Engineering and Metallographic Aspects of Gas Turbine Engine Failure Investigation: Identifying the Causes

by
Robert E. Dundas, Principal Engineer
Factory Mutual Engineering & Research

Technicians are seldom assigned the responsibility of analyzing the cause of a gas turbine engine failure, but it is not uncommon for them to be involved in the investigation of a premature gas turbine engine malfunction or failure.

As a participant in the tear-down inspection of the engine and review of the findings, the technician must understand the modes of metallic component failures and how each can be identified during the investigation.

The purpose of investigating a gas turbine engine failure is to identify a definitive cause of the failure to provide knowledge of how such failures can be avoided in the future. Knowing the features of cracks and fractures in materials used in gas turbine engines is important in associating them with failures.

Table 1 (page 2) lists the most likely initiating failure mechanisms for the major components of gas turbine engines. The list is derived from engine case histories and an understanding of the design and function of each component. The mechanisms in boldface represent the most common failures.

Cracks and fractures in gas turbine engine parts, both rotating and

Table 1
Failure Mechanisms of Gas Turbine Components

Section	Components	Problem
Compressors	Disks	High-cycle fatigue Low-cycle fatigue
	Blades	High-frequency fatigue because of resonant vibration High-frequency fatigue because of flutter **Clashing and clanging because of surge***
	Stator vanes	**Clashing because of surge** High-frequency fatigue because of resonant vibration or flutter
Combustors	Liner	**Thermal fatigue** Overheating
Turbines	Disks	Low-cycle fatigue, possibly aggravated by thermal gradients Fracture because of embrittlement
	Blades	High-frequency fatigue because of resonant vibration **Creep-rupture**
	Nozzle vanes	**Thermal fatigue** Overheating

*Problems in boldface represent the most common failures.

Source: Robert E. Dundas

stationary, occur as a result of four mechanisms:

- Short-term loading;
- Fatigue;
- Creep; and,
- Embrittlement.

In nearly all cases of short-term loading, cracks progress almost instantly to complete fracture.

Fatigue, creep and embrittlement are time-dependent phenomena, so cracks sometimes become evident before complete fractures occur.

Almost all materials of importance in gas turbine engine failure investigations are ductile, which means that the materials can be stretched, drawn or hammer-forged without breaking. Nickel-based alloys used in turbine blades have very low ductility at room temperature, but the alloys become more ductile at their operating temperatures.

The features of cracks and of fracture surfaces provide indications about which mechanism produced the crack or fracture. These can be studied by fractography (macroscopic or microscopic) and metallography.

Fractography is the examination of fracture surfaces by macroscopic (use of the naked eye or up to 10x magnification) or microscopic means. Microscopic examination can be up to 60x magnification. Scanning electron microscopy (SEM) also permits magnifications of 5,000x or greater.

Metallography is the study of the structures and physical properties of metals and alloys.

Short-time fracture occurs when a component is overloaded, as in a tensile-testing machine. The only way this can occur in a gas turbine engine is by rotor overspeed, and a rotating disk is usually the part with the least margin in overspeed limitations. Overspeed damage is usually easily identified without metallography analysis.

Ductile material fractures as a result of shearing flow of the material at an angle approximately 45 degrees to the applied stress. This creates the characteristic appearance of the fracture surface, typified by a lip at the edge, formed by shearing forces as the two parts of the component separate. The face of the fracture surface tends to be rough and angular because of the shearing flow. Ductile fractures are usually transgranular, in contrast with brittle fractures, which are usually intergranular.

Fractured Blades Become Missiles

When a rotating blade fractures in a gas turbine engine, it becomes a high-energy missile that can do extensive impact damage to other blades in the same stage and downstream stages of the engine. If a gas turbine failure involves the fractures of many blades, it is necessary to determine which blade failed first. Sometimes this is obvious (as in the case of high-cycle fatigue), but it is usually less obvious (as in the case of creep rupture). Thus, it is important to recognize the characteristics of a short-term impact fracture.

Impact fracture of a rotating blade involves a combination of bending and transverse shear. In the bending mode, the fibers on the side of impact are in tension, and the tension field quickly moves across the blade as the fracture progresses to completion. The macroscopic fracture surface is rough and angular, but there may be a distinct pattern of ridges roughly parallel to the direction of fracture progression.

