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3D MODEL OPTIMIZATION OF FOUR-FACET DRILL FOR 3D DRILLING SIMULATION

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Abstract

The article is focused on optimization of four-facet drill for 3D drilling numerical modelling. For optimization, the process of reverse engineering by PowerShape software was used. The design of four-facet drill was created in NumrotoPlus software. The modified 3D model of the drill was used in the numerical analysis of cutting forces. Verification of the accuracy of 3D models for reverse engineering was implemented using the colour deviation maps. The CAD model was in the STEP format. For simulation software, 3D model in the STEP format is ideal. STEP is a solid model. Simulation software automatically splits the 3D model into finite elements. The STEP model was therefore more suitable than the STL model.

Key words

Reverse engineering, modelling, drill, simulation, four-facet drill

INTRODUCTION

Reverse engineering

Engineering is the process of designing, manufacturing, assembling, and maintaining products and systems. There are two types of engineering: forward engineering and reverse engineering. Forward engineering is a traditional process of moving from high-level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part/product without any technical details, such as drawings, bills-of-material, or without engineering data. The process of duplicating an existing part, subassembly, or product without drawings, documentation, or a computer model is known as reverse engineering. Reverse engineering is also defined as the process of obtaining a geometric CAD model from 3-D points acquired by scanning/digitizing the existing parts/products (1).

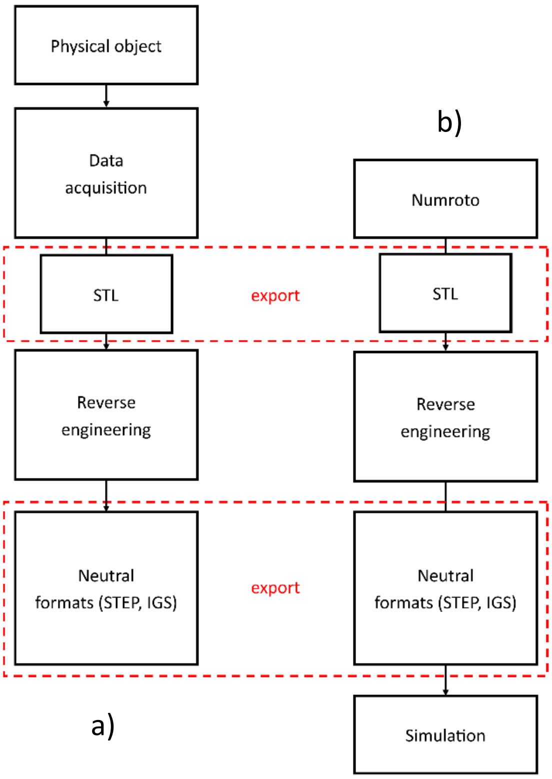

Fig. 1 *Reverse engineering*
a) The 3D data obtained by the 3D optical scanner
b) The data obtained from the NumrotoPlus software

Simulation

In the recent decades, with the emergency of more and more powerful computers and the development of numerical techniques, the numerical methods such as finite element method (FEM) are widely used in machining industry. FEM has become a powerful tool in the simulation of cutting process because various variables in the cutting process such as cutting force, cutting temperature, strain, strain rate, stress, tool war, etc. can be predicted, including those that are very difficult to detect by experimental methods. For the analysis of FEM machining technology, it is also possible to use the 2D and 3D methods. The 2D FEM method is used as the basis for analysis of technology turning or milling. The 2D FEM analysis method of cutting forces during a hardened turning was reported in (2). Due to the complex geometry of the cutting tool, is required for drilling FEM analysis use the 3D method. It has been shown (3, 4) that it is important to use the 3D FEM analysis software for drilling. DEFORM-3D is a robust FEM simulation tool to model complex machining processes by the 2D and 3D methods. The program has many features to simulate and analyse drilling operations. One of the most difficult problems facet with modelling drilling operation is obtaining an accurate model of a drill bit.

Drilling

Drilling is a term which covers all methods of making cylindrical holes in workpiece with chip cutting tools. The fact that drilling is by far the most common machining operation and that the great majority of hole diameters are within the range 10-20 mm, shows quite clearly how important the operation is in the field of modern metal cutting. With the development of tools for short hole-drilling, the need for preparatory and subsequent machining has changed drastically. Modern tools have led to the solid drilling being carried out in a single operation without previous drilling of centre and pilot holes, and to the hole quality where subsequent machining to improve the measurement accuracy and surface texture is often eliminated (5). Cutting forces influence the energy consumption during the process. High cutting forces mean high performance, and usable performance is always limited. High cutting force causes a greater deflection of the cutting tool and workpiece, which can result in vibration and deformation of the workpiece (6).

