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Chapter 1 : Materials | Special Issue : Advances in Structural Health Monitoring for Aerospace Structures

aerospace materials Summary This paper reviews the status of selected aerospace materials currently under development or moving to application and assesses the difficulties inherent in their transition from research to commercial use, in particular those factors affecting affordability.

Manufacturing Forty years ago, aluminum dominated the aerospace industry. As the new kid on the block, it was considered to be lightweight, inexpensive, and state-of-the-art. Readily available, aluminum was used everywhere from the fuselage to main engine components. Most of the non-critical structural material â€” paneling and aesthetic interiors â€" now consist of even lighter-weight carbon fiber reinforced polymers CFRPs and honeycomb materials. Meanwhile, for engine parts and critical components, there is a simultaneous push for lower weight and higher temperature resistance for better fuel efficiency, bringing new or previously impractical-to-machine metals into the aerospace material mix. Aerospace unique among industries Aerospace manufacturing is unique among other volume manufacturing sectors, and this is especially true of aerospace engine manufacturing. The engine is the most complex element of an aircraft, houses the most individual components, and ultimately determines fuel efficiency. To meet these temperature demands, heat-resistant super alloys HRSAs , including titanium alloys, nickel alloys, and some nonmetal composite materials such as ceramics, are now being brought into the material equation. These materials tend to be more difficult to machine than traditional aluminum, historically meaning shorter tool life and less process security. Because margins for error are non-existent at 35,ft cruising altitude, tolerances in aerospace are more precise than almost any other industry. This level of precision takes time. Longer machining times are required for each component, and more time per part makes scrap relatively expensive, when factoring in time investment. Also, compared to other industries, aerospace component orders often consist of short run quantities and long lead times, rendering scheduling for productivity, throughput, and profitability difficult. Unlike any other industry but oil and gas, which also has high temperature, pressure, and corrosion requirements, aerospace materials themselves impact component design. Design for manufacturability DFM is the engineering art of designing components with a balanced approach, taking into consideration both component function and its manufacturing requirements. This approach is being applied more and more in aerospace component design because its components have to accomplish certain loads and temperature resistances, and some materials can only accommodate so much. Material and component designs truly drive one another, as opposed to one following the other. This give-and-take relationship between material and design is a particular consideration when investigating next-generation materials. Aerospace manufacturers are a breed apart for all of these reasons. New material landscape Standard aerospace aluminums â€" , , and â€" and traditional aerospace metals â€" nickel , titanium 6Al4V, and stainless PH â€" still have applications in aerospace. These metals, however, are currently ceding territory to new alloys designed to improve cost and performance. Rather, they are new to practical production application, as machine tools, tooling technology, and insert coatings have sufficiently advanced to tackle difficult-to-machine alloys. Even though the amount of aluminum is declining in aircraft, its use is not completely disappearing. In fact, aluminum is coming back, especially in cases where the move to CFRP has been cost prohibitive or unsuccessful. Titanium aluminide TiAl and aluminum lithium Al-Li , for example, which have been around since the s, have only been gaining traction in aerospace since the turn of the century. But TiAl is more easily machined, exhibiting similar machinability characteristics to alpha-beta titanium, such as Ti6Al4V. Case in point, both low-pressure turbine blades and high-pressure compressor blades, traditionally made of dense Ni-based super alloys are now being machined from TiAl-based alloys. General Electric was a pioneer in this development and uses TiAl low-pressure turbine blades on its GEnx engine, the first large-scale use of this material on a commercial jet engine â€" in this case in the Boeing Dreamliner. Another re-introduction of aluminum to aerospace is found in weight-saving Al-Li, specifically designed to improve properties of and aluminum. Overall, the addition of lithium strengthens aluminum at a lower density and weight, two catalysts of the aerospace material evolution. Airbus is currently using AA The alloy can also be found in the fuel and oxidizer tanks in the SpaceX Falcon

9 launch vehicle, and is used extensively in NASA rocket and shuttle projects. Titanium Ti is another metal that is reasonably new to aerospace, exhibiting high strength, light weight, and good corrosion resistance. Major structural components that need to be stronger and lighter than the previously used stainless steel alloys are perfect application points for this titanium alloy. Nicknamed triple , this has been a notoriously difficult material to machine â€" until recently. Extensive research and development has been devoted to making the metal practical to machine, and triple has recently proven to be very predictable with machining consistency similar to more traditional titanium alloys like the aforementioned Ti6Al4V. The variances in the two materials require the use of different cutting data to obtain similar tool life. But once an operator has proper parameters set, triple machines predictably. The key with triple is to run a bit slower and optimize the tool path and coolant system to achieve a good balance of tool life and tool security. Some structural pieces, like fasteners, landing gear, and actuators, require raw strength, with lightweight properties being less of a priority. In such cases, Carpenter Technology Ferrium S53 steel alloy has provided mechanical properties equal to or better than conventional ultra-high-strength steels, such as M and SAE , with the added benefit of general corrosion resistance. This can eliminate the need for cadmium coating and the subsequent related processing. Composites hit their stride Composite materials also represent a growing piece of the aerospace material pie. They reduce weight and increase fuel efficiency while being easy to handle, design, shape, and repair. Also important, composite components can be formed into complex shapes that, for metallic parts, would require machining and create joints. In doing so, composite materials are helping to drive an industry-wide trend of fewer components in overall assemblies, using one-piece designs wherever possible. CMCs are comprised of a ceramic matrix reinforced by a refractory fiber, such as silicon carbide SiC fiber. Accelerating this evolution of new materials, advancements in machining and cutting technology give manufacturers unprecedented access to materials previously deemed impractical or too difficult to machine. New material adoption is happening exceptionally quickly in aerospace, requiring DFM-minded interaction between material characteristics and component design. Meanwhile, one-piece designs are continuing to reduce the number of components in overall assemblies. In general, this bodes well for composites in aerospace, which can be formed instead of machined. A variation of this trend exists in metallic structures, as more components are conditioned in forgings to get to near-net shape, reducing the amount of machining. Elephant skins, roughed-in shapes, and thin floor sections all reduce material costs and the total number of components, but setup and fixturing continue to be challenges. Some manufacturers are turning to waterjet and other technologies to reduce or eliminate raw stock materials in need of removal. Still, difficulties exist in workholding, surface finish, and CAM tool paths. The mix of materials in aerospace will continue to change in coming years with composites, freshly machineable metals, and new metals increasingly occupying the space of traditional materials. The industry continues to march toward components of lighter weights, increased strengths, and greater heat and corrosion resistance. Component counts will decrease in favor of stronger, near-net shapes, and design will continue its close collaboration with material characteristics. Machine tools builders and cutting tool manufacturers will continue to develop tools to make currently unviable materials machineable, and even practical.

Chapter 2 : Aerospace materials â€" past, present, and future - Aerospace Manufacturing and Design

Engages in research, development, and flight application of advanced materials, structures, and mechanisms for aerospace systems, with activities ranging from materials research at nanoscale to design and testing of structures and mechanical systems for aeronautics and space flight programs.

Chapter 3 : Advances in Manufacturing and Processing of Materials and Structures - CRC Press Book

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