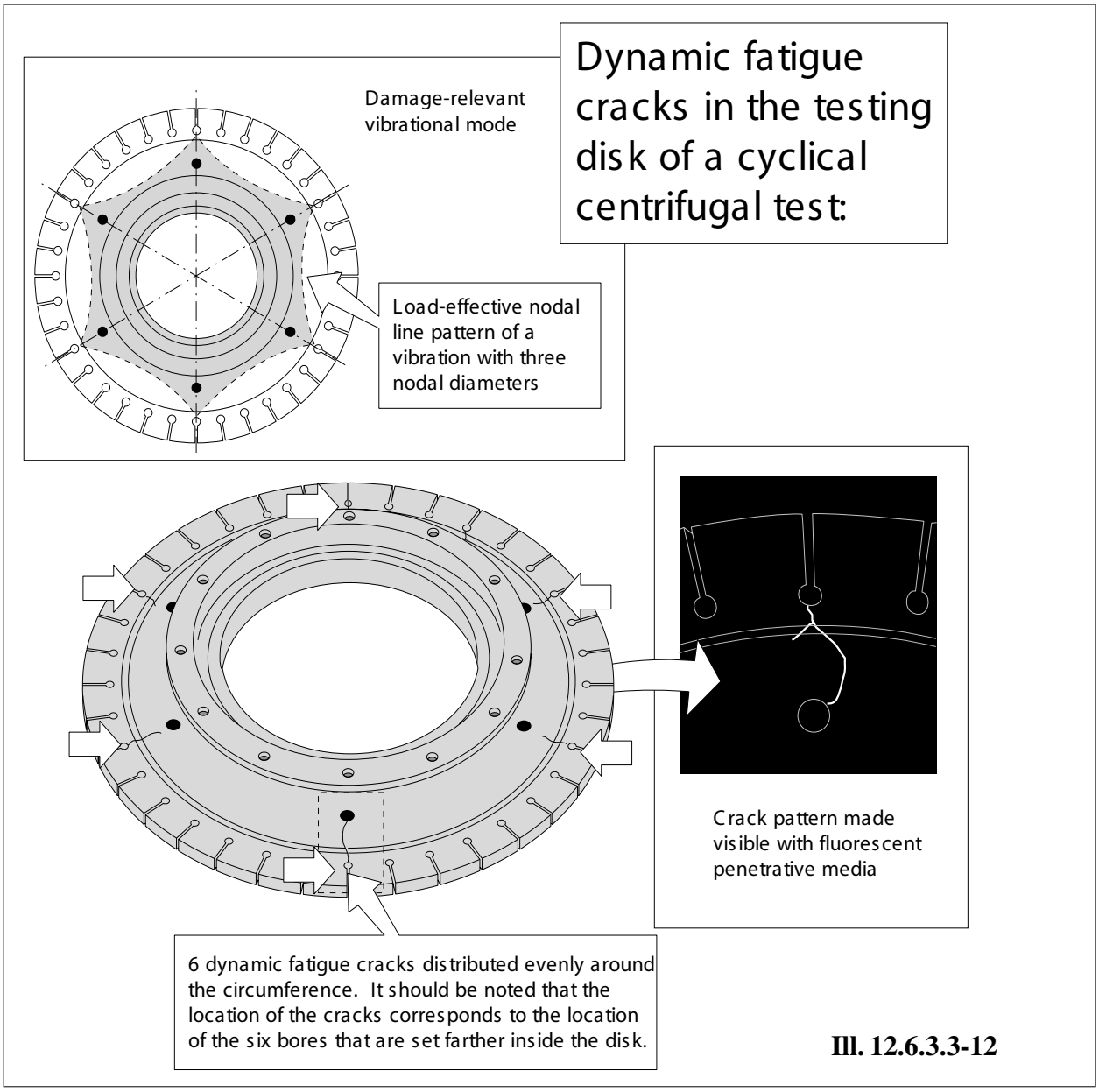
