Lightweightening by Combining Together Casting and Additive Manufacturing

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Abstract: Two technologies, conventional Casting and Additive Manufacturing, are combined together in an innovative approach to result in a reduced weight component, as an example the passenger seat in a commercial airliner. A complex precursor plastic assembly, produced by Additive Manufacturing, is converted using the lost wax process, to an Aluminum metal assembly with weight lower than the conventional part. The weight of the component can be reduced further by using a non-flammable low density magnesium alloy. The latter alloy has already been qualified for use in the interior of Airlines.

Keywords: Conventional casting, Additive manufacturing, Combined processes, Airliner passenger seats, Lost wax process, Reduced weight parts, Magnesium alloys, Non-Burning.

1. INTRODUCTION TO ADDITIVE MANUFACTURING (AM)

The two broad classes of AM component building: powder bed fusion (PBF) and direct energy deposition (DED) are based on the concept of slicing a solid model into multiple layers, and then building the component layer by layer in compliance with the sliced model computer data [1].

1.1. Powder Bed Fusion

PBF technologies involve the laying down of a layer of metal powder onto the build platform and subsequently scanning the powder bed with the heat source, which can be a laser or electron beam under which the powder is partially or completely melted followed by re-solidification. Figure 1 demonstrates this process;

Figure 1: Schematic showing powder bed fusion technology (courtesy Jim Sears).

1.2. Directed Energy Deposition

DED technologies involve injection of material into the meltpool, Figure 2 is a schematic of the DMD technology (laser based metal deposition). Successive layers follow the same procedure and build up the component layer by layer until completion of the part.

Figure 2: Schematic showing Direct Metal Deposition (DMD) technology (courtesy DM3D Technology).

2. COMBINING THE OLD AND THE NEW

At the Autodesk technology center in San Francisco Andreas Bastian combined together AM and conventional metal casting [2] to create a lightweight frame for a commercial airplane seat (Figure 3). This could both reduce carbon emissions and also save airlines significant weight and money through an
associated fuel saving. The innovative reduced weight seat frame is shown in Figure 4, details of how the weight is reduced are contained in the subsequent text.

The mass distribution for a commercial airplane passenger seat is shown in Figure 5 [3]. The goal was to maintain a strong frame, but make it significantly lighter; using lattice and surface optimization, the software was able to design a complex structure that will make the aircraft seats so lightweight that the need for jet fuel is significantly reduced. However, conventional manufacturing methods would not be able to create the complex geometries that can be used with AM technology, and the AM cost is at a point where it can be competitive with traditional production methods such as casting [1].

Also, even using Autodesk Project Escher technology [2], 3D printing volumes are typically just a few cubic feet, while casting can work with massive
objects. By combined the two technologies together positive molds for the seat frames, containing the lattice geometry, were AM printed in plastic, and then used to make affordable, ceramic casting molds (Figures 6 and 7) by basically using the “lost wax” process (Figure 8). Examples of the actual final complex seat assembles are shown in Figures 4 and 9.

An algorithm in Autodesk’s Netfabb software was used to produce the geometry for the aircraft seat frame, which would work in any standard commercial jet. The goal was to maintain a strong frame, but make it significantly lighter; using lattice and surface optimization, the software was able to design a complex structure that will make the aircraft seats so lightweight that the need for jet fuel is significantly reduced. However, conventional manufacturing methods would not be able to create the complex geometries that are often used with AM technology, and the AM cost is at a point where it is competitive with traditional production methods such as casting [1].

Figure 5: Mass distribution in Conventional Passenger Airline Seats.

Figure 6: Pouring Molten Metal into a Complex Ceramic Assembly Fabricated Using the Lost Wax Process [2].
The weight of the airplane seat frame could be reduced even more if it was cast in magnesium, which is 35% lighter than the typical aluminum use making the new approach even more attractive.

The chair design was first AM printed in plastic, and then coated in ceramic to make a negative mold; the plastic was later heated and vaporized off after the ceramic shell had hardened. Using the mold, parts were cast, and it was demonstrated that the process could actually scaled up to 160 seats per two days (Table 1).

It was determined that each individual seat frame, weighing in at 766 grams, is 56% lighter than the aluminum seats currently in use: the magnesium
accounts for 24% of this weight reduction, while the design optimization is responsible for the other 30%. So if Airbus, for example, replaced the 615 seats on 100 A380 jets, which have a typical 20-year lifespan, with the lightweight frames, the airline could save over $205,000 (this is based on 2015 average jet fuel costs). Going back to eco-friendly matters, this results in a reduction of 126,000 tons of carbon emission.

Thus the combined old plus new approach has been demonstrated to be a viable fabrication technique for production of Commercial Aircraft Passenger Seats. However the approach should be applicable in many other applications including automotive, medical/dental, industrial and consumer components [2].

3. USE OF MAGNESIUM IN COMMERCIAL AIRPLANE PASSENGER SEAT FRAMES

A concern with Magnesium alloys is its flammability. However Magnesium Elektron have recently developed rare earth containing alloys which are not susceptible to this problem [3]. Both Elektron® 21 (also known as ASTM EV31A), a sand casting, and Elektron® 43 (Mg-4.0Y-2.9RE-0.2Zr) (also known as ASTM WE43C), a wrought plate or extrusion alloy, have undergone extensive flammability testing (which can be catastrophic in nature, Figure 10 [3]) by the Federal Aviation Administration (FAA). The FAA has shown that the use of these Elektron® 21 and Elektron® 43 alloys in aircraft interior components (such as seat frames) does not reduce the level of safety of the aircraft when compared to heavier aluminium seat components, this is, a very significant and major break-through for Mg alloys. The technology being used produces a cast structure and so the integrity of the investment casting is critical, also the ability to scale up to the necessary volumes whilst maintaining the quality. There are at least 400,000 seats being made annually. All the work Magnesium Elektron have done to date involves both high strain rate impact testing to meet the various loading criteria, most extreme of which is the 16g forward load requirement, and fatigue; although 20,000 cycles is the minimum specified the seat producers and airlines generally work to a much higher standard [3].

CONCLUSIONS

Key to the technology described in this paper is the utilization of AM to fabricate a complex plastic precursor which is then used to produce the mold for a metal casting.

Figure 10: Results of a Flame Test on the Seats of a Commercial Airliner [3]. Compare this with how the seats looked prior to the flammability test Figure 1.
As there are a lot of areas in an aircraft seat where moderate tensile strength in conjunction with moderate ductility is best practice, magnesium now has a chance for introduction into the aircraft passenger seat business. The aircraft seat industry has been eager to get clearance for take off and landing with magnesium alloys for a long time, and now has this approval.

REFERENCE


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