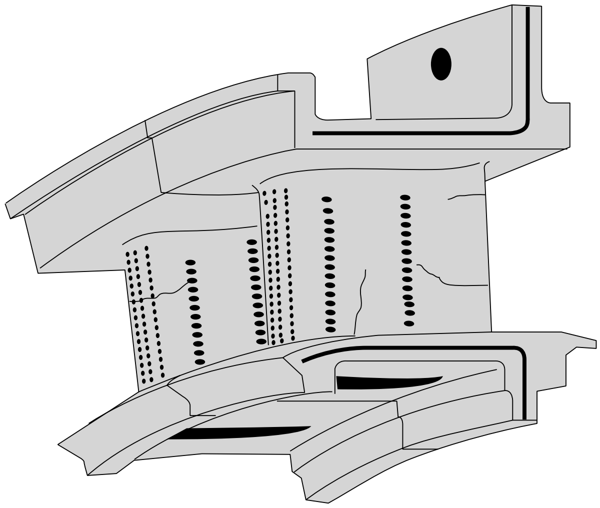
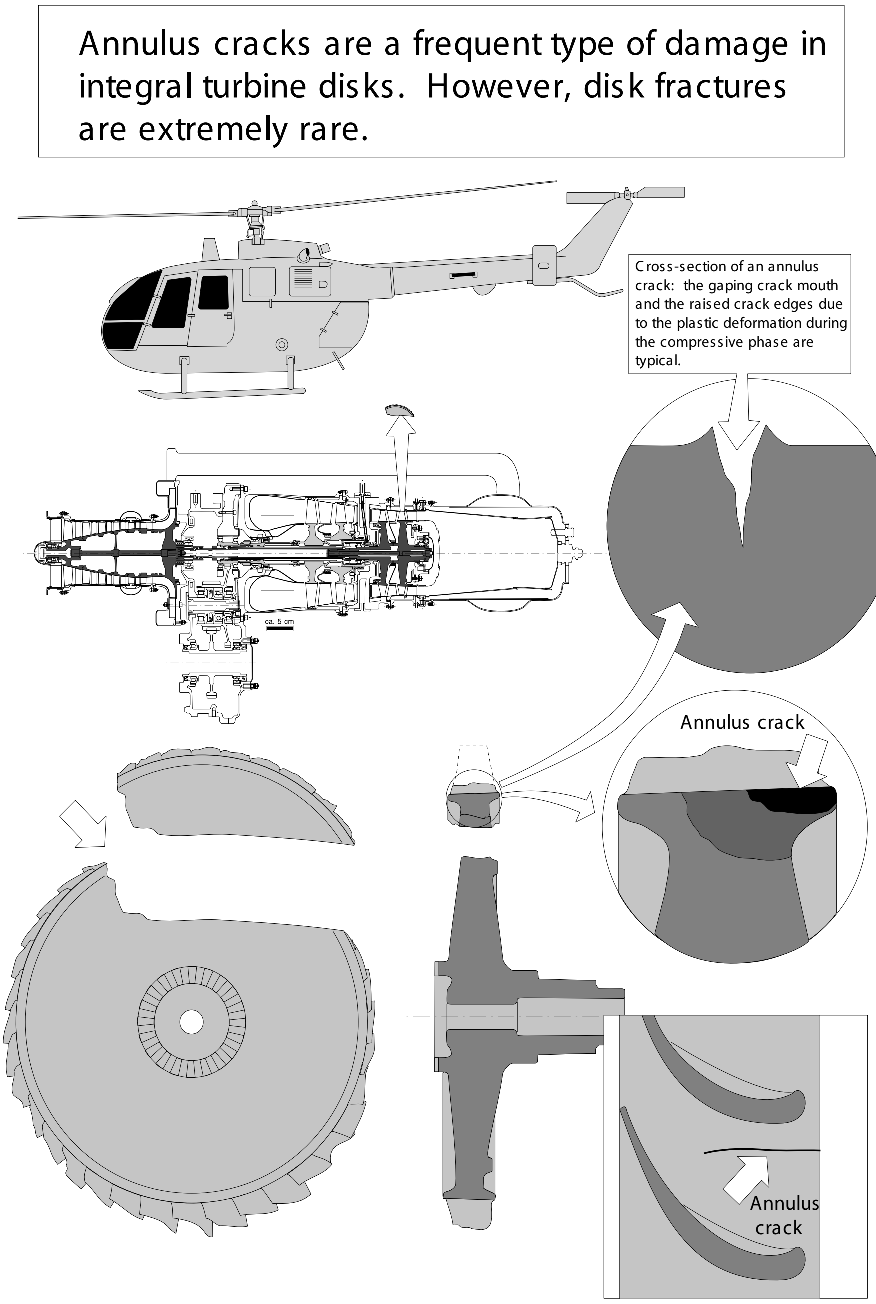
12.6.2.2 Damages due to Thermal Fatigue



Rising power concentrations and low fuel consumption force an increase in gas temperatures (Ill. 12.1-4). Because the thermal resistance of the available materials does not increase as quickly as the rising hot gas temperatures would require, the **cooling of the hot parts** must be intensified accordingly. This leads to greater temperature gradients in the engine parts (especially the combustion chamber and turbine) and, in the case of restricted thermal strain, increased thermal stress. Temperature cycles of the parts follow the gas temperature (i.e. engine power output). This also makes thermal fatigue damages more likely. The largest gradients are to be expected during startup and shutdown (Ills. 11.2.3.1-7 and 11.2.3.1-8).

Thermal fatigue damages are explained and discussed in the chapters dealing with individual engine components such as combustion chambers (Chapter 11.2.2) and turbines (Chapter 11.2.3). For this reason, the following text only treats a few exemplary damages and explains the influence of coatings on thermal fatigue.

Illustration 12.6.2-12 (Ref. 12.6.2-4): Integral turbine disks *tend to* ***annulus crack initiation.*** *These cracks are allowable in some turbines within certain limits. This is a rare exception for cracks in highly-stressed rotating parts. These cracks are* ***thermal fatigue cracks*** *that form during cooling in the compressed annulus areas between the cracks. The compression can be easily recognized by certain crack characteristics (raised crack edges, gaping cracks, see detail). The crack growth rate slows because the annulus zone initially has large, radially-oriented stress gradients during operation. In order to ensure safe controllability of the cracks, they are not allowed to spread from the near-surface pressure zone into a zone with increasing tensile stress during the approved life span (Ill. 11.2.3.1-7). There is a danger of uncontrollable crack growth in the latter zone (Ref. 12.6.2-5). If the cracks spread into the blades, fractures due to high-frequency vibrations are likely (Ill. 12.6.2-14, Example 12.6.2-1).*
Therefore, the cracks can only be tolerated for life spans that have been shown analytically and in tests to have controllable crack growth rates (i.e. slowing crack growth; Ref. 12.6.2-7). Generally, turbine disks with annulus cracks



Ill. 12.6.2-12

will not be approved for reinstallation. However, this should not be interpreted as meaning that annulus cracks are generally not tolerated, since the engine evidently "lived with" the cracks until the inspection.
The verification of benign annulus cracks requires that there are no ***disk vibrations*** *that could cause accelerated crack growth, and that are known to have caused cracked disks to burst in several cases.*

Optimized annulus cooling can be a successful remedy for annulus cracks. In the context of design, dangerous circumferential stresses in the annulus can be prevented through the use of a ***"drained annulus"*** *(see Ill. 12.6.2-19).*