DESIGN OF FOUR-FACET DRILL

The design of the four-facet drill was designed in NumrotoPlus software. NumrotoPlus is a comprehensive software package for producing and resharpening a whole range of tools. NumrotoPlus uses leading edge technology to exploit all the capabilities of modern PCs and operating systems. It can be easily networked and also used with your in-house software. NumrotoPlus includes support of the 2D and 3D grinding simulation. One of the results of four-facet drill design in NumrotoPlus software is a list of grinding operations. Two types of grinding wheels for grinding simulation were used: periphery wheel (1A1) and cup wheel (11V9). Periphery wheels are mostly used for flute machining, gash out and radial clearances. Cup wheels are used for relief machining and sometimes for circular grinding. Result of the 3D simulation is shown in Fig.2. Another result is the export 3D model (STL model).

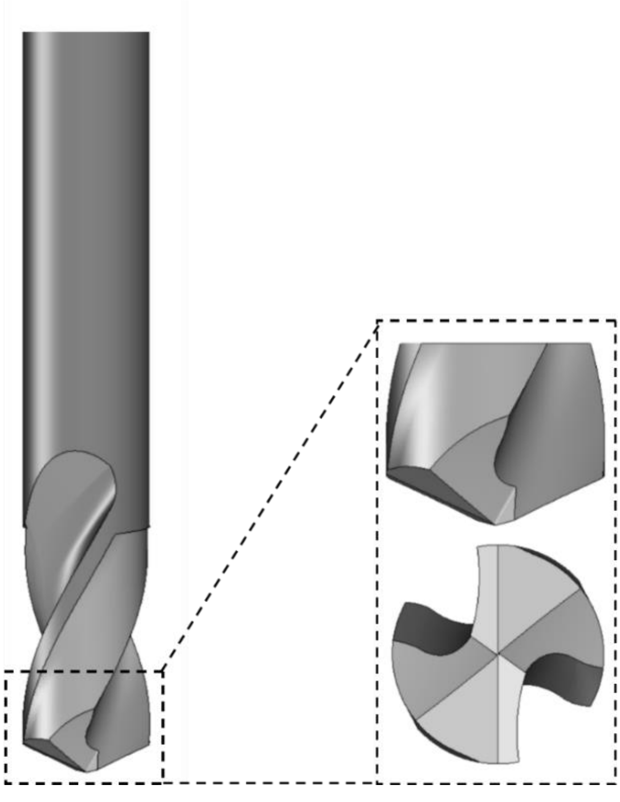

Fig. 2 *3D model of four-facet drill and tip details*

QUALITY OF THE STL MODEL

Export data was necessary after grinding simulation of four-facet drill. Standard export data is the STL format. The file extension of STL is derived from the term *stereolithography*. The STL files use triangular facets (tessellation) to describe the surface of 3D objects. Table 1 shows a quality 3D model of four-facet drill from NumrotoPlus.

Table 1 Quality 3D model of four-facet drill from NumrotoPlus

Column heading	Compression (%)	Number of Facet	File size (MB)	File type
Original STL	-	3983392	189.9	Binary
Simplified STL	50	1991696	94.97	Binary
Simplified STL	75	995848	47.49	Binary
Simplified STL	95	199169	9.5	Binary
STLpack	95	199168	1.8	Binary

Fig. 3 shows the quality of 3D model of four-facet drill from NumrotoPlus. The important data are number of facets. The number of facets reflects the quality of the STL model. The more of number of facets means better quality of STL model.

