Dissertation Johanna Menges

Bestimmung und Verbesserung der Fehlerauffindwahrscheinlichkeit bei der Ultraschallprüfung von Triebwerksbauteilen

Abstract

Aircraft engines are subjected to high requirements on security. If they fail, a lot of human lives are threatened. The materials in aircraft engines have to persist high stresses at high temperatures, which is a challenge to material science. With defects in material fatigue will occur very fast, which usually leads to breaking of the rotating engine part. Therefore all engine parts have to be inspected nondestructively during all processing steps to detect material defects like pores, cracks, inclusions, segregations, etc. Nondestructive inspection methods which are used are for example Ultrasonic Testing, Fluorescence Penetrant Testing, X-Ray Testing and other. The safety of an aircraft engine depends highly on the reliability of the inspection method. But as the inspection methods use technical processes to make defects, which are invisible to the human eye, observable, is it hard to define the reliability. The inspections methods usually only give information about the smallest defect, which could be detected. No information exists on the biggest defect which was missed. Although this one is the most important for the reliability of the system. So there is a need for a defined process to determine the reliability of an inspection system. This need is met by the POD process. POD is the probability of detection and the process to determine it is described in this work. A huge amount of artificially built defects is needed for it, they are produced in so called reference blocks. The defects have to represent flaws that occur in real parts. The reference blocks are inspected by different inspectors, at different locations, at different times. Hence a big data-set of inspection results is obtained, which will be evaluated statistically to result in a POD.

This thesis describes developments to improve the POD for ultrasonic testing of aircraft engine parts. Two aspects are considered. First an improvement of the process to determine a POD. Second an improvement of the result of the POD, which is a nominal value of the smallest defect, which can be detected reliably (90% probability with a 95% certainty). By the necessity to built a huge amount of reference blocks with artificial defects the cost of a POD are enormous. Technically a new POD-study should be done for each new inspection configuration (different sensors, different equipment, etc.). But due to the high costs, usually everybody takes existing POD-curves for other configurations, instead of executing a new POD-study. In this work two methods are described, which can reduce the costs for the POD. The first method is the result of a big European project, which investigated the use of simulation tools for the determination of POD. One experiment is shown for which inspections and simulations were done. The results of the POD are similar but cannot be compared completely, because the used simulation tools are not able to represent all

inspection uncertainties exactly. Further work is already done here and promises good results. The second method to improve the process is to use glass with laser engravings as a reflector for ultrasound waves. Basic research on the applicability of this reference blocks is done in this work. It is shown, that the laser engravings can be used as reflectors, with the limitation that the received signal is weaker than in a metal reference block. It is demonstrated that the limitation is no problem, because in glass the sound moves with almost no scattering, so the gain can be increased easily. Furthermore the developed gain difference is constant over different sizes for one reflector geometry.

The second aspect of this work is the improvement of the POD result, hence enhancement of the inspection technique to detect smaller defects. It is shown that the phased array ultrasound technique brings an improvement of the POD compared to conventional ultrasound inspection. A comparison between the two techniques is executed which shows advantages of the phased array technique regarding the handling of surface damages and tilted flaw direction. A new application of the phased array technique to modulate the sound field is introduced. There a matrix array is used to built non-diverging, self-healing sound fields. With this technique a more flexible inspection is possible at which it can be switched between two modes, “fast / large material depth” and “sensitive / small section”. By using the “fast / large material depth” mode an economical inspection is possible, which has as well a low POD defect size due to the possibility to switch to the “sensitive / small section” mode when an indication can be seen in the ultrasonic results.

This work makes a contribution to maintain the high standard in reliability of aircraft engines, even with increasing air traffic.