparable conventional processes at process or machine levels [2]. The need to effectively consider optimal strategies for management leads to the development of Industrial Additive Manufacturing Systems [3].

"Rapid tooling" describes the additive manufacturing of tools, tool inserts, gauges, and molds. The additive manufacturing of tool inserts is older than those of final products and was introduced in the early 1990s [4]. In the last decade, some companies started to deliver machine tools with replaceable inserts fixed in the holders produced using the additive manufacturing processes [5]. Within the space of the laser printer, tool geometries can be created unhindered by machine clamps, tools and production means [6]. In the present paper, investigations on the drill base body fabricated with AM technology are described.

2. Strength analysis of the drill base body

Conventionally, the main body of the drills with replaceable inserts is made out of steel. Fabrication process involves such operations as turning and grinding of the main body with proper flutes ensuring chip removal, cutting out the seat for replaceable insert, as well as drilling of the inner ducts for the cooling liquid. Technically, those coolant ducts lead centrally to the front where the coolant is then distributed to the inserts via a Y-fork shown in the Fig. 1.

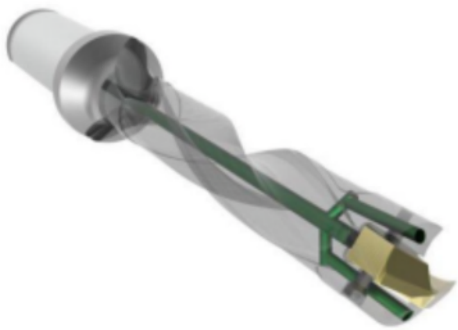

Figure 1. Coolant ducts in the conventionally fabricated drill base body

However, the central coolant chanell substantially weakens the drill core and makes it unstable. The smaller the diameter of the drill base body is, the more its performance is affected by the inner coolant ducts. Therefore, usually the insert drill is manufactured conventionally above 13 mm diameter [6].

Additionally, the base body is weakened by the openings for the screws or other elements holding the inserts. Stiffness and strength of the body is especially decreased in case of small diameter drills. Application of 3D printing technology enables to shape the coolant ducts spirally along the flutes without weakening the drill core, as it is shown in the Fig. 2.

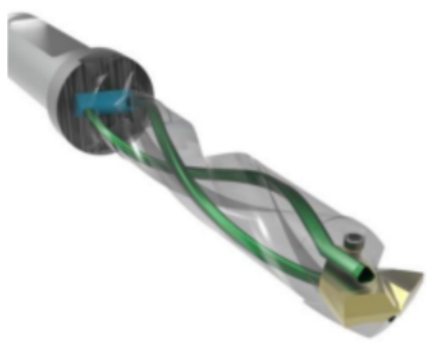

Figure 2. Spiral coolant ducts in the AM fabricated drill base body

AM technology enables to keep the coolant ducts diameters large enough for proper cooling process, despite small diameters of the drill. Moreover, their intersection can be different from round shape, e.g. triangle, absolutely inachievable in any conventinal technology. This way it is possible to produce the insert drills with diameters as small as 8 mm keeping them sufficiently strong. FEM analysis proved that the inner stresses in the drill base body fabricated in AM technology is ca. 50% smaller than that in the conventionally made ones. The example in Fig. 3 presents the example where inner stresses of the 3D-printed base is 820 MPa while the ones for conventional steel drill base body is 16883 MPa.

