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Laser Engineered Net Shaping Technology

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Abstract Laser engineered net shaping (LENS) technology is a new type of rapid prototyping technology, which combines the conventional rapid prototyping technology with the laser cladding technology, and studies the rapid manufacture technology of metal components and moulds with comparatively complex shape or complex component. The laser engineered net shaping system is made up of by five modules. The hardware composition and operating principle of the modules are introduced in detail.

Key words rapid prototyping, laser engineering net shaping, metal function component.

1 Introduction

The concept of using metal powder or wire to fabricate an object came of early days of 1980's[1]. However, the continued development of faster, more powerful computers coupled with the existing level of the rapid prototyping techniques has allowed this technology to be exploited to begin to fabricate reasonably complex geometrical features in metallic materials directly from the CAD solid model[2].

The LENS (laser engineered net shaping) technology is brought forward by Sandia National Laboratories USA firstly[3]. The LENS combines traditional rapid prototyping technology with laser cladding technology and studies the rapid manufacture technology of metal components and moulds with reasonably complex shape or complex component[4,5].

The LENS technology keeps the excellences of the RP(rapid prototyping). At the same time the LENS has some characteristics that the RP does not have. LENS may directly fabricate metal function components whose form and structure are reasonably complicated. The range of metal or alloy material being fabricated is broad, the heterogeneity material can be fabricated, the metallurgy process and material prototyping process are unified and some high melting point and difficult machining materials can expediently fabricated.

2 Principle of the LENS Technology

The LENS process is a new kind of RP technology, which is brought forward by Sandia National Laboratories USA firstly. Some papers call the LENS as Laser Near Net Shaping[6,7]. The LENS process is produced through combining the traditional rapid prototyping technology with the laser cladding technology.

The shaping process of the LENS system includes two phases, the data processing and the shaping machining.

In the data processing phase firstly the component CAD solid model is drawn using the computer CAD software. Then the CAD model is reproduced and saved as an .STL file. At last the .STL file is dissected into thin layers using conventional slicing algorithms and create the scan track, which is saved as a .CLI file. The. CLI

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files will controls the system motion.

In the shaping machining phase a component is fabricated by focusing a laser beam onto a substrate while simultaneously injecting metal powder particles to create a molten pool. The substrate is allocated onto the *X-Y* working table and the working table is moved beneath the laser beam by the drive motors according to the .CLI file track. After deposition of each layer, the powder delivery nozzle and focusing lens assembly are incremented in the positive *Z*-direction and a new layer is deposited, thereby building a three-dimensional metal function component layer additively. The metal powder is delivered to the nozzle from the powder storage bin. For promoting the powder flow and preventing the melt metal oxidation the shielding gas is filled into the storage bin. The LENS process is showed in Fig. 1.

In LENS process the metal powder can reach metallurgical bonding through layer-by-layer build up and so the high density and high strength metal function component can be rapidly obtained.

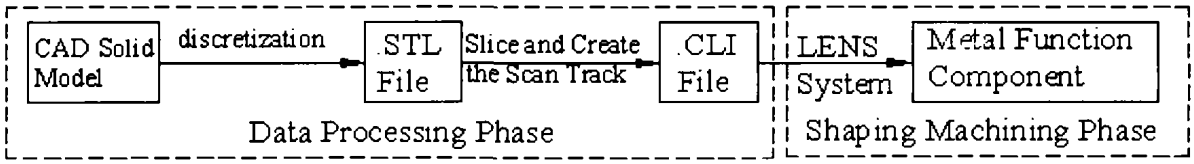

Fig. 1 LENS operating principle

3 LENS Position in RP

There are many processes in the RP technology. According to the work material the RP material includes liquid state and solid state. The solid-state material includes powder, sheet and silk. And the solid-state powder includes nonmetal and metal. The solid-state metal powder material is exploited in the LENS technology. Some RP processes and their material requested are listed in Table 1.