Figure 1 shows the features of an impact fracture involving a thin section. This is typical of the impact fracture of a thin compressor blade or of a thin-walled turbine vane or blade.

Fatigue failures might be or might not be life-related. One category includes high-frequency fatigue that is caused by blade, stationary vane and disk vibration. This is usually resonant vibration, but, increasingly, there are examples of self-excited vibration (flutter). This type of failure can occur very early in the life of a gas turbine engine.

Another category includes low-cycle fatigue, thermal fatigue and corrosion fatigue. This type of failure occurs only after the gas turbine engine has been in service for a long period.

The stress/cycle curve in Figure 2 (page 5) shows in broad terms the cycle regimes of the various types of fatigue.

The regime of low-cycle fatigue and thermal fatigue extends up to 10,000 cycles of operation. A cycle includes startup, followed by operation and shutdown. The upper end of this range may never be realized, although aircraft engines are typically designed for fatigue-free periods of 20,000 cycles or more.

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Figure 1. Matching surfaces of a thin plate of medium-carbon alloy steel, fractured by impact. Origin is at top of upper face and at bottom of lower face.[1]

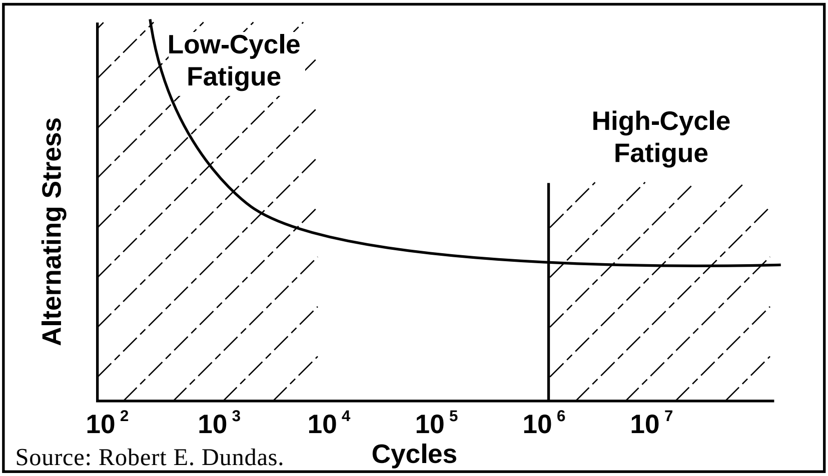

Figure 2. Stress/cycle (S/N) curve shows in broad terms the cycle regimes of various types of fatigue.

The high-cycle or high-frequency fatigue regime is where the S/N (stress against number of alternating load cycles to failure) curve is a horizontal line marking the fatigue strength or endurance limit. For most materials used in gas turbine engines the S/N curve "runs out," and the fatigue life should be indefinite.

The curve in Figure 2 represents the number of cycles at which the first discernible (by usual nondestructive testing) fatigue crack appears on the surface. This is generally considered to be a crack 0.03-0.06 inches (0.76-1.52 millimeters) long, which is no larger than a material flaw that can be reliably detected by nondestructive testing. Thus, a new part that has passed inspection for flaws can actually contain minute flaws. If the part is then subjected to alternating stress until failure, the crack might then be initiated at one of these minute flaws. The cause of the failure is often incorrectly attributed to the flaw, when the actual cause might be resonant vibration, flutter, shaft misalignment or an excessive number of operating cycles.

The high-cycle regime is usually considered to start at 10^6 cycles. This regime involves stresses that are usually just above the fatigue strength after stress concentrations are included. Such stress ranges are usually not experienced unless the component suffers damage that would increase the stress concentration at the point of maximum stress, or the fatigue strength is reduced by corrosion.

If the misalignment of a gas turbine engine's bearings is sufficient to produce alternating stresses in the shaft above the fatigue strength, the shaft will eventually fail in high-cycle fatigue. Cycles of alternating stress build at the rate of one per revolution. Thus, 10^7 cycles could be developed in approximately 50 hours and, after initiation of a fatigue crack, final fracture could occur in a few hours.

