A Novel Aero-engine Blade 3D-print Technique Based on Cloud Database

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Abstract. The precision of surface of laser manufactured component is strictly depend on the process parameters and the manufacture device. In this research paper, we explore a novel alternative based on cloud database of making an aero-engine blade. The designed equipment can continuously move along curvilinear paths of an object being fabricated, producing new objects much longer, wider and taller than 3D printing unit. This set of device cleverly combines a small portable 3D printer and a column climbing robot linking to cloud database to ensure product variety and flexibility. It adopts an reciprocating fabrication loop which works as: printing, reanchoring to a new start point, and printing again. We illustrate the structure, sub-functional unit, and characterization of the 3D print robot along with an example on the fabrication of aero-engine blade based on cloud database. 3D print has been demonstrated to possess the freeform fabrication capabilities for complex components and of course the 3D print robot connected with cloud database could easily printing a blade. The results obtained in this study have potential applications for construction industry, product design and promisingly greatly broaden the applications of up-to-date 3D printing.

1. Introduction

3D additive manufacturing devices show a different trend from subtractive manufacturing devices, such as traditional mills, lathes.\cite{1,2,5} 3D print robots with the capability to print components much larger than themselves will produce many opportunities for the progress of the heavy industry. 3D printing machines has already shown off their talents to directly produce interlocked alloy components without costly assembly lines\cite{4}.

The ability of 3D print robots to manufacturing compact and portable components is closely bounded to the transition of high consumption and high investment centralized mass manufacturing\cite{5} to distributed cloud manufacturing\cite{6} in the future.

2. Modular Design of 3D Print Robot Equipped with Cloud Database

This paper explores a novel modular design of printing an alloy component through the combination of a 3D printer and a robot connecting with cloud database. Such 3D print robot is capable of receiving real-time parameters of 3D printing process from cloud database and producing aeronautic structures which much larger than 3D printing unit itself. Noticeably, it is the robot that moves 3D printing unit along the curve data provided by cloud database and not an line print laser print model output from a static data control center. As shown in figure 1 and table 1.
2.1. Additive Manufacturing Controlled by Cloud Database
Not only blade but also impeller and blisk curve data can be transmitted from cloud database and be utilized in 3D laser print. Moreover, a vertical column climbing structure robot can be much lighter in weight than a tracked mobile robot.

Table 1. Cloud database output and online supervision of user terminal.

| Cloud database output                  | Online supervision                                                                 |
|----------------------------------------|------------------------------------------------------------------------------------|
| Real-time laser parameter              | Power, single-layer-height, speed                                                   |
| Real-time laser calibration by item     | Read out location data set item Remedial measures shall be taken in case of large single-layer displacement occur |
| Emergency stop                         | Clear progress and return base-point process should be interrupted                  |

2.2. Light in weight robot design
A 3.7 m tall additive manufactured structure can be produced by a tracked mobile robot coupled with their Digital Construction Platform (DCP) in previous study. However, a vertical column climbing structure robot can be much lighter in weight than a tracked mobile robot. In this study, a X-Y-Z multi-axis vertical column robot equipped with rotating unit and smart and portable 3D printing unit is assembled for 3D print of large scale component.
2.3. Surface Treatment

The aeronautic engine blade is characterized by thin-walled freeform surface with large size, and its grinding and finishing requires both high dimensional accuracy and surface quality. Considering the robot grinding is featured with multivariety and high-precision production it is adopted in this study. The traditional grinding of aeronautic engine blade is either by hand or multi-axis CNC machine tools. But the error control of manual operation is difficult. Besides, the in-depth application of the multi-axis CNC grinding is limited owing to the high cost of millions U.S. dollars.

3. Details of the Robot for Large Scale Blade 3D Print in Light of Cloud Database

The characteristics of robot are as follows:

- The robot's motion consists of reciprocating motion along the rigid X-Y-Z three axes.
- The robot's motion also includes circular motion along the Z-axis, which means that the Z-axis can rotate flexibly to drive the X-axis and Y-axis as well as the smart and portable 3D printing unit to rotate. The radius of the circumference depends on the displacement on the X-axis.
- All movements are controlled by the PLC at the bottom of the Z-axis and precisely executed by four servo motors.
- Prioritize different model of aeronautic engine blade samples at any time, if necessary.
- Allow single user terminal or multi-user terminal to supervise 3D printing process at the same time.

4. Experiment

The surface accuracy of 3D printing of aeronautic engine blade depends on the deposition height of single layer. Theoretically, a lower monolayer height can produce a higher surface accuracy, but the reduction of monolayer height is not infinite. The relationship between the value $h$ of the height of a single layer and other laser parameters follows the following equation 1. In equation 1, $P$ is the laser power, $v$ is the laser speed, $a(r)$ refers to the shortest distance between the center lines of adjacent laser path curves, which is a function of the laser beam radius $r$.

Besides, the laser process parameters are shown in table 2.
5. Results
The original 3D printed surface is shown in figure 3. Furthermore, the ground and finished surface is shown in figure 4.

The average diameter of alloy powder utilized in 3D laser print manufacture is 40 μm. As such, the precision of as-printed component surface is much better than that of traditional laser cladded component in which the conventional particle diameter for alloy powder is 60 μm.

6. Conclusions
There a novel 3D printing robot combined with cloud database is proposed. Such system is designed for multiple models of aeronautic engine blade.

References
[1] E. Malone, H. Lipson, Fab@Home: the personal desktop fabricator kit, Rapid Prototyp. J 13 (2007) 245 – 255.
[2] A. Calderon, J. Griffin, J.C. Zagal, BeamMaker: an open hardware high-resolution digital fabricator for the masses, Rapid Prototyp. J. 20 (3) (2014) 245 – 255.
[3] R. Jones, P. Haufe, E. Sells, P. Irvani, V. Oliver, C. Palmer, A. Bowyer, RepRap – The replicating rapid prototyper, Robotica 29 (2011) 177 – 191.
[4] H. Lipson, M. Kurman, Fabricated: The New World of 3D Printing, John Wiley & Sons, Indianapolis, 2013, pp. 7 – 20.
[5] D. Mourtzis, M. Doukas, F. Psarommatis, A multi-criteria evaluation of centralized and decentralized production networks in a highly customer-driven environment, CIRP Ann. Manufactur. Technol. 61 (2012) 427 – 430.

[6] L. Bo-hu, L. Zhang, W. Shi-long, T. Fei, C. Jun-wei, J. Xiao-dan, S. Xiao, C. Xu-dong, Cloud manufacturing: a new service-oriented networked manufacturing model, Comput. Integrat. Manufactur. Syst. 16 (1) (2010) 1 – 7.

[7] S. Keating, J. Leland, L. Cai, N. Oxman, Toward site-specific and self-sufficient robotic fabrication on architectural scales, Sci. Robot. 2 (5) (2017) 1 – 15.