Table 1 RP processes and LENS position

Material shape	Liquid	Solid-state powder			Solid-state sheet	Solid-state silk
		Nonmetal	Metal powder			
Material name	Light-sensitive resin	Wax powder Plastic powder Coated ceram Coated sand	Single metal Coated metal	Single metal Complex metal Function grads	Paper Plastic + bond Tinsel + bond	Wax silk ABS silk
PR process	SLA	SLS		LENS	LOM	FDM

Table 1 shows both SLS and LENS can use metal powder material to shape metal component. However the components has an essential difference. Through SLS process the component is multihole so its density and intensity are low. For improving this kind of component performance the complicated aftertreatment processes such as infiltration and hot isostatic pressing have to be done. But through LENS process the component density and intensity is so high that it can be used as metal function component directly. Moreover the complex material and the function grads material can be shaped by LENS process that other RP processes can not.

4 LENS System Composition

According to the modular design thought, the LENS system mainly includes five modular. There are laser energy supply modular, numerical control worktable

modular, computer control modular, rubdown machine modular and metal powder feed modular.

4.1 Laser energy supply modular

In LENS system the laser energy must be enough powerful to directly melt the metal powder and deposit. The superpower, crosscurrent, pipe sheet, multimode, carbon dioxide laser are exploited. Its wavelengh is 10.2 μm and its most output power is 2 kilowatt.

Besides the laser, the laser energy supply modular includes light gate, correction laser, reflector, plano-convex lens and cooling system, as shown in Fig. 2, the light gate and the correction laser reflector move together. A semiconductor laser radiates the correction laser, which wavelengh is 1.02 μm and its color is red. The correction laser and the CO_2 laser are concentric.

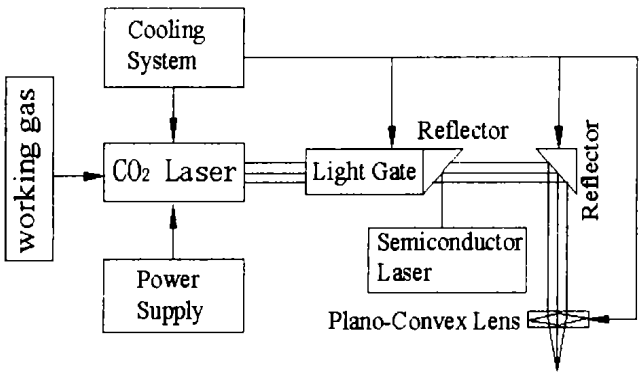

Fig. 2 Laser energy supply blocking

4.2 Numerical control worktable modular

The three-dimensional motion is performed through the numerical control worktable modular. This modular includes a precise *X-Y* two-dimensional plane worktable, a precise *Z*-axis worktable, stepper motors used to drive the worktable and their drive circuit. The range of three-dimensional motion is 200 mm × 200 mm × 200 mm, and its repeatable accuracy is ±0.02 mm.

4.3 Computer control modular

In LENS system the computer control modular will control the entire component shaping process besides CAD data processing. This modular includes software and hardware. The software, known as the system application program, will produce a .CLI file from a CAD solid model and orderly achieve the entire component shaping process according to the .CLI file. The hardware includes an industrial computer, an EPCIO–605 control card and a PCII–1750 control card developed by Advantech Co. Ltd., Taiwan, China.

4.4 Rubdown machine modular

In manufacturing according the shaping manner there are three manners: remove shaping (turning, mill, planning and grind *etc.*), addition shaping (rapid prototyping *etc.*), forced shaping (forging, foundry *etc.*) and growth shaping (clone *etc.*). The remove shaping and the forced shaping belong to conventional shaping manner, but the addition shaping such as rapid prototyping breaks through the conventional shaping manners.

In LENS technology some elements such as powder feed fluctuation, laser power fluctuation, scanning beam superposition *etc.* will result in scan plane roughness and rugosity. These surface drawbacks will badly affect the subsequent shaping. Herewith the rubdown machine is introduced into the LENS system. Every deposit a layer polish once, thereby the surface drawbacks are effectively wiped off and the subsequent shaping is gone with a swing. The LENS process is even more characteristic as result of the remove shaping is introduced.