High-frequency fatigue falls into the category of high-cycle fatigue. However, the process of failure in high-frequency fatigue is brief, after the excessive alternating vibratory stresses are established. For example, the initial crack can appear in 14 hours at a vibratory frequency of 200 Hz (hertz), a typically low value, with final fracture occurring no more than a few hours later.

Figure 3 shows the surfaces of a turbine blade that fractured in high-frequency fatigue. The crack progressed in an elliptical pattern from an origin on the blade surface until it covered 40 percent or more of the blade cross section. The crack surface is smooth, while the short-term final fracture surface is rough and characteristic of a ductile material. The crack surface contains distinctive lines or patterns concentric with the origin. These lines, known as beachmarks, are associated with progression of the crack at different rates and stress levels as it extends through the blade cross section.

In all investigations of turbine blade failure, microscopic examination of 5,000x or greater helps identify striations whenever the crack surface is smooth and does not extend over the entire fractured section, even if beachmarks are not clearly evident at lesser magnification. SEM or transmission electron microscopy (TEM) can be used for this

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Figure 3. High-cycle fatigue fracture of a turbine blade, showing typical beachmarks.[2]

examination. SEM is used when a small sample of the crack surface can be cut away from the failed part, and TEM involves replication of the crack surface and microscopic examination of the replica. Magnifications to 10,000x can be obtained with either of these techniques.

Microscopic examination of a surface cracked by fatigue almost always reveals the phenomenon of fatigue striations. These are closely spaced parallel lines indicating the cyclic progression of a high-cycle fatigue crack in a direction normal to them. Figure 4 shows striations in a material used in gas turbine engines. Magnifications of 5,000x or greater should be used in the examination of cracked surfaces if high-cycle fatigue is suspected.

Care is required in the identification of high-cycle fatigue striations. There are a number of microscopic features with which they can be confused. Fatigue striations characteristically never cross each other, as can be seen in Figure 4.

Low-cycle fatigue is a characteristic failure mode of components in which normal operating centrifugal stresses are close to the yield strength of the material and may be higher than the yield strength when stress concentrations are included. A minute (and undetectable) flaw in some highly stressed surface on the gas turbine engine's compressor disk grows into a distinct crack. Further crack growth then leads to a critical crack size, with subsequent unstable growth to complete rupture. The crack grows an infinitesimal, but increasing, amount per cycle of operation. Each cycle involves stressing of the disk to a maximum at operating speed, followed by a deceleration to rest.

Low-cycle fatigue failure caused by centrifugal stresses alone is rare in aircraft gas turbine engines. Nevertheless, thermal fatigue, in which the centrifugal stresses are accompanied by thermal strains caused by thermal gradients from bore to rim of the disk during startups and shutdowns, is a significant hazard to

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Figure 4. High-cycle fatigue striations in INCO 718 nickel-based alloy material.[2]

turbine disks. It occurs when the total strain (centrifugal and thermal) includes a substantial plastic component, and involves cycles of straining throughout the complete operating range of the machine.

Low-cycle fatigue striations tend to be broader than high-cycle fatigue striations, and tend to be discontinuous, terminating in a distinctive lap (Figure 5).

A purer form of thermal fatigue occurs in turbine stationary nozzle vanes. The vanes, especially in the first stage, are exposed to the hottest temperatures in the gas turbine engine at maximum power. The vanes are usually cooled to extend the thermal fatigue life of the nozzle vanes as long as possible or economical. The mechanical stresses involved are low, and crack development is almost entirely caused by the thermal gradients developed throughout the parts because of the constraints the various sections of the vane structure impose on each other. Thermal cracks in these vanes often develop after relatively few cycles of operation.

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Figure 5. Typical low-cycle fatigue fracture surface, shown at 2,000x magnification.[2]

After a crack begins, it tends to relieve the thermal strains that produced it, and crack growth is slowed rather than accelerated during subsequent cycles. Some cracking, therefore, can be tolerated, subject to cyclic limits developed by experience, as long as the cooling flow in the nozzle vane is not disrupted. Continued cycling can lead to breakup of the nozzle vanes with extensive downstream damage. If a fuel nozzle deteriorates by being blocked, or if the combustor suffers serious damage, severe hot spots (more severe than those anticipated in design) can develop in the flowpath at the nozzles. Continued cycling will cause breakup of the nozzles.