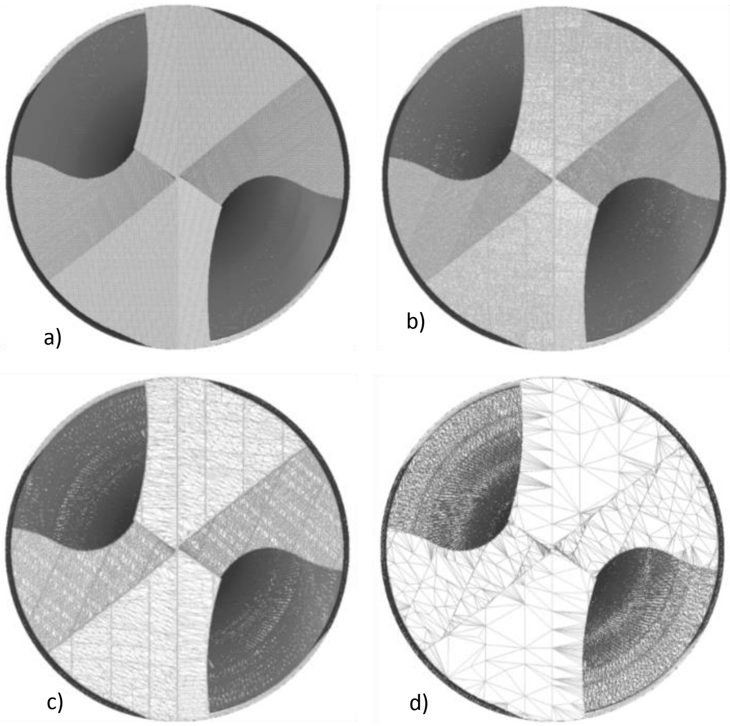

Fig. 3 *STL model quality*
a - original STL, b - simplified STL 50,
c - simplified STL 75, d - simplified STL 95

REVERSE MODELLING OF FOUR-FACET DRILL

Reverse engineering was implemented in the PowerSHAPE software. It is necessary to obtain the optimal file size of the STL model, because a too big file of the STL model requires a powerful computer. For reverse engineering, a model size 47.49 MB by compression of 75 % was used. The used functions of the PowerSHAPE software were dynamic section or oblique section, segment mesh (automatically or manually), surface modelling and solid modelling. For numerical modelling of cutting process, only a part of drill is needed, like the tip of four facet drills and a part of flute. Therefore, the reverse engineering was carried out by only one part of the drill. The result of the reverse engineering of the four-facet drill is shows in Figure 4.

The resulting 3D model was the solid model in STEP format. The 3D model is ideal for use in numerical modelling. The 3D mode of drill was used in the Deform3D software for the numerical simulation of the drilling process.

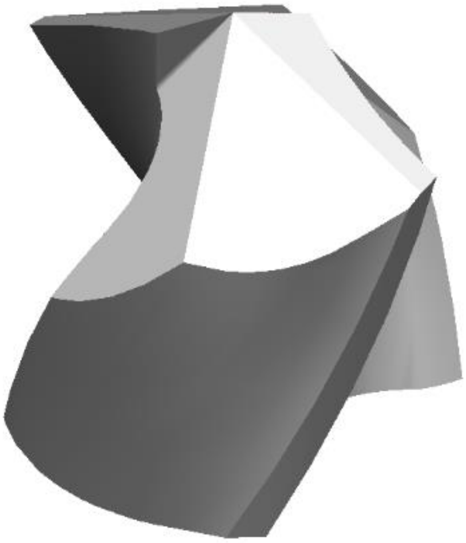

Fig. 4 *Result of 3D model of four-facet drill after reverse engineering*

SURFACE COMPARISON

The PowerShape software computes the perpendicular distance of each polygon point on the CAD data to the actual data. The software displays the deviation as a colour plot on a copy of the CAD data. In the PowerShape legend, the deviation representation colour ranges from blue to green and red. Blue visualizes measured surfaces that lie beneath the CAD surface. Red shows that the measuring data are above the CAD surface. Green shows the area without deviations. Figure 5 illustrates comparison of the STL model form NumrotoPlus with the reversed 3D model.

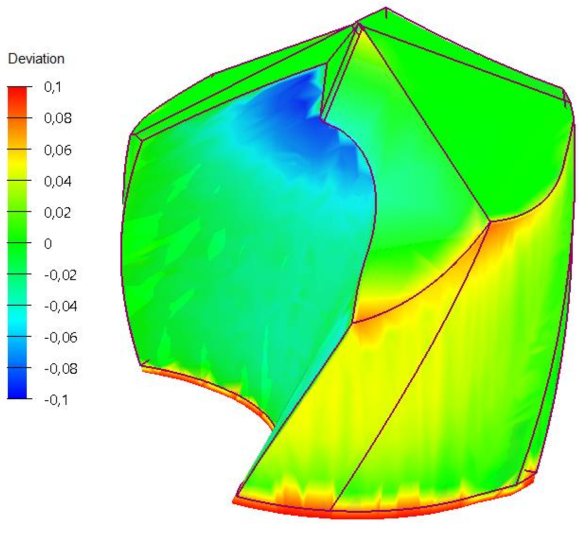

Fig. 5 *Result of comparison (STL model – CAD model)*

CONCLUSION

The research described in this paper shows that a reverse engineering process is ideal for optimizing a 3D model of four-facet drill. The 3D model was successfully validated for numerical simulation of drilling process. Figure 6 illustrates the result of numerical simulation and a chart of load and torque. The main tasks and the significant findings of this investigation can be summarized as follows:

- The higher number of facets means better quality of the STL model.
- For reverse modelling (engineering), it is necessary to have an ideal size of the STL model.

An ideal size of the STL model means that the performance requirements of PC are below when the model has 500MB than 1000MB, and the process of reverse engineering is faster.