4.5 Metal powder feed modular

The metal powder feed modular is notable characteristics of the LENS technology and it is the mostly reason that LENS differs from SLS too. The SLS process first paves the powder then sinters while the LENS process ejects the powder to the laser focal point at same time deposited, namely coaxial powder-feed.

Design of the coaxial powder-feed equipment is the mainly difficulty of the LENS system because it determines the powder-feed stability and homogeneity when processing the metal function component. The metal powder feed modular includes powder feed equipment, powder nozzle and shielding gas circuit. The powder nozzle is the most important part because it is the uniform outlet of focused laser, focused powder and shielding gas. Fig. 3 shows the diagrammatic sketch of the nozzle and Fig. 4 shows the shaping scene.

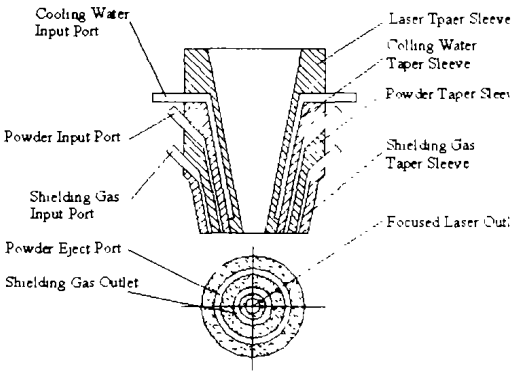

Fig. 3 Schematic representation of the powder nozzle section

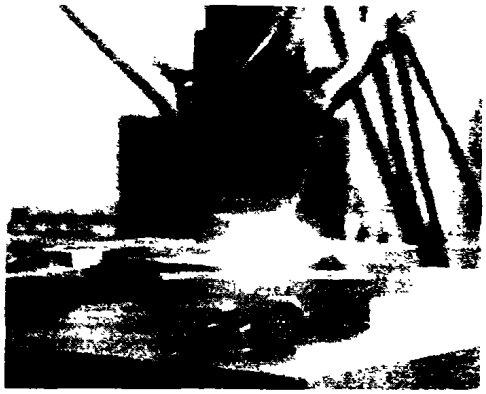

Fig. 4 Photographs of the powder nozzle

5 Summary of the LENS Technology

The LENS technology is a new kind of rapid prototyping technology, which combines conventional rapid prototyping technology with laser cladding technology, and studies the rapid manufacture technology of metal components and moulds with comparatively complex shape or complex component. The LENS system mainly includes laser energy supply modular, numerical control worktable modular, computer control modular, rubdown machine modular and metal powder feed modular. These modular coordinate movement under the control of the computer application program and complete the process of shaping the metal function component.

References

[1] Method for Fabricating Articles by Sequential Layer Deposition[P]. US Patent # 4,323,756, April 6, 1982.

[2] Keicher D M, *et al.* Using the laser engineered net shaping (LENS) process to produce complex components from a CAD solid model[A]. *SPIE Proceedings*[C]. 1997, **2993**: 91–97.

[3] Griffith M L, *et al.* Freeform fabrication of metallic components using laser engineered net shaping (LENS)[A]. *Solid Fabrication Symposium Proceedings*[C]. University of Texas, Austin, 1996: 121–128.

[4] Wang Xiufeng, *et al.* Rapid Prototyping Technique of Manufacture[M]. China Light Industry Publishing Company, 2001 (in Chinese).

[5] Wang Xuerang, *et al.* Rapid Forming Theory and Technology[M]. Aviation Industry Publishing Company, 2001 (in Chinese).

[6] Deng Qilin, *et al.* Laser net shaping technique of manufacture[J]. *Electromachining*, 1999, **6**: 37–40 (in Chinese).

[7] Hu Xiaodong, *et al.* Metal direct shaping technique development and expectation[J]. *Tool Technique*, 2001, **35**(10): 3–6(in Chinese).

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