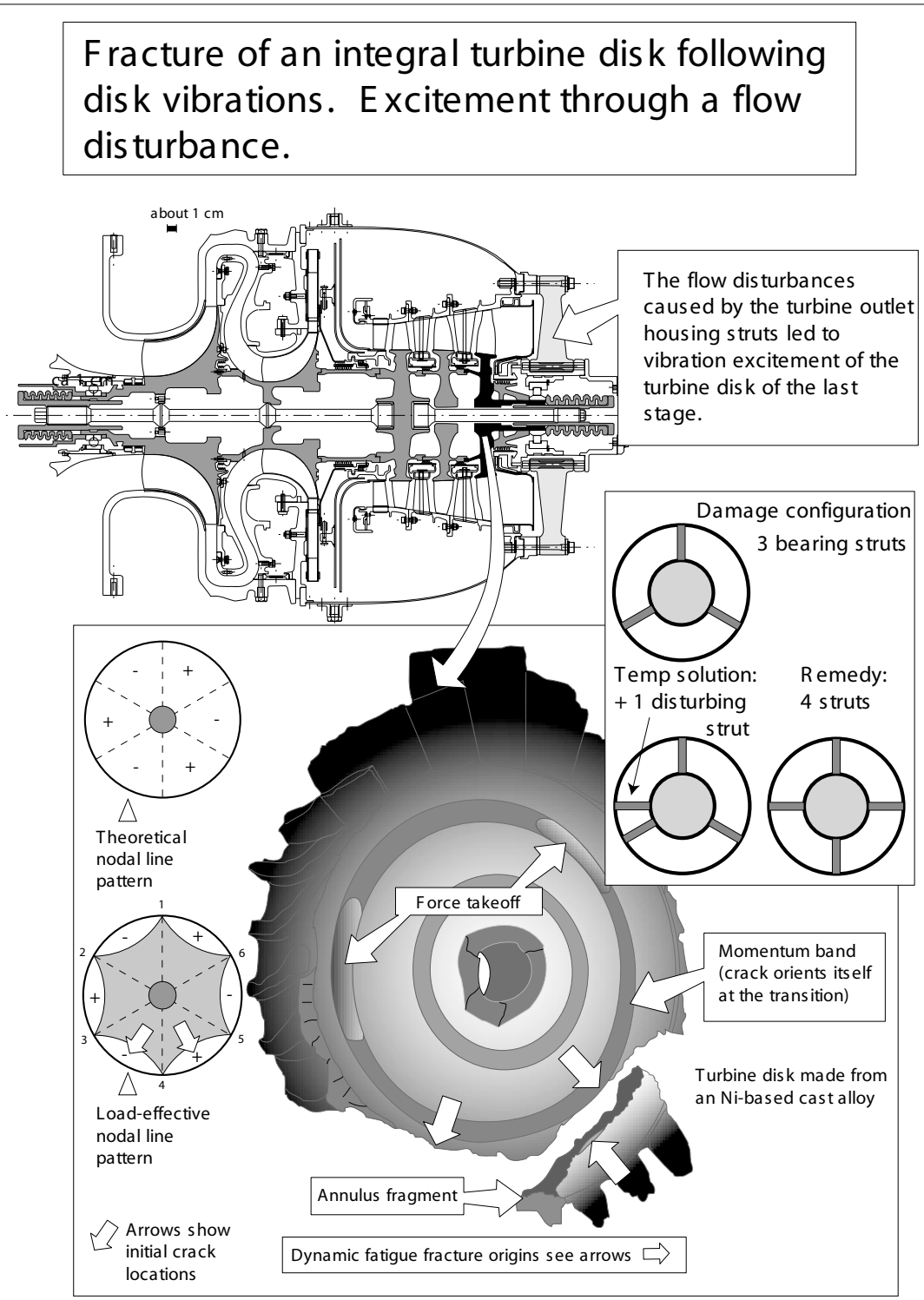


