

SME Aerospace & Defense Yearbook

Airplanes Don't Fly Without Heat Treating

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Heat treating is the unsung hero of the commercial and military aviation industries. Much like the support staff behind any good play or movie, and the mom behind the Olympic athlete, heat treating of critical aerospace parts is relegated to the background, to the fine print of the credits...if at all. But if it weren't for heat treating, planes wouldn't fly, ships wouldn't sail, submarines wouldn't dive, and cars wouldn't drive.

This article introduces you to the technical world of vacuum heat treating and why vacuum thermal processing is vital to the aerospace and defense industries.

First, let's nail down what we mean by "heat treating." In simple terms, heat treating is cooking metal much like you would cook food – with a predetermined recipe and desired outcome in mind. Metal is placed into an oven, or more accurately a furnace (ovens typically don't handle temperatures over 1,000°F), and precisely held at a specified temperature for a pre-determined period of time. The metal is then cooled either slowly or quickly depending on what properties are desired. Thermal processing can make the metal harder, softer, stronger, more flexible, more rigid, more wear resistant, chemically altered, or a host of other desirable properties.

In aerospace and defense, the vast majority of metals must be heat treated in a special type of furnace that is void of air. These furnaces are called vacuum furnaces. Vacuum furnaces keep detrimental elements such as water molecules and oxygen from coming into contact with the metal. A vacuum furnace does this by sealing the critical metal components inside an air tight vessel, pumps out all the air

from within the vessel to a deep vacuum level, then performs the heat treatment recipe before returning the load to room temperature and breaking the vacuum. Many titanium, stainless steel, and nickel alloys are very reactive at elevated temperatures and will become contaminated if exposed to any air or water molecules. Vacuum furnaces help eliminate these detrimental metallurgical reactions.

Secondly, let's take a look at what flight critical parts are vacuum heat treated on a typical airplane.

Parts are broadly categorized as engine parts and structural parts. Critical parts are found in jet engines where turbines, stators, vanes and other engine parts are exposed to extremely high operating temperatures for sustained periods of time. Most of these parts are made of titanium and nickel alloys that require vacuum heat treating in order to give them the strength and wear resistance necessary to be reliably installed in jet engines. GE, Pratt & Whitney, and Rolls Royce are among the leading supplier of jet engines and heat treatment of these parts is critical and heavily controlled.

Today's commercial aerospace engineers are making greater use of composite technology in airframes and primary structures. This approach offers a weight savings on average of 20% when compared to conventional aluminum designs. Since carbon fiber reinforced plastic, or composites, are inferior when handling compressive loads but are excellent with tensional loads, aerospace engineers needed another metal to support the major structural and flight-critical components within the new aircraft. When searching for the optimum material to address strength, weight, and resistance to galvanic corrosion, it was quickly decided that aluminum was a poor choice. Titanium, however, can withstand comparable loads better than aluminum, has minimal fatigue concerns, and is highly resistant to corrosion. Since titanium is stronger than aluminum and their weights are equivalent, you can use less titanium by weight than aluminum to achieve the same part strength. Since weight reduction drives down fuel consumption, titanium in both military and commercial aerospace is king!

Titanium

Because titanium plays such a critical role in today's aerospace arena, let's take a more thorough look at why titanium needs to be heat treated and more specifically why it needs to be vacuum heat treated.

Titanium is both chemically and thermodynamically very reactive. At elevated temperatures, titanium will absorb hydrogen if present. Hydrogen, unfortunately, once diffused into titanium causes the metal to become brittle and reduces the appealing properties of titanium. When titanium is heated in an air furnace (not in a vacuum furnace), hydrogen will impregnate the titanium. The process of removing this hydrogen from titanium is called vacuum degassing. Currently, most aerospace material specifications require that all titanium have no more than 30 parts per million (ppm) of hydrogen.

Because titanium is an expensive metal, more people are looking at recycling. In the titanium scrap world, there are times when infusing hydrogen into titanium is beneficial. For example, when a titanium reclaimer wants to pulverize titanium into a powder for further processing, it is much easier to do when the metal is brittle. Super-saturating hydrogen into titanium – hydriding – can only be done inside a vacuum furnace and is always followed by a dehydride once the titanium is in final form.

Vacuum Heat Treating – In-House or Outsource

The expertise necessary to operate a vacuum heat treating furnace is notable. Vacuum technology has immensely improved over the years and operating a vacuum furnace today is truly a science. Some manufacturers buy and operate their own vacuum furnaces. These furnaces typically run the same product day in and day out. Maintaining and troubleshooting vacuum furnaces can be a very time consuming distraction. The true hidden costs of running and maintaining a vacuum furnace are not very well known.

Other companies choose to outsource their heat treating to commercial heat treaters who vacuum heat treat 24/7/365. These heat treat companies relieve their customers of the headaches of owning and operating a vacuum furnace and benefit by allowing vacuum heat treat experts to take care of that portion of their manufacturing process and compliance to stringent specifications.

Current Market Conditions

The vast majority of contract or commercial heat treaters know early in the process when industries are picking up. The aerospace industry, especially commercial aerospace, is experiencing significant growth currently. With commercial aircraft sales at an all-time high, vacuum heat treatment is strong today and well into the future. Airbus' decision to locate an assembly plant in Mobile, Alabama, is just one additional sign that the commercial aerospace industry is experiencing aggressive growth and looking to expand their supply base.

On the defense side, sequestration has hurt many aerospace projects. Growth in this sector is, to say the least, flat.

New Processes and Materials

One process that could significantly impact the aerospace community is additive manufacturing. For more on additive manufacturing, refer to www.americamakes.us. This process 3D prints parts utilizing various methods. Some parts are produced by laying down atomized powdered metals or laying down wire layer after layer until the entire part is fully printed or constructed. Unlike "subtractive" manufacturing which takes a bar of metal and shaves off the unneeded excess, additive manufacturing adds only that metal which is needed and there is essentially no scrap. With subtractive manufacturing, frequently 80% of the original metal stock ends up as scrap and needs to be recycled.

Exactly how additive manufacturing will impact the aerospace world remains to be seen. There are multiple metallurgical hurdles to overcome before any flight-critical part is placed in an aircraft. Even parts additively manufactured need vacuum heat treating, most notably vacuum stress relieving or vacuum sintering. Nonetheless, additive manufacturing is something that SME, machinists, and vacuum heat treaters around the country will be watching.

Russia

The final unknown in the world of aerospace manufacturing is Russia. As the world's primary supplier of titanium, any political unrest in Russia translates into jitters for Boeing's and Airbus' top management. Even the recent unrest in the Crimean peninsula of Ukraine has resulted in increased quoting activities from many of the major U.S. titanium producers.

Nadcap

Any heat treater of aerospace parts must comply with the critical processing criteria enforced by Nadcap (<http://www.p-r-i.org/nadcap/>), an organization established years ago to ensure that aerospace suppliers were meeting and maintaining high quality standards. Heat treaters also have to be AS9100:2009 certified before they can process aerospace parts. In addition to Nadcap, many aerospace companies have their own quality standards audited by their individual customers. These are called "prime certifications" and these standards meet and often surpass requirements from Nadcap and AS9100:2009.

Conclusion

Although heat treating plays a relatively hidden part in the aerospace and defense supply chain, it is a critical link in the chain and one not widely understood even by manufacturers who produce parts out of titanium and other aerospace alloys. Working with your local vacuum heat treater early in the process

will prove to be a good investment. Solar Atmospheres, for example, has a research and development team (SMART – Solar Metallurgical Advanced Research Team) that can help in the early stages of part development to assure proper heat treating and/or brazing can be performed. Partnering with a commercial vacuum heat treater is a smart investment. And seeing as the future for aerospace looks bright – especially commercial aviation – it seems aerospace heat treating will continue to be an important link in the supply chain for many years to come.