Combustor cracking is also often caused by this form of thermal fatigue. Thermal cracks develop after a relatively small number of cycles of operation with severe hot spots because of nonuniform combustion. The combustor cooling flow is badly disrupted as the cracks open, and the cracks can progress to complete disintegration of the combustor.

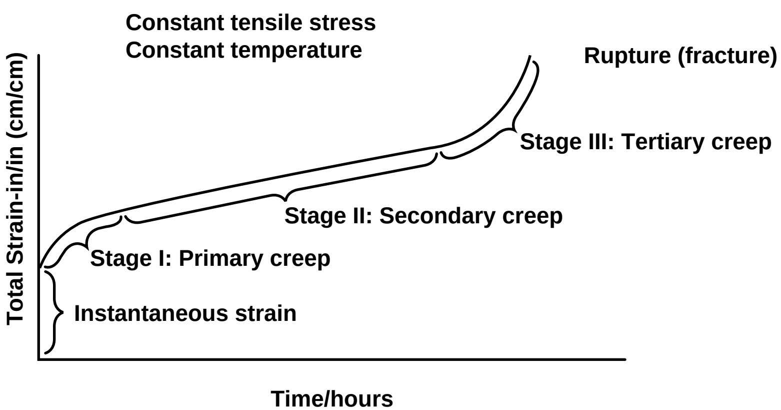
The crack surfaces of parts that have failed in low-cycle or thermal fatigue are not easily distinguishable from those that have failed in high-cycle fatigue. Because disks can, and do, fail in high-frequency fatigue, detailed microscopic examination of the fracture surface should be undertaken whenever fatigue is suspected.

The phenomenon of creep occurs in a component subject to stress and high temperature over time. The curve in Figure 6 shows strain of a material at constant stress and temperature; it is characterized by creep rate and time to rupture. Failure is taken as the initiation of tertiary creep, after which the component stretches unstably to rupture. The rupture life is the number of hours at which the rupture occurs.

Turbine blades are the most likely gas turbine engine components to fail in stress rupture. Blades can be designed for creep lives of 60,000 hours, but extrapolation of laboratory creep data to such long lives is uncertain, and premature failures have occurred. If the blade cooling air is interrupted, failure may occur in a very short time.

When a ductile material undergoes creep under stress at elevated temperature, voids develop in the grain boundaries as the grains move relative to one another. Thus, stress rupture fractures in ductile materials are intergranular and are characterized by the intergranular voids (Figure 7, page 10).

Surge occurs when a gas turbine engine compressor is no longer able to compress the incoming air to exceed the pressure in the combustion section. The air flow suddenly reverses and large dynamic loads are



Source: Robert E. Dundas.

Figure 6. Creep vs. time for a material under constant stress and temperature.

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Figure 7. Intergranular fracture in a nickel-based alloy (Waspaloy) because of stress rupture.[2]

generated on the pressure sides of the blading. The blades deflect forward, generally in groups. Two types of damage may result from a severe surge:

- Clashing occurs when the blade deflection is great enough to impact the trailing edges of a previous row of stator vanes. The blades leave a triangular impact footprint on the vanes near the outer flowpath wall. The vanes are sometimes torn or broken off completely by the impact.

- Clanging occurs when groups of blades deflect in a wave pattern. The blades do not all deflect the same amount, and the trailing edge tip edges impact the leading edges of the adjacent blades on the pressure sides (Figure 8). Clanging is not usually catastrophic because complete blades are usually not broken off. The tip corners of the blades are, however, likely to be bent, torn or broken off.

Surge damage includes much impact damage, and is often confused with foreign object ingestion damage. Nevertheless, the impact during surge has a distinctive pattern, and unless a foreign object or loose part can be readily identified, caution should be exercised in dismissing the possibility of surge. The operating condition at which the failure occurred is of fundamental significance. Surge is most likely to occur at low-power settings and particularly if gas turbine efficiency has deteriorated. Surge also occurs during startup, often involving malfunction of the compressor bleed-valve system.