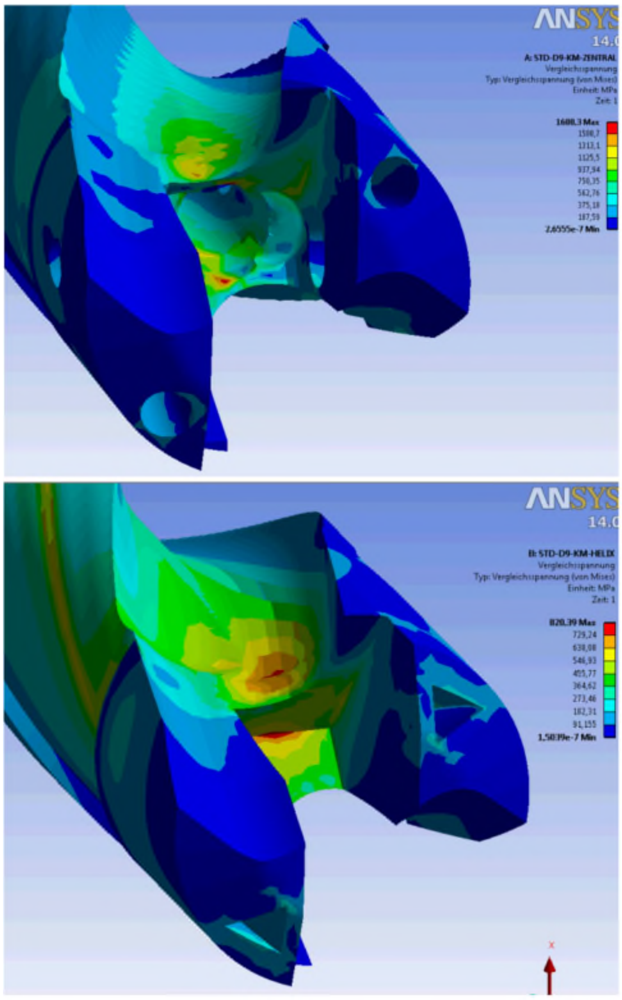

Figure 3. Example of FEM analysis of the inner stresses in the conventionally fabricated (upper) and 3D-printed drill base body

Additionally, AM technology enables easy rear relief formation so it is shaped for optimal chip removal.

3. Structure and porosity

Analysis of material structure was performed in order to obtain data on homogeneity and porosity of the material. The drill base body was made out of the powder No 1.2709 using the AM device Concept Laser Machine M1 (Concept Laser GmbH, part of GE Additive). Fig. 4 presents the photomicrograph of drill body section etched with nital, where laser-made structure is clearly distinguishable, and the pores are visible. Porosity rate in different areas was varying from 0.35% up to 0.85% which was found highly satisfactory.

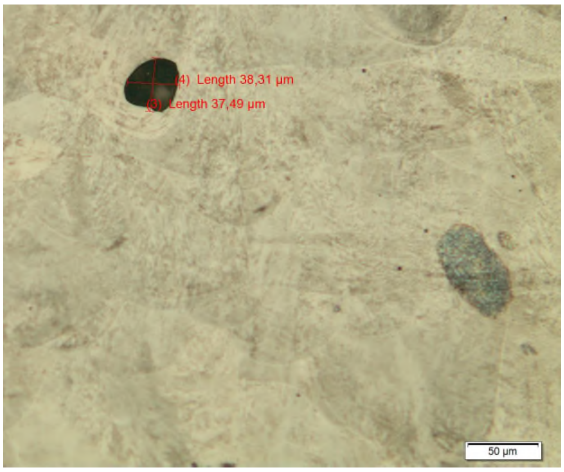

Figure 4. Material microstructure with a visible pore

Globular pores were found to be more frequently distributed close to the coolant ducts and the body edges. Maximal dimensions of the vacancy did not exceed 0.04 mm.

The structure produced by laser layer-by-layer sintering is seen, but the material integrity is almost complete. Only sporadically can be found discontinuities between the layers in form of irregular slots. The largest found slot was of 0.22 mm length.

4. Conclusions

Investigations on the 3D-printed drill base body proved that there are many advantages compared to the conventionally produced ones.

First of all, it was possible to prepare the drills of smaller diameters with sufficient coolant ducts. The ducts were placed spirally along the flutes and did not affect the drill core keeping its stiffness. The shape of those ducts was close to triangle, which had smaller weakening impact on the drill strength. Fabrication of such structure with any conventional subtractive manufacturing appears to be impossible.

Next, the analysis of inner stresses with FEM proved that the obtained drill base body has smaller stresses, and thus better durability.

Finally, the analysis of structure provided information that the material has very small porosity rate, high inner integrity and homogeneity. These features ensure its durability and failure resistance.

To sum up, the 3D printing technology may be successfully applied in the production of the drill base bodies, ensuring their better performance than conventional technologies. The drills of smaller diameters may be produced, meeting all the requirements on strength.

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