Ill. 12.6.3.3-12

Illustration 12.6.3.3-12: *The vibration excitement of a rotor disk can also occur with flexural modes of the rotor. In the depicted example, a specimen disk was cyclically stressed in a vacuum vertical centrifugal testing rig by an* ***annulus that had been "drained"*** *by keyhole bores (to simulate blade loads). After a short operating time, penetrative crack detection discovered several cracks (right diagram) in the annulus area that were primarily radially oriented and periodically distributed (bottom left diagram). The findings from the crack surface inspection indicated dynamic loads in the HCF range. This was plausibly explained by a* ***disk vibration*** *with three nodal diameters. The vacuum in the testing rig made vibration excitement due to aerodynamic forces impossible. However, there was also no effective air damping. Therefore, the only possible excitement was from the testing rig spike that powered the disk. The spike is elastically suspended in the testing rig on the free end, together with the disk. In the case of imbalance, it runs into a safety bearing. Evidently the rotor vibrated within itself in a way that no externally noticeable imbalances occurred.*

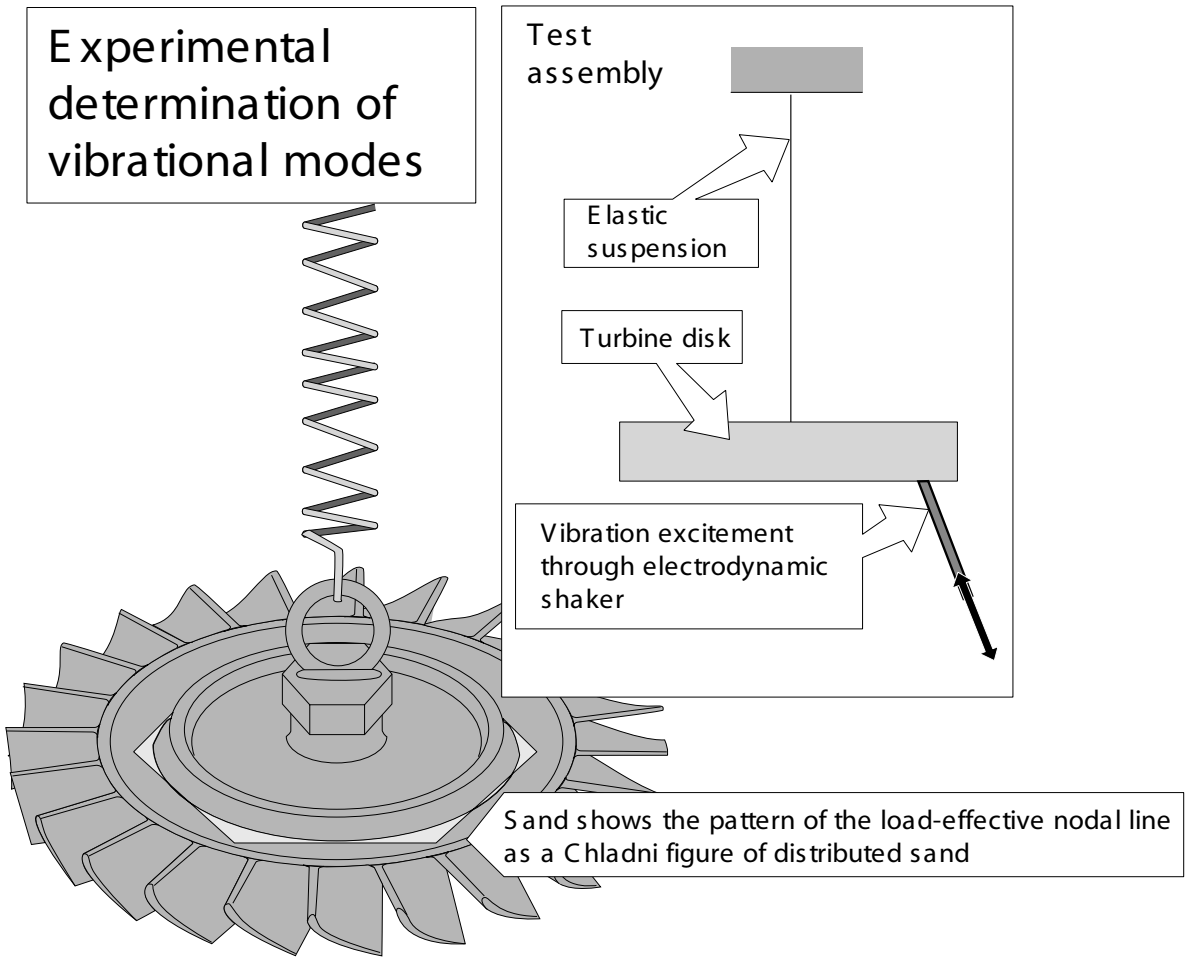


Ill. 12.6.3.3-13

Illustrations 12.6.3.3-13 and 12.6.3.3-14: *This case occurred during the development phase of a small, low-performance turbine for a helicopter (top diagram). Without any indication of imbalances or other anomalies in operation, the integral cast turbine disk of the last stage burst at full RPM in a steady operating state.* ***Fragments of the annulus*** *had broken off the disk. The entire fracture surface could be seen as a combination of two*

fractures that ran together at an angle to one another that was tangential to the balancing ring (bottom diagram). The fracture surface analysis revealed a bow-shaped limited fracture zone in the middle of each of the annulus fragments near the balancing ring. It also showed stage 1 characteristics (cleavage cracks) that are typical for this Ni-based cast material (Ill. 12.6.3.2-4). A ***testing-technical vibrational analysis*** *(Ill. 12.6.3.3-14) with heaps of powder resulted in a distribution pattern that corresponds with the bottom left diagram. This* ***Chladni figure*** *showed that a three nodal diameter vibration (Ill. 12.6.3.1-8) is excited exactly at full RPM by the three bearing braces of the exit housing located behind the disk.*

A successful provisional solution was the installation of a ***disturbing brace*** *with no load-bearing function. It was only intended to dampen the vibration in the right rhythm with a disturbing pulse. The final solution was four equally-spaced supporting braces, from which no dangerous excitement was expected (middle diagram). The effectiveness of this solution was confirmed by later experience.*



Ill. 12.6.3.3-14