Japanese Aerospace Literature This month: *Fatigue Tests*

A95-45392 Mechanical properties of a titanium matrix composite SiC(CVD)/Beta21S at elevated temperature. H. NAKATANI, M. IMUTA, H. NAKAYAMA (Kawasaki Heavy Industries, Ltd., Kakamigahara, Japan), and N. OHNO (Nagoya Univ., Japan), *Materials Challenge Diversification and the Future; Proceedings of the 40th International SAMPE Symposium and Exhibition*, Anaheim, CA, 1995. Book 2 (A95-45236 12-23), Covina, CA, Society for the Advancement of Material and Process Engineering (Science of Advanced Materials and Process Engineering, Vol. 40), 1995, pp. 1934–1943. 11 Refs. Documents available from Aeroplus Dispatch.

A unidirectional metal matrix composites consisting of Beta21S, a new metastable beta titanium alloy, and SCS-6, continuous SiC(CVD) fibers, was consolidated by vacuum hot pressing. Isothermal fatigue and creep rupture tests of the SCS-6/Beta215 composite were performed to investigate its mechanical properties at elevated temperature. For the SCS-6/Beta215 composite, the fatigue life diagram displayed abrupt decreases in the maximum stress in the high cycle region over 104 cycles, because the fatigue cracks propagated easily across the fibers through the tight fiber-matrix interface. The endurance limit was observed to be about 0.2% strain. This composite exhibited an outstanding creep strength under 823 K. In addition, the creep life of this composite was longer than that of other TMCs owing to high creep and oxidation resistance in the matrix. (Author)

A95-45338 Influence of stress ratio on fatigue behavior in the transverse direction of unidirectional CFRP. M. K. McMURRAY, M. NAKADA, and Y. MIYANO, (Kanazawa Inst. of Technology, Japan), *Materials Challenge Diversification and the Future; Proceedings of the 40th International SAMPE Symposium and Exhibition*, Anaheim, CA, 1995. Book 2 (A95-45236 12-23), Covina, CA, Society for the Advancement of Material and Process Engineering (Science of Advanced Materials and Process Engineering, Vol. 40), 1995, pp. 1316–1329. 12 Refs. Documents available from Aeroplus Dispatch.

The influence of stress ratio on flexural fatigue behavior was investigated at several frequencies and temperatures in the transverse direction of two unidirectional CFRPs consisting of a single type of carbon fiber with two types of matrix resins, one a general type and one high glass-transition temperature type matrix resin. Three point bending fatigue tests were performed at various constant temperatures and two frequencies under various stress ratios which is defined as the minimum stress/maximum stress. Near room temperature and well below the glass-transition temperature the flexural fatigue strength decreases as stress ratio decreases from 1 to 0.05. This shows the flexural fatigue strength is dependent on stress amplitude, so the fatigue strength is controlled mainly by fatigue damage. At a temperature in the vicinity of the glass-transition temperature, the flexural fatigue strength increases as stress ratio decreases from 1 to 0.05. This shows the flexural fatigue strength is dependent on mean stress, so the fatigue strength is controlled mainly by creep damage. (Author)

A95-42798 Fatigue characterization of fiber/metal laminates. Y. TOI and Y. FUJIWARA (Fuji Heavy Industries, Ltd., Utsunomiya, Japan), *AIAA, 1st Aircraft Engineering, Technology, and Operations Congress*, Los Angeles, CA, 1995, p. 7. 2 Refs. Documents available from Aeroplus Dispatch.

An overview is conducted of the potential contribution of the 'Glare' family of ARALL-like matal/reinforced-polymer laminates to the maximization of fatigue life in next-generation SST pressurized cabins. This interest in long-fatigue-life materials is prompted by the great damger posed by decompression at the stratospheric altitudes typical of SST flight. Attention is given to the results of crack-propagation tests and an empirical crack-growth model.

A95-42797 Development and test results of full CF/PEEK (APC-2) horizontal stabilizer models—Basis for SST structure. T. ISHIKAWA, Y. HAYASHI, S. SUGIMOTO, M. MATSUSHIMA (National Aerospace Lab., Tokyo, Japan), and K. AMAOKA (Fuji Heavy Industries, Ltd., Tochigi, Japan), *AIAA, 1st Aircraft Engineering, Technology, and Operations Congress*, Los Angeles, CA, 1995, p. 10. 10 Refs. Documents available from Aeroplus Dispatch.

Two test specimens have been developed and tested to evaluate carbon fiber-reinforced thermoplastic (PEEK) matrix composite horizontal stabilizer structures applicable to a next-generration SST. Impact damage assessments and simulated flight fatigue load tests have been conducted. A potential weight reduction of 35% is anticipated for structures of this type, relative to baseline metallic structures representative of current practice.