Many failures in gas turbines involve radial rubbing between rotating components and stationary blade rings. Understanding these patterns is very important in failure investigations. The

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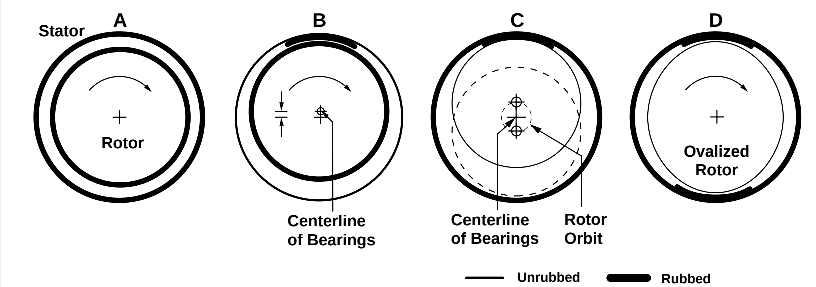
Figure 8. Typical clanging damage pattern.[3]



Source: Robert E. Dundas.

Figure 9. Usual rubbing patterns associated with turbine engine failures.

most common combinations of rubs on the rotor and stator shown in Figure 9 are the following:

- A 360-degree rub on both rotor and stator. The rotor and stator have bound radially at some time during operation, probably during startup or shutdown. There is insufficient radial clearance between rotor and stator;
- A 360-degree rub on rotor, local rub on stator. The stator is misaligned (offset) relative to the rotor bearings;
- A 360-degree rub on stator, local rub on the rotor. This is caused by excessive rotor whirl; and,
- A 360-degree rub on stator, local rub at two diametrically opposite locations on the rotor. The rotor has become ovalized by creep.

A technician who understands the causes behind metallic component failure will be important during an investigation to determine the cause of a gas turbine engine failure.

References

1. American Society for Metals. *Fractography*. Volume 12 of *ASM Metals Handbook*. 9th ed. American Society for Metals: 1987.
2. American Society for Metals. *Fractography and Atlas of Fractographs*. Volume 9 of *ASM Metals Handbook*. 8th ed. American Society for Metals: 1974.
3. Walker, John L. "U.S. Naval Marine Gas Turbine Maintenance." In *Gas Turbines/ Turbocompressors*. Volume 1 of *Sawyer's Turbomachinery Maintenance Handbook*. Turbomachinery International Publications: Norwalk, Connecticut, U.S., 1980.

Search Identifies Aviation Mechanic Pioneers

A few months ago, the *Aviation Mechanic's Bulletin* began a search to identify the first A&P mechanic licensed by the United States. With assistance from the U.S. Federal Aviation Administration (FAA) and the Professional Aviation Maintenance Association (PAMA), it was determined that Frank G. Gardner of Norfolk, Virginia, U.S., was issued the first aviation mechanic's license on July 1, 1927.

Gardner was following closely behind other aviation pioneers.

A 1948 *Collier's Weekly* magazine article relates the experiences of Charley Taylor, a skilled machinist.

In 1902 the Wright brothers returned from Kitty Hawk, North Carolina, U.S., after spending the summer perfecting their gliders. They were now determined to build a powered aircraft, but could not find an engine to meet their requirements. They went to Taylor.

The Wrights were busy designing and building the airframe, so they engaged Taylor to build an engine that would produce 12 horsepower and "wouldn't weigh too much." Taylor's shop consisted of only a drill press and a lathe, both powered by belts driven by a stationary gasoline engine.

Taylor said, "We didn't make any drawings. One of us would sketch out the part we were talking about on a piece of scratch paper, and I'd spike it over my bench." The crankshaft was made from a block of machine steel 6 by 31 inches (12 by 79 centimeters) and a little more than 1.5 inches (3.8 centimeters) thick. He traced the outline on this slab of metal, drilled the basic outline with a series of holes and knocked away the waste. The resulting blank was then chucked in his lathe and turned down to size. It weighed 19 pounds (8.6 kilograms) in its finished form and was perfectly balanced.

The completed engine weighed 180 pounds (81.6 kilograms) and developed 12 horsepower at 1,025 rpm. The entire engine was built in just six weeks.

