THERMAL AND STRUCTURAL ANALYSIS FOR TURBINE ENGINE BLADES AT MAXIMUM TEMPERATURE

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ABSTRACT

Additive manufacturing is the process of making objects from 3D model data by joining materials layer by layer, as opposed to subtractive manufacturing methodologies, such as traditional machining. It processes can reduce waste, speed up production, and enable designs that might not be feasible with conventional production processes. The novel shapes and unusual material properties the technology makes possible, such as propeller, turbine blades optimized for strength at one end and flexibility at the other could change the way airplanes are designed. Additive Manufacturing offers the freedom to design very complex components, which makes it an extraordinary tool to meet your most challenging requirements. More recently, AM is being used to fabricate end-use products in aircraft, dental restorations, medical implants, automobiles, and even fashion products. Additive manufactured parts are used in the aerospace industry for functional parts including engine turbine blades, fuel systems and guide vanes. The topological optimization of parts can improve functionality and reduce weight. Lighter parts can contribute to lighter aircraft and reduce fuel consumption. This project explores the effective use of additive manufacturing complex designs, for this jet engine turbine blade is modeled in software and then manufactured using 3D printer to get cost effective and light weight parts.

Keywords: Additive manufacturing, Aircraft technology, Jet engine, Turbine blade, 3D printing.

INTRODUCTION

In a variety of different technology sectors. Like with many manufacturing technologies, improvements in computing power and reduction in mass storage costs paved the way for processing the large amounts of data typical of modern 3D Computer-Aided Design (CAD) models within reasonable time frames. Nowadays, we have become quite accustomed to having powerful computers and other complex automated machines around us and sometimes it may be difficult for us to imagine how the pioneers struggled to develop the first AM machines.

This chapter highlights some of the key moments that catalogue the development of Additive Manufacturing technology. It will describe how the different technologies converged to a state where they could be integrated into AM machines. It will also discuss milestone AM technologies. Furthermore, we will discuss how the application of Additive Manufacturing has evolved to include greater functionality and embrace a wider range of applications beyond the initial intention of just prototyping.

3D printing, also known as additive manufacturing, was developed in the 1980’s as a process used to make threedimensional objects. Additive manufacturing creates parts from the ground up by fusing together layers of material. Its counterpart, subtractive manufacturing, begins with material and removes excess until only the desired shape remains.

Additive Manufacturing (AM) technologies build near-net shape components one layer at a time using data from 3D CAD models. AM technologies are the result of evolution of work in 3D printing and stereolithography (the STL files used to convert 3D CAD to layers for building parts come from stereolithography terminology) and could revolutionize many sectors of U.S. manufacturing by reducing component lead time, cost, material waste, energy usage, and carbon footprint. In addition, AM has the potential to enable novel product designs that could not be fabricated using conventional subtractive processes and extend the life of in-service parts through innovative repair methodologies. The opportunities for the offshore oil and gas industry largely remain to be identified, but are considered to involve combined functionality, functionally gradient materials, and embedded sensors for structural health or other monitoring functions.

Additive Manufacturing

Additive manufacturing (AM) is an additive fabrication process where a three-dimensional part is produced by stacking layers of thin 2-D cross sectional slices of materials one over another without use of tooling and human intervention. The process begins with a solid model CAD drawing of the object. The CAD model is then converted in to .STL file format and sent to an AM machine for prototype building [1]. The whole process of design to physical model through various intermediate interfacing stages is shown in Fig. 1. These steps are common to most AM systems but the mechanisms by which the individual layers are created depend on the specific system.

Currently, many technologies exist that into the broad definition of AM. These technologies are supported by various distinct process categories. These are: photo polymerization, powder bed fusion, extrusion-based systems, printing, sheet lamination, beam deposition, and direct write technologies [2, 3]. Each of these processes has its own distinct set of advantages and disadvantages regarding characteristics such as surface finish, manufacturing speed and layer resolution. Of these different processes, three technologies are most commonly used: fused deposition modeling (FDM), stereolithography (SLA) and selective laser sintering (SLS). These three processes will be briefly outlined in the following sections.

3D Printing Revolutionizes Gas Turbine Blade Production

Until now, blades for gas turbines were either cast or forged. The casting of turbine blades requires complex mold construction before each blade can be individually cast – a complex, time-consuming, and costly procedure. Additive manufacturing changes all this. With AM, a laser beam is directed at fine layers of metal powder, which are heated and melted. When the laser is removed, the metal cools. The process is repeated layer by layer until the blade model from the 3D printer is finished. Thanks to additive manufacturing, the team was able to reduce the period of time from the design of a new gas turbine blade to its production from two years to two months.

“Exciting AM technology changes the way we produce. Using this technology, we can develop prototypes up to 90 percent faster,” says Meixner. “Siemens is a pioneer in the field of additive manufacturing. We’re speeding up the development of new gas turbines with higher efficiency levels and increased availability and can thus deliver these improvements to our customers faster. The new flexibility in production allows us to more precisely tailor development to our customers’ requirements and deliver individual spare parts on demand.”

LITERATURE REVIEW

Additive manufacturing (AM) has been defined as “the process of joining materials to make objects from three-dimensional model data, usually layer upon layer" (ASTM International, 2012). After many years of development, AM has evolved from applications mostly limited to rapid prototyping of polymeric objects to commercial production of both polymeric and metallic components in a number of different industries (Huang et al., 2013; Wohlers, 2013; Horn and Harrysson, 2012). Early adopters include the aerospace, medical, and automotive industries, which use a variety of different polymers and metals for AM components, the latter of which include steel, aluminum, nickel, and titanium alloys (Frazier, 2014; Melchels et al., 2012).

Compared to conventional manufacturing (CM) processes such as thermoforming, injection molding, and blow molding (for polymeric components) and casting, forging, machining, and finishing (for metallic components), AM holds at least three promising advantages. First, AM enables designs with novel geometries that would be difficult or impossible to achieve using CM processes (Horn and Harrysson, 2012; Tuck et al., 2008), which can improve a component's engineering performance. Second, AM can reduce the "cradle-to-gate" environmental footprints of component manufacturing through avoidance of the tools, dies, and materials scrap associated with CM processes (Morrow et al., 2007; Serres et al., 2011).

Third, novel geometries enabled by AM technologies can also lead to performance and environmental benefits in a component's product application (Huang et al., 2013; Horn and Harrysson, 2012). For example, the aircraft industry has adopted a number of different AM components for reducing aircraft massdincluding flight deck monitor arms, seat buckles, and various hinges and bracketsdwhich can lead to greater aircraft fuel efficiency (Immarigeon et al., 1995; Oak Ridge National Laboratory (ORNL), 2010; Munsch et al., 2012; Carrington, 2013).

This study quantifies the life-cycle energy and greenhouse gas (GHG) emissions savings potential of AM technologies for metallic aircraft components in the United States. As an early adopter of metallic AM components, the aircraft industry provides a compelling case study of the life-cycle environmental savings potential of AM technologies. Firstly, lighter weight aircraft are a critical strategy for reducing societal energy use and GHG emissions (Immarigeon et al., 1995).

Aviation is currently the second largest consumer of transport fuels globally (IEA, 2010). In 2009, the world's aircraft consumed 250 million tons of oil equivalents and comprised 12% and 9% of global transport sector energy use and GHG emissions, respectively (IEA, 2010; Schlumberger, 2012

Furthermore, global aircraft fuel use is projected to triple by 2050 due to rapid economic growth and increasing globalizationda growth rate that is faster than any other transportation mode, including automobiles (Faganha et al., 2012; Rodrigue et al., 2009). In the US, air travel's share of transportation sector energy use is 9.4%, though projected growth rates are slower (Energy Information Administration(EIA), 2014).

METHODOLOGY

The most commonly used technology in this process is fused deposition modeling (FDM)

The FDM technology works using a plastic filament or metal wire which is unwound from a coil and supplying material to an extrusion nozzle which can turn the flow on and off. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism, directly controlled by a computer-aided manufacturing (CAM) software package. The object is produced by extruding melted material to form layers as the material hardens immediately after extrusion from the nozzle. This technology is most widely used with two plastic filament material types: ABS (Acrylonitrile Butadiene Styrene) and PLA (Polylactic acid) but many other materials are available ranging in properties from wood filed, conductive, flexible etc. FDM was invented by

Scott Crump in the late 80's. After patenting this technology he started the company Stratasys in 1988. The software that comes with this technology automatically generates support structures if required. The machine dispenses two materials, one for the model and one for a disposable support structure.

RESULTS AND DISCUSSIONS

Structural analysis Results of Steel

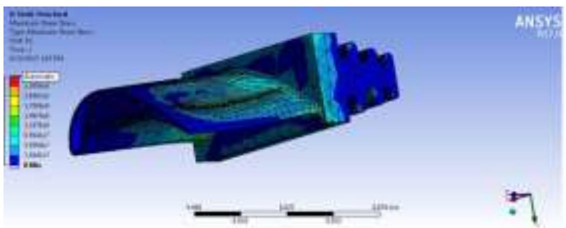

Figure : Maximum shear stress for steel material

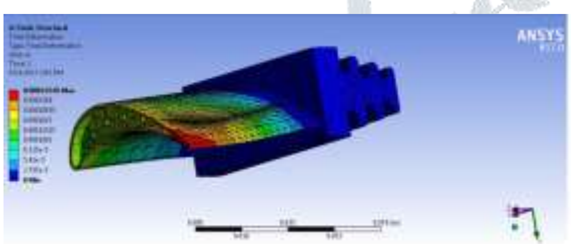

Figure : Total deformation for steel turbine blade

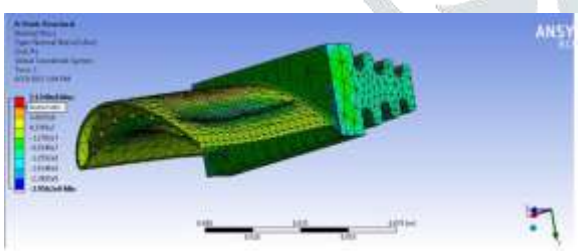

Figure : Norma stress (X axis) for steel material

CONCLUSIONS AND FUTURE SCOPE

In this project we are designing jet engine turbine blade by using CATIA V5 R2 following required design specifications and blade angles. We compared both steel and ABS plastic material Turbine blades in ANSYS work Bench. We conclude in ANSYS the weight of the ABS turbine blade much less than the Steel turbine blade. We calculated blade efficiency is sensitive to the thickness of the blade trailing edges, and various analyses of this effect indicate that the ratio trailing edge thickness/blade pitch is the significant parameter against which loss in efficiency may be correlated. Additive manufactured parts are used in the aerospace industry for functional parts including engine turbine blades, fuel systems and guide vanes. The topological optimization of parts can improve functionality and reduce weight. Lighter parts can contribute to lighter aircraft and reduce fuel consumption. The attempt has been taken to show the basic design, forces action on the blades, prototyping of the blade for the blade using additive manufacturing, scope of producing complex shape using additive manufacturing and applying it to the aerospace industry for making parts like turbine blades attributes key in this design of jet engine turbine blade design . Proper selections of design parameters are real derivatives of huge extrapolation of the topic. Air foil profile and cooling effects are the most basics to be taken care off while optimizing blade profile design for maximum efficiency. To find the proper correlation between the designs parameters are the basic objectives of the present work and applying additive manufacturing to make the turbine blade by 3 D printing technology to get cost effective and light weight parts

REFERENCES

- DEGARMO'S MATERIALS AND PROCESSES IN MANUFACTURING Y PAUL DEGARMO, J. T. BLACK, RONALD A. KOHSER.
- MEHERWAN P. BOYCE GULF PROFESSIONAL PUBLISHING (2002)- GAS TURBINE ENGINEERING HANDBOOK, SECOND EDITION, PP. 403-404.
- Joanna R. Groza, James F. Shackelford CRC Press (2007) , Materials Processing Handbook. Brian Cantor, H Assender, P. Grant CRC Press (2001), Aerospace Materials, pp. 81-86.

- By Rainer Kurz, Solar Turbines Inc., San Diego, CA, Klaus Brun, Southwest Research Institute, San Antonio, TX, and Saeid
- Mokhatab, Contributing Editor | September 2011, Vol. 238 No. 9
- Thermal Analysis of an aero gas turbine compressor blade and vane using temperature sensing thermal paints.
- Defence Science Journal, Vol. 52, No. 4. Octoba 2002, pp. 363-3670 2002, DESlDOC
- Y. Li, P. Gu, Free-form surface inspection techniques state of the art review, Journal of Computer-Aided Design, 36 (13) (2004), pp.1395–1417.Volume 34 No. 5, ISSN: 0271-5333; eISSN: 1527-1323
- New Potentials of PenetrantTesting , ECNDT 2006 - Th.1.8.1