AIRCRAFT ENGINE STRUCTURE MATERIALS

Göran Sjöberg

Volvo Aero Corporation, 2008

1. Introduction

Some years ago, more specifically 1990, as a newly appointed materials application engineer at GE, Evendale, I met and made friends to some extent with Dr. Stanley Wlodek, well renowned within the superalloy materials field. He was a fountain who brought cold water to a thirsty young doctor-engineer trying to understand how materials application in aircraft engine designs best could be monitored. Early he warned me not to trust design engineers who he considered being to optimistic in their use of design material for aircraft engines. He told me that they were as the farmer in the short story by Dostoyevsky about the farmer and the devil and he asked me if I had read the story but of course I hadn't and sad to say I have not been able to trace this story later. He told me the following story.

The poor farmer met the devil who asked if he wanted more land to his small farm. "Of course!" was the immediate reply and after a while: "How much can I get?" "As much as you want." – the devil replied. "As much as I want! – what does that mean?" "Well, as much as you can walk around in one day." The farmer still puzzled scratched his head and asked "When can I start in the morning?" "Well, when the sun rises." " And when do I have to be back home?" "Well, when the sun sets." The farmer after scratching his head a little more asked his final question. "But, if I am not back when the sun sets?" "In that case your soul is mine" was the confident statement by the devil.

The outcome was as can be expected that the farmer was to optimistic finally searched for and found far away from home; dead and with his soul with the devil.

So the monitoring of materials application in aircraft engines should in principle be done by raising the warning finger to the design engineers and the materials application engineer responsible for that task could belong to a 'police department'. A designer with liberal attitudes I worked with some years ago finally got so tired of me that he one day after all warning fingers finally exclaimed. "Say something positive for once!" That was a hard blow to take but the project leader was happy with me and told me I was the only one to control the designers. "When you say it is OK to use a material/process we know that it is OK!" Some comfort after all.

In the following 20 pages or so I will now try the almost impossible task to intelligibly summarize what is essential for materials application engineering in aircraft engines in general and with a special focus on structures. Due to the strong interest in ultimate performance there will however be a bias towards the hot end of the engine (read superalloys) since engine efficiency for thermodynamic reasons is governed by the resistance of the materials meeting the highest temperatures at the turbine inlet. Interestingly enough, although the amount of superalloy material used is extremely insignificant in comparison with all other metallic materials used in our society, the amount of research work carried out on this type of materials is in contrast very significant not least due to military interests. Temperature is, however, often the limiting factor when optimizing the material choice also for the other parts of the engine.

Since this paper mainly is about materials for aircraft engine **structures** it is important to know what we mean when we are using the word structure. I the general sense the word imply some kind of hierarchical organization where structure is the most important concept and taken as such structures would involve engine parts of high hierarchical importance to organize the engine. Hence, for clarification, figure 1 confirms this view and illustrates what we usually consider as a typical aircraft engine structure, albeit a rather complex one. This type of structures also belongs to the core business of Volvo Aero Corporation.

The structure of figure 1, an intermediate compressor casing for the Rolls&Roys Trent 900 engine, consists of two separate vacuum investment cast titanium parts joined by a circumferential electron beam weld. It is a multifunctional part in the center of the engine and as such classified as a pressure vessel and joining the forward cooler structure and with the hotter structural aft part. It is also obvious from the photograph that it carries a number of engine mounts telling that it has to carry the engine load and also transfer the engine thrust to the aircraft.

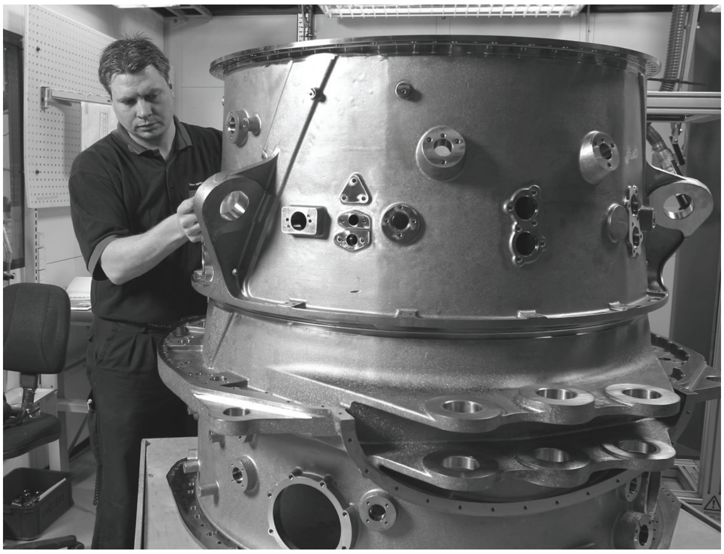

Figure 1. An aircraft engine titanium structure made by vacuum investment casting technology. The intermediate compressor casing for the R&R Trent 900 engine.

The material selection is a rather complex process and to a considerable extent governed by ‘what is standard’ for the specific part but this varies of course with time. For instance, large