The engine was block tested using a resistance fan with blades 1.5

inches wide and 5 feet 2 inches (157 centimeters) long. It was then shipped to Kitty Hawk, where it was mounted on the aircraft for its historic flight.

ASNT Publishes New Visual Inspection Handbook

The American Society for Nondestructive Testing (ASNT) has released volume eight of the second edition of the nondestructive testing series *Visual and Optical Testing.* It is an extensively indexed, 380-page book with more than 400 illustrations devoted to the fundamentals and techniques of inspection by means of visible light.

Subjects covered in detail include the physiology of vision, vision acuity, the physics of light, visual inspection procedures and standards, borescopes, image processing, machine vision, remote viewing and robotics.

The book is available from ASNT and costs US$121.25 for non-ASNT members and $97.25 for ASNT members. For more information, contact: ASNT's Book Department, 1711 Arlingate Lane, Columbus, OH 43228-0518, Telephone (614) 274-6003 or fax (614) 274-6899.

This information is intended to provide an awareness of safety problems so that they may be prevented in the future. Maintenance alerts are based on preliminary information from government agencies, aviation organizations, press information and other sources. The information may not be entirely accurate.

Additional Factor Cited as Possible Cause of Cessna 402C Crash

A Cessna 402C crashed shortly after takeoff in the vicinity of the Grand Canyon in Arizona, U.S., in June 1992. The aircraft was returning from a sightseeing flight over the canyon and carried nine passengers in addition to the pilot. Everyone on board was killed, and the airplane was destroyed by impact forces. Initial evidence indicated a problem with wear on the wing fuel tank inlet valve piston shafts. This condition was reported in the May/June 1993 issue of *Aviation Mechanics Bulletin.*

The U.S. National Transportation Safety Board (NTSB) later became aware of another possible factor in this fuel starvation accident. The engine manufacturer issued a service bulletin calling for the installation of a new type of engine-driven fuel pump drive shaft. The new shaft is somewhat longer (0.12 inches [.30 centimeters]) and is designed to provide additional engagement of the shaft with its driving recess.

The NTSB recovered the accident airplane's drive shaft and found evidence that it was "rounded off" or stripped to the extent that just one-thousandth of an inch (.002 centimeters) more wear would have completely disengaged the drive shaft. In fact, there were circumferential marks indicating that the shaft had disengaged to some extent in the past.

As a result of these findings, the NTSB issued a safety recommendation to the U.S. Federal Aviation Administration (FAA) calling for the issuance of an emergency Airworthiness Directive to require operators of affected engines to comply with the manufacturer's Service Bulletin #M93-9 Revision 1 within 30 flight hours.

This problem affects approximately 12,454 units of various Teledyne Continental motors such as the IO 520, the IO 550, the TSIO 520 and the TSIO 550. Technicians involved in the maintenance and inspection of aircraft using any of these engines should be alert for this problem while conducting their inspections.

Excessive Free Play in Aileron Tab Blamed in Fatal Twin Commander 690 Accidents

In the past year, Twin Commander 690 series turboprop aircraft have been involved in three accidents, two of which resulted in fatalities.

In August 1993, a 690A sustained an inflight loss of lateral control at about 16,500 feet (5,032 meters) during a descent with the autopilot off. The pilot experienced a sudden uncommanded roll to the right that continued through a full 360 degrees before he could recover. The pilot made a successful landing, although he reported that full-up elevator was required to maintain control during the descent and approach.

A U.S. National Transportation Safety Board (NTSB) investigation determined that approximately five feet (1.5 meters) of the outboard section of the right horizontal stabilizer and elevator had failed and folded upward, although it remained attached to the airplane. Small compression buckles were also noted on the lower left side of the vertical stabilizer. In addition, the push-pull rod attachment brackets on both the left and right elevator torque tube assemblies showed evidence of having impacted adjacent structure as a result of gross overtravel of the elevators. Both left and right aileron inboard hinges, particularly the right inboard hinge showed evidence of contact with aileron cove structure, indicating aileron overtravel.

A rigging check of the airplane disclosed that the electrically actuated trim tab on the left aileron had a free play of 0.230 inches (0.584 centimeters). The manufacturer's manual specifies a maximum allowable free play of 0.125 inches (0.317 centimeters). Right and left maximum aileron control travel limits were also found to be incorrect. There was no other evidence of airframe flutter or nodal vibration signatures.

