

Application of Laser Rapid Prototyping Technology in PDC Bit

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Abstract: Rapid prototyping of objects can be achieved with the technology of laser rapid prototyping. In the application of PDC bits, compared with the conventional processing methods, it is concluded that the laser rapid prototyping technology is more accurate than the forging press and turn-milling, and the surface roughness is smaller. With this technology, it is possible to fabricate the drill bit for complex curved surfaces, which indicates that the laser rapid prototyping technology has great potential in the application of petroleum bits.

Keywords: rapid prototyping technology; laser; PDC bit.

1. DEVELOPMENT STATUS

Laser rapid prototyping is a new and high technology developed in 1980s. It is a multidisciplinary integrated technology utilizing laser technology, CAX technology, automatic control technology, new material technology, direct modeling, and rapid manufacturing product model. 3DSytems company of USA produced the first SLA250 type in the world in 1988. The light curing rapid molding machine has created a new era of rapid development and promotion of laser rapid prototyping technology. After that, more than twenty systems have been developed, but there are small differences between each system. At present, laser rapid prototyping technology is mainly used in aerospace, automobile, toy manufacturing and other industries [1-2]. It has not been applied in the oil manufacturing industry yet.

2. PRINCIPLES AND CHARACTERISTICS

Laser rapid prototyping technology is based on layering technology, stacking molding, and the advanced manufacturing technology assembly for rapid prototyping producing samples or parts which directly based on the CAD model.

It uses CAD to generate 3D solid models, which are used to drive and control laser beams by layering with stratified software and with the two-dimensional data of each thin section. The beam sprayed liquid, powder or sheet material, and processed thin layers of required shape to form solid models layer by layer. In a simple way, laser rapid prototyping is the the discrete and stacking process of materials. Unlike traditional processing methods which removed materials to get the model, such as turning, milling, drilling, grinding, and planing, while the rapid prototyping technology only adds materials to the place where the material needs to be added. Thus, from the design to the manufacturing automation, from the knowledge acquisition to the

computer processing, from the plan to the interface and the communication, the rapid prototyping is very suitable for CIM, CAD and CAM. Compared with the traditional manufacturing methods, it shows many advantages [3].

The rapid prototyping technology has following features:

- (1) It produced rapidly, reducing cost and saving time, which brings vitality to the traditional manufacturing. Moreover, it can achieve free manufacturing, and the cost and process of product manufacturing nearly has nothing to do with the volume and complexity of the product. [4-5]
- (2) The use of non-contact processing is conducive to environmental protection, without traditional processing of residual stress problems, props replacement and wear and other problems, even cutting, noise and vibration.
- (3) Rapid molding and abrasive manufacturing can be achieved, especially for new product development and single part production.

3. APPLICATION OF LASER RAPID PROTOTYPING TECHNOLOGY IN PDC BIT MANUFACTURING

In the manufacturing process of PDC bit, the forming of abrasive tools is the key to accurately implement the bit design. The accuracy and quality of the mold determines the performance of the PDC bit. The traditional bit molding process is not precise and efficient. Besides, the it takes a long time to develop and cycle products, which is not conducive to the quick response to the field demand, and the bit production of complex structure is more difficult to realize. Aiming at various problems in the manufacturing process of traditional matrix PDC bits, people began to introduce laser rapid prototyping technology to the manufacturing of matrix PDC bit.

The PDC bit has complex structure, especially the high precision of cutting angle and the height of the cutting teeth. In traditional PDC bit manufacturing process, the master model is processed on the CNC machine based on particular design. Generally, the master model is machined on the three axis CNC machine tool with manual fixture and assisted by artificial reshaping. Then the milling mould maker use the milling machine, equipped with a fixture, to adjust the proper tooth angle and depth of the cutting teeth on the contour design of the processed bit master model, and place the water trough block, forming the PDC bit sintering mold. The above-mentioned machining process shows that the machining technology is not accurate, and the quality of the drill bit is hard to guarantee [6].

By combining with computer technology, numerical control technology, glue mold forming technology and clay powder forming technology, the laser rapid prototyping technology can realize the processing of the complex shape of PDC bit sintering grinding tool. Moreover, it solves the problem of low accuracy of traditional PDC bits. It can be seen from table 1 that there are some differences in the three techniques and the accuracy of the moulds manufactured by the new technology is greatly improved. Besides, the laser rapid prototyping technology can

realize the processing of complex surface. If this technology is applied to the manufacture of bit mold, the production of complex structure PDC bit can be realized.

Table 1. Machining precision of three kinds of technology

Processing technology	Accuracy of cutting tooth Angle ($^{\circ}$)	Precision of cutting teeth height (mm)	Flume position accuracy (mm)
Laser technology	0-0.1	0-0.1	0-0.1
Moulded section	0.5-1.0	0.2-0.8	0.1-0.8
Milling mold molding	0.5-1.0	0.2-1.0	0.2-1.0

In summary, the application of laser rapid prototyping technology to drill has the following advantages.

- (1) The drill bit manufacturing cycle is greatly shortened, and it can quickly meet the needs of different bit manufacturing.
- (2) The manufacture of PDC drill with complex structure, such as spiral flume and shockproof gear, can be realized.
- (3) The improvement of bit machining accuracy will greatly improve the service life and penetration rate of drill bits.

4. EXISTING PROBLEMS AND SOLUTIONS

(1) The application of laser rapid prototyping technology to the manufacture of bit is still in the trial stage. It is concluded that the application of laser rapid prototyping technology in PDC bit is feasible from the comparison of the processing flow and accuracy with the conventional process.

(2) Laser rapid prototyping is a very complicated non-equilibrium short-time physical metallurgy process. It involves the melting of the alloy powder under the action of laser, the surface remelting of precipitated materials and the non-equilibrium solidification of the continuous mobile small pool. The high temperature gradient and complex heat action process will form complex thermal stress, structural stress and external force inside the drill, resulting in the deformation and cracking of the bit. It is necessary to further study and master the internal stress evolution and effective control methods of different alloy powders during laser rapid forming.

(3) The process of the laser rapid forming of the bit is accomplished by the continuous formation of the mobile pool and the subsequent solidification. The bit is closely related to the process parameters and the external environment conditions in the solidification forming, and it is not easy to control. According to the shape of different alloy powder materials and parts, it is necessary to realize the intelligent and accurate control of each parameter in the forming process on the basis of obtaining the optimized molding process, so as to ensure that the molded parts have higher internal quality and uniformity of internal organization.

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