METAL FATIGUE

A new theory makes it possible to predict the life span of any structural component in aircraft or missiles

A new theory which makes it possible to predict the life span of any structural component in aircraft or missiles has been developed at Caltech by Sitaram R. Valluri, senior research fellow in aeronautics.

Metal fatigue is one of the most serious problems in the aircraft industry. The failure of structural components such as landing gear, or the sudden disintegration in midair of certain types of aircraft, has, in the past, been attributed to a variety of reasons. It has been found, however, that in many cases such failures have been due entirely to metal fatigue.

Dr. Valluri's theory is concerned primarily with an estimation of the residual strength of a component and an analysis of the factors affecting it. According to the theory, imperfections inherent in the material are the starting points of fatigue damage. The damage usually begins near the surface of the metal, due to the applications of such stresses as air loads, temperature changes, impact on landing of the aircraft, and noise. Acoustical damage from jet engines, for instance, is a major fatigue problem.

Metals generally consist of layers of atoms arranged in precise and regular rows, forming a lattice structure. Under the present methods of producing metals, the lattice is not perfect. The inherent dislocations or imperfections in metals are submicroscopic, and are caused by dislocations of the metal structure. In one cubic inch of metal, there are millions of dislocations.

Under certain stresses, the movement and interaction of these dislocations cause submicroscopic cracks to start – probably on the order of one millionth of an inch long. These submicroscopic cracks tend to join together like the tributaries of a river, to lead gradually to a larger and damaging crack. This is one of the important postulates of Valluri's theory. The result of such a growth pattern shows up in the form of rings, much like the growth rings in a tree.

While the theory has certain limitations, as all theories do, this method has proved amenable to a successful treatment of failure problems in complicated structures such as aircraft and missiles. It has been confirmed to a considerable extent by tests performed in industrial and governmental laboratories. Results have been predicted with a much greater accuracy than ever before.

The fatigue damage to which an aircraft is subjected is a continuous process which begins when a plane is built, and continues on as the plane flies through fair weather and foul. To successfully apply Valluri's theory, two factors must be known – the extent and kinds of stresses to which the structure is subjected, and the basic behavior of the metal during fatiguing. A piece of the same metal used in the component is tested under different kinds of stress in the laboratory, and, from mathematical calculations, the life and behavior of the component can be determined quite accurately, even as the plane is flying.

This research has been primarily concentrated on the slow progress of the cracks. Now, engineers are preparing an attack on the reaction of the metal when it gets to the point where the fracture failure can be catastrophic. Using a high-speed camera which can photograph up to 200,000 frames a second, the actual movement in a large fracture will be studied.

All metals in usable quantities now have these inherent weaknesses, but it should be possible in the future to produce the same metals with much more

Sitaram Valluri, senior research fellow in aeronautics, in a practical demonstration of his new theory, studies the aluminum alloy hub of a large propeller blade that failed because of metal fatigue. The blade ripped loose from the hub several years ago at Caltech's Co-operative Wind Tunnel, causing great damage. A small dent at the edge of the hub caused submicroscopic cracks to start, leading gradually to a larger crack.

strength. Physical metallurgists have been able to produce "whiskers" of metal crystals in the laboratory, each of which has only one dislocation. Unfortunately, they have been able to produce only small quantities so far.

These whiskers are frequently from 10 to 100 times stronger than similar metals produced in the usual way. While ordinary metal might have a strength of less than 100,000 pounds per square inch, the whiskers can stand stresses up to a million pounds per square inch or more. Aircraft made of the new metals would thus have a safer structure and a prolonged life.

Dr. Valluri's research is supported by the U.S. Air Force. At present, such firms as the Douglas Aircraft Company and the Northrop Corporation are actively pursuing the theory to establish its regions of validity and to develop it further.