A95-40220 Fatigue damage initiation and growth in notched FRP plates. H. HYAKUTAKE, T. YAMAMOTO (Fukuoka Univ., Japan), and H. NISITANI (Kyushu Univ., Fukuoka, Japan), *1st Asian-Pacific Conference on Aerospace Technology and Science*, Hangzhou, China, 1994, Proceedings (A95-40201 11-31), Beijing, International Academic Publishers, 1994, pp. 170–175. 13 Refs. Documents available from Aeroplus Dispatch.

On the basis of the concept of linear notch mechanics, we derived a fatigue failure criterion for predicting the fatigue life of notched FRP plates. The criterion was subjected to further experimental scrutinization. An experimental program is presented which examines the effect of notch-root radius on the fatigue failure of notched FRP plates. This is accomplished by obtaining experimental data on the notched specimens of two kinds of FRP plates in pulsating tension. The process of initiation and growth of fatigue damage near the notch root was measured by means of the luminance-measuring system with a CCD camera. The experiment shows that the number of cycles to the fatigue damage initiation was governed predominantly by both the notch-root radius and the maximum elastic stress at the notch root. Applying the fatigue failure criterion derived here, the experimental results can be clearly elucidated. (Author)

A95-40217 Influence of oil environment on the fatigue strength of aluminum alloys. N. KAWAGOISHI, X. WANG, H. TANAKA (Kagoshima Univ., Japan), H. NISITANI (Kyushu Univ., Fukuoka, Japan), and T. TOYOHIRO (Miyakonojo National College of Technology, Japan), *1st Asian-Pacific Conference on Aerospace Technology and Science*, Hangzhou, China, 1994, Proceedings (A95-40201 11-31), Beijing, International Academic Publishers, 1994, pp. 144–149. 5 Refs. Documents available from Aeroplus Dispatch.

To investigate the influence of the oil environment on the fatigue strength, rotating bending fatigue tests were carried out on specimens of an extruded aluminum alloy and a drawn one in air and in oil. The fatigue lives in the drawn aluminum alloy increase by the existence of oil under all of the stress levels. On the other hand, in the extruded aluminum alloy, the fatigue lives in oil and in air are nearly equal to each other under a high nominal stress, though the fatigue lives in oil increase when the stress level is low. Moreover, SN curves in the extruded aluminum alloy exhibit the shape of the double stages in both environments. These results are discussed on the basis of the change in the crack propagation mechanism and the mechanical effect of oil. (Author)

A95-40210 Statistical characteristics of fatigue behavior of a 6061-T6 aluminum alloy. M. GOTO, H. MIYAGAWA (Oita Univ., Japan), H. NISITANI, Y. ODA (Kyushu Univ., Fukuoka, Japan), and N. KAWAGOISHI (Kagoshima Univ., Japan), *1st Asian-Pacific Conference on Aerospace Technology and Science*, Hangzhou, China, 1994, Proceedings (A95-40201 11-31), Beijing, International Academic Publishers, 1994, pp. 78–83. 4 Refs. Documents available from Aeroplus Dispatch.

Using the age-hardened Al alloy 6061-T6, rotating bending fatigue tests of plain specimens were carried out under constant stress amplitude. The successive observations of the specimen surface were made by the plastic replica method. The crack initiation and propagation processes were studied, and then the statistical characteristics of crack growth lives were analyzed by assuming the Weibull distribution. Furthermore, the length distribution of all the cracks longer than 10 μ and initiated within a specific region whose area is 20 sq mm were examined. (Author)

A95-35436 An accelerated testing method of ZrO_2-based FGM coating for gas turbine blades. C. Y. JIAN, T. HASHIDA, H. TAKAHASHI (Tohoku Univ., Sendai, Japan), N. SHIMODA (Nippon Steel Corp., Chiba, Japan), and M. SAITO (Miyagi Prefectural Inst. of Technology, Japan), *FGM 94; Proceedings of the 3rd International Symposium on Structural and Functional Gradient Materials*, Swiss Federal Inst. of Technology, Lausanne, Switzerland, 1994 (A95-35401 09-23), Lausanne, Switzerland, Presses Polytechniques et Universitaires Romandes, 1995, pp. 419–424. 3 Refs. Documents available from Aeroplus Dispatch.

This paper presents the results of thermal shock and fatigue tests conducted on ZrO_2 thermal barrier coating systems under the simulated temperature environments of gas turbine blades. Cylindrical specimens of a conventional two-layer coating and a functionally gradient material (FGM) coating were tested. Acoustic emission (AE) monitoring was conducted to detect the fracture process of the coating systems. To determine an appropriate thermal load for an accelerated testing method, four different heating/cooling thermal cycles were used for the thermal shock and fatigue tests. The results of the temperature and AE measurements were used to determine the delamination growth during the fatigue tests, and the growth rate was used to evaluate the effects of heating rate and cooling rate on the fracture of the coating. Finally, a suitable thermal cycle for accelerated testing was determined. (Author)

A95-31353 Fracture behavior of silicon nitride at elevated temperatures. M. MATSUI and M. MASUDA (NGK Insulators, Ltd., Nagoya, Japan), *Tailoring of Mechanical Properties of Si_3N_4 ceramics; Proceedings of the NATO Advanced Research Workshop on Tailoring of High Temperature Properties of Si_3N_4 Ceramics*, Munich, Germany, 1993 (A95-31326 08-27), Dordrecht, Netherlands, Kluwer Academic Publishers (NATO ASI Series, Vol. E 276), 1994, pp. 403–414. 11 Refs. Documents available from Aeroplus Dispatch.

Static and cyclic fatigue tests were carried out under tensile stress to clarify slow crack growth behavior and creep behavior for silicon nitride at elevated temperatures. The static fatigue mechanism was classified into slow crack growth of preexisting flaws or creep deformation, depending on the temperature and the applied stress. In the slow crack growth realm, the strength degradation was controlled by the power law for crack growth rate. In the creep deformation realm, the modified Larson–Miller parameter was applicable to the life prediction under static stress. At elevated temeratures, the cyclic fatigue strongly depends on the frequency, the lower the frequency,

the less the fatigue resistance. A failure diagram was constructed to show the effects of mean stress and stress amplitude on fatigue strength. It was concluded that a design methodology proposed for metal fatigue is applicable to the sintered silicon nitride examined at elevated temperatures. (Author)

A95-29346 Fatigue crack growth behavior of surface cracks in silicon nitride. Y. MUTOH, M. TAKAHASHI, A. KANAGAWA (Nagaoka Univ. of Technology, Japan), *Cyclic Deformation, Fracture, and Nondestructive Evaluation of Advanced Materials: Second volume* (A95-29344 07-23), Philadelphia, PA, American Society for Testing and Materials (ASTM Special Technical Publication, No. 1184), 1994, pp. 19–31. 24 Refs. Documents available from Aeroplus Dispatch.

Cyclic fatigue crack growth tests of silicon nitride specimens with surface cracks as well as through-the-thickness cracks were carried out. The surface crack length was measured by a surface film gage technique. The fatigue crack growth rate for surface sracks was less than that for through-the-thickness cracks. From SEM observations, more significant bridging was found in the wake of surface cracks compared to through-the-thickness cracks. From evaluations of the stress shielding effect due to bridging based on the measurements of the crack mouth opening displacement, it was found that the crack growth curve determined from the crack tip stress intensity factor for surface cracks almost coincided with that for through-the-thickness cracks. (Author)

A95-26189 The environmental effect on cyclic fatigue behaviour in ceramic materials. G. CHOI (National Research Inst. for Metals, Tsukuba, Japan) and S. HORIBE (Waseda Univ., Tokyo, Japan), *Journal of Materials Science* (ISSN 0022-2461), Vol. 30, No. 6, 1995, pp. 1565–1569. 24 Refs. Documents available from Aeroplus Dispatch.

To understand the environmental effects on cyclic fatigue, static and cyclic fatigue behavior was investigated in air and in vacuum for normally sintered silicon nitride and alumina. The cyclic fatigue lifetime in vacuum is considerably longer than that in air, indicating a remarkable stress corrosion cracking effect in the latter, especially in alumina. In addition, the cyclic loading effect in vacuum is almost the same in silicon nitride relatively insensitive to environmental effects and alumina susceptible environmental effects. From such results, it has been found that cyclic fatigue in air is approximately expressed as the superposition of pure cyclic loading effect, which is defined as cyclic loading effect in vacuum, and environmental effect. This relation was applied to some kinds of ceramics with different values of fracture toughness or different microstructures, and the results obtained were discussed. (Author)

A95-24222 Mechanical fatigue of epoxy resin. M. NAGASAWA, H. KINUHATA, H. KOIZUKA, K. MIYAMOTO, T. TANAKA, H. KISHIMOTO (Toyota Technological Inst., Nagoya, Japan), and T. KOIKE (Yuka Shell Epoxy Co., Ltd., Yokkaichi, Japan), *Journal of Materials Science* (ISSN 0022-2461), Vol. 30, No. 5, 1995, pp. 1266–1272. 13 Refs. Documents available from Aeroplus Dispatch.

In static bending fatigue tests, epoxy resins show practically no fatigue if the stress given to specimen is lower than a critical value, which is close to the bending strength of the specimen. In cyclic bending fatigue tests, on the other hand, the resins are easily fractured even though the stresses are far below the critical values. Some strain may be accumulated on the surface of specimen through cyclic deformations. However, the strain accumulated is reversible. If the specimen is allowed to rest, the strain disappears. If the strain reaches a critical value, an irreversible transition may be induced, probably in the arrangement of segments on the surface. A crack nucleus thus created may propagate and cause the final fracture of the specimen, following the fracture mechanics of elastic materials. The lifetime of epoxy resins under cyclic bending load is determined by the time required for creating a crack nucleus on surface. (Author)

A95-22000 Stochastic analysis and engineering applications—In memory of Frank Kozin. Y. SUNAHARA (ed.) (Kyoto Inst. of Technology, Japan), Tokyo, Japan, Mita Press, 1994, p. 414. (No individual items are abstracted in this volume). Documents available from Aeroplus Dispatch.

The volume discusses stochastic processes, stochastic stability, and stochastic differential equations; parameter estimation and adaptive algorithms; probabilistic models of cumulative damage; and applications to moving vehicles and civil and mechanical engineering problems. Attention is given to applications to the densities and moments of a class of stochastic systems, moments of the output of linear random systems, a survey of the stability of stochastic systems, and a characterization of consistent estimators. Other topics addressed include dynamic updating of cumulative damage models for reliability and maintenance based on service information, a cumulative damage model for fatigue crack growth based on reaction rate theory, a limit theorem for processes with stationary independent increments, and the probability densities of the output of some random systems.

A95-20903 Effects of shear stress component and loading path on fatigue strength under tension/torsion biaxial cyclic loading. Y. MORITA (Doshisha Univ.; Murata Machinery, Ltd., Kyoto, Japan) and T. FUJII (Doshisha Univ., Kyoto, Japan), *American Society for Composites, 9th Technical Conference*, Univ. of Delaware, Newark, 1994, Proceedings (A95-20803 04-24), Lancaster, PA, Technomic Publishing Co., Inc., 1994, pp. 975–982. 6 Refs. Documents available from Aeroplus Dispatch.

The material degradation and its mechanism of a plain woven glass fabric under tension/torsion biaxial cyclic loading were investigated. Different types of loading sequence were applied to thin-walled tubular specimens to estimate the effect of shear stress component on fatigue degradation of the composite under biaxial cyclic loading. All biaxial loads were proportionally applied to the specimens, but the number of torsion loading cycles and its direction were changed. Various wave forms were also used to estimate the effect of loading path. Loading path was changed but the final stress state was the same. Stress-strain relation and stiffness reduction were observed to evaluate the degree of fatigue damage. The experimental results show that the role of shear stress is important when the material degradation is dominated by the shear stress component although the effect of shear stress component on fatigue strength decreases with an increase of tensile stress component under tension/torsion biaxial loading. (Author)

A95-20902 Low-cycle and high-cycle fatigue failure process characterization of CFRP cross-ply laminates. N. TAKEDA (Tokyo, Univ., Japan), S. OGIHARA, and A. KOBAYASHI (Tokyo, Science Univ., Noda, Japan), *American Society for Composites, 9th Technical Conference*, Univ. of Delaware, Newark, 1994, Proceedings (A95-20803 04-24), Lancaster, PA, Technomic Publishing Co., Inc., 1994, pp. 967–974. 10 Refs. Documents available from Aeroplus Dispatch.

Damage progress in toughened-type CFRP cross-ply laminates under tensile fatigue loading was measured by the replica technique. The damage parameters, the transverse crack density and the delamination ratio, were presented. Based on the data, simple shear-lag analysis combined with the modified Paris law model was conducted to model the damage progress. In addition, a novel power-law model was proposed, which related the cyclic strain range and the number of cycles. The loading-unloading tests were also performed to obtain the Young's modulus reduction and the permanent strain as functions of the damage state. The shear-lag predictions of the Young's modulus reduction and the permanent strain showed good agreement with the experimental data, when the interaction between transverse cracking and delamination were taken into account. (Author)

A95-19610 Effect of heat treatments on hydrogen environment embrittlement of Alloy 718. S. FUKUYAMA and K. YOKOGAWA (MITI, Chugoku National Industrial Research Inst., Kure, Japan), *Superalloys 718, 625, 706 and Various Derivatives; Proceedings of the International Symposium*, Pittsburgh, PA, 1994