The Twin Commander 690 aircraft typically descends at close to the maximum certificated operating airspeed, making any encounter with turbulent air particularly severe. The NTSB concluded that excessive free play in the aileron trim tab and/or improper aileron primary and balance cable tensions may result in gross aerodynamic overbalance at high speeds and loss of lateral control. The Frise type ailerons installed on these aircraft are susceptible to overbalance as they are deflected, destroying the normal static relation of the two ailerons.

In addition to the possible effect on Frise aileron synchronization and aerodynamic balance, aileron rigging and trim tab free play limitations must also be maintained in order to avoid aileron/wing flutter at high speeds or in turbulence.

The aileron deflections that could result might exceed the maximum wheel force that the pilot could exert. As a result of these findings, the NTSB has recommended that the U.S. Federal Aviation Administration (FAA) issue an Airworthiness Directive requiring a check of the Twin Commander 690's aileron control system rigging and adjustments, in which particular attention is given to maintaining the tab free play within the specified limits.

The NTSB also recommended that the FAA conduct a design review of the Frise aileron control systems as installed on 690-series airplanes to determine the adequacy of lateral control under all anticipated conditions.

Technicians involved with the inspection and maintenance of Twin Commander 690-series aircraft should ensure that they are familiar with the rigging, adjustment and maintenance of aileron control systems for the aircraft.

NTSB Warns Some Fire-blocking Materials May Be Defective

While investigating an inadvertent slat actuation incident on a McDonnell Douglas MD-11 aircraft, the U.S. National Transportation Safety Board (NTSB) determined that fire-blocking material under the dress covers of passenger seat cushions had deteriorated to the extent that the material no longer provided fire protection.

Samples of this fire-blocking material from the incident airplane, a sample of the same material installed in an ATR-42 commuter aircraft, and a new sample supplied by the manufacturer failed to meet the standards set in U.S. Federal Aviation Regulations (FAR) 25.853, the NTSB said.

It was also found that the material degraded under both normal and simulated wear-and-tear conditions equal to two years in service.

As a result of the findings, the NTSB recommended that any aircraft using Testori-manufactured fire-blocking material be retrofitted with new material that meets the fire-retardant requirements of FAR 25.853. The NTSB identified the defective material as Testori 0200-316 and 0206-100.

Inadequate Maintenance Manual Cited as Factor in Landing Gear Failure

A Fokker F-28-MK-0100 operated by a U.S. air carrier experienced a landing gear collapse during landing in May 1993. Subsequent investigation disclosed that the left main gear strut had failed in the area of the upper torque link attach point.

Fokker had previously installed shimmy dampers to provide torsional/lateral stability to the landing gears during the landing roll. Post-incident examination of this aircraft found that spacers on the upper and lower torque link attach points had been reversed during assembly resulting in inadequate damping capability of the assembly. The two spacers are similar, but one is 1.6 inches (41.9 millimeters) long while the other is 1.3 inches (33.3 millimeters) long. With the two spacers switched, the total damping capability is reduced to about 20 percent of the intended capacity.

Discussions with the aircraft's technician and a review of maintenance and illustrated parts manuals detailing this installation confirmed that the manual information was inadequate. Although the spacer installation is depicted in the maintenance manual, it was not specific about the dimensions of the two spacers.

As a result of these findings, the U.S. National Transportation Safety Board (NTSB) recommended that the U.S. Federal Aviation Administration (FAA) issue an alert to affected operators and suggested that the manufacturer revise maintenance manuals to include an improved description and illustration of the correct installation of these critical spacers. The NTSB also suggested that the manufacturer consider redesigning the landing gear shimmy damper spacer assembly to prevent the possibility of inadvertently interchanging these parts.

FAA Warns of Potential Fuel Dye Hazard

The U.S. Federal Aviation Administration (FAA) has issued a safety alert following a recent decision by the U.S. Environmental Protection Agency and U.S. Internal Revenue Service requiring that certain diesel and kerosene fuels be dyed in colors ranging from yellow to dark red. These colors also include the red, blue and green dyes used to identify aviation fuels. Officials say there is a danger that nonaviation fuels could end up in aircraft fuel tanks because of the mandate.

"I consider this potential hazard to be critical to aviation safety," said Charles Huettner, acting FAA associate administrator for aviation safety.

The FAA alert said: "Aviation fuels are similarly dyed red (80/87), blue (100LL) and green (100/130) to assist in identifying one from another. As a result, the potential for a significant safety hazard exists.

"Pilots, fixed-base operators (FBOs), fuel vendors, air carriers and others engaged in aviation activities should be especially alert to ensure that aircraft receive the appropriate fuel when serviced."

Environmentally Safe Contact Cleaner Available

As a result of the international ban on freon-based chemical products, new products are being developed with alternative contents. CRC Industries recently introduced a contact cleaner that is alcohol-based and free of chlorinated solvents and ozone-depleting substances.

QD Contact Cleaner

CRC claims that its QD Contact Cleaner has outstanding cleaning power and effectively removes contaminants from electrical components and contacts. It evaporates rapidly, leaves no residue, and is harmless to most sensitive plastics, according to the manufacturer.

For more information, contact: CRC Industries, Inc., 885 Louis Drive, Warminster, PA 18974, U.S. Telephone (215) 674-4300.

Hangar Floor Coating Offers Slip Resistance

Crossfield Products Corp. has developed a urethane hangar floor coating product that is available with five different slip-resistant profiles.

The manufacturer claims that the Dex-O-Tex hangar flooring system has excellent wear and abrasion resistance, resists Skydrol and other chemicals encountered in aircraft maintenance activities and can be applied to a wide range of prepared surfaces.

The Dex-O-Tex Aero-Flor reflects light and is offered in 12 standard colors, in addition to clear and white. Selection of the slip-resistant profile to be used will depend on the degree of slip resistance and the cleaning characteristics desired. The coating is normally applied after the floor is shotblasted, acid etched or mechanically scarified to ensure proper bonding. Application is by squeegee/roller and involves a two-coat process.

For more information, contact: Dex-O-Tex Division, Crossfield Products Corp., 3000 E. Harcourt Street, Compton, CA 90221, U.S. Telephone (213) 636-0561.

Silicone Sealants in Pressurized Cans Stay Usable Longer

Permatex Industrial Corp. has introduced a line of silicone sealants packaged in pressurized dispenser cans. This packaging/dispenser unit is said to keep the product fresh with a self-sealing plug that is easy to remove.

The manufacturer claims that the various silicone sealants can be applied by simply pressing one finger against the nozzle, thus allowing one-hand application in difficult locations. The packaging is also intended to eliminate waste and allow a consistent, uniform bead of sealant to be applied.

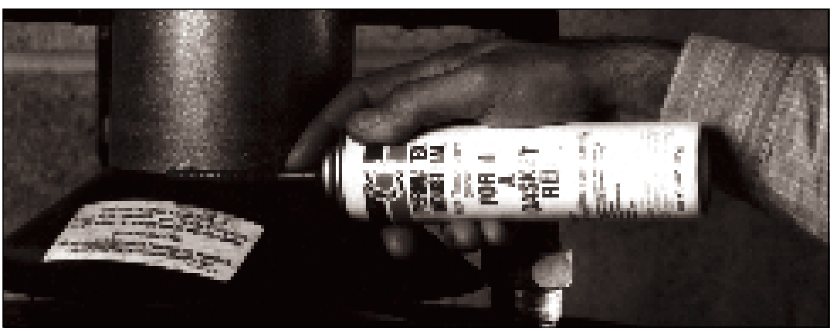
The sealants are available in several colors, each with specific applications and benefits:

- Blue — Best for fast gasketing in place. Fills gaps and forms flexible, leak-proof seals on industrial equipment.

- Clear and Black — Best for waterproofing and bonding. Moisture-proof, ozone-resistant and authorized for applications in galleys, etc.

- Red — Best for sealing heating elements and high-temperature ductwork. Resists intermittent temperatures from 600 degrees F (315 degrees C) to 650 degrees F (343 degrees C).

For more information, contact: Permatex Industrial Corp., 705 North Mountain Road, Newington, CT 06111, U.S.



Silicone Sealant