- PowerShape software is a powerful tool for reverse engineering.
- Reverse modelling (engineering) needs a powerful computer.

Processor Type:	Multi-core CPU, preferably quad-core
RAM:	8GB for 64-bit applications (Minimum)
Graphics Card:	NVIDIA Quadro Graphics Cards (At least 2GB fully OpenGL 2.0 compliant)
Hard Disk Size:	160 GB
Screen Resolution:	1920 x 1200
Operating System:	Windows 10 64 -bit Professional Edition

- STEP format is ideal for the DEFORM 3D software.

The STEP format is ideal, because it is solid; DEFORM 3D automatically creates a better mesh than that of the STL model.

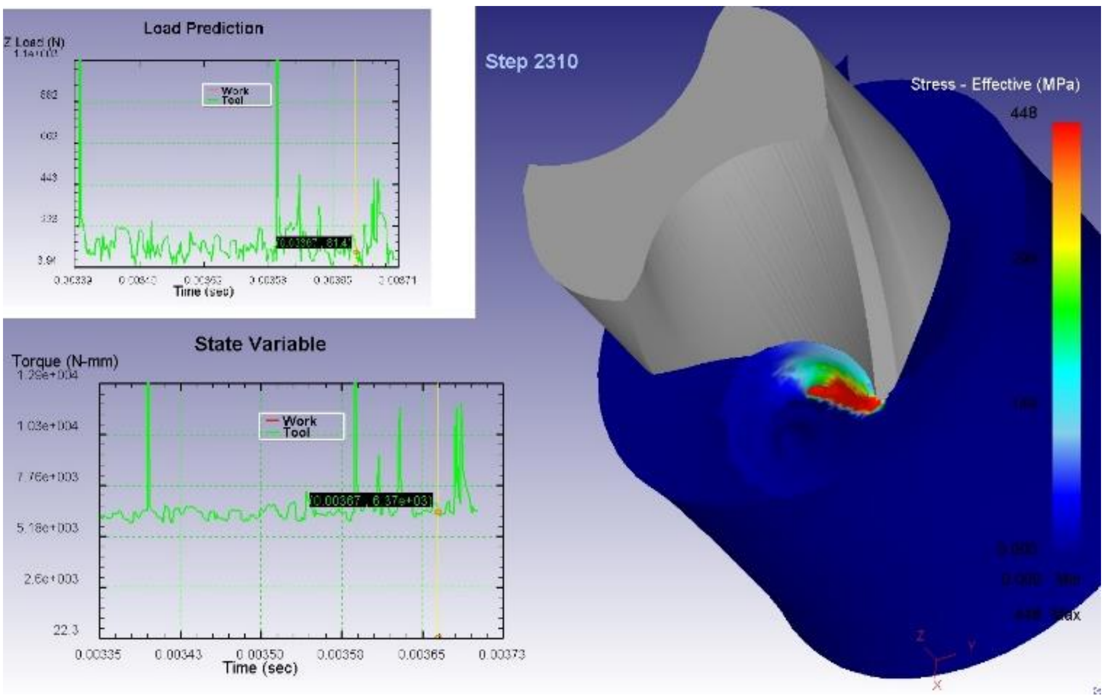

***Fig. 6** Numerical simulation of drilling process*

Acknowledgements

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References:

1. RAJA, V., FERNANDES K. J., 2008. *Reverse Engineering - An Industrial Perspective*. XVIII, 242, Hardcover. ISBN 978-1-84628-855-5.
2. MAŇKOVÁ, I., KOVAC, P., KUNDRAK, J., BEŇO, J. Finite element analysis of hardened steel cutting. *Journal of Production Engineering*, Vol. 14.
3. GARDNER, J. D. & DORNFELD, D., 2006. *Finite Element Modeling of Drilling Using DEFORM*. Laboratory for Manufacturing and Sustainability. UC Berkeley: Laboratory for Manufacturing and Sustainability. Retrieved from: http://escholarship.org/uc/item/9xg0g32g
4. M. ABOURIDOUANE, F. KLOCKE, D. LUNG, 2013. Microstructure-based 3D Finite Element Model for Micro Drilling Carbon Steels. *Procedia CIRP*, Volume 8, pp. 94-99. ISSN 2212-8271. http://www.sciencedirect.com/science/article/pii/S221282711300348X)
5. Sandvik Coromant, Drilling. In: *Modern Metal Cutting – a practical handbook*, 1994. ISBN 91–97 22 99–0–3.
6. Patrick De VOS, 2012. Technical Guide - How about cutting forces? In: *MMSpektrum*, No. 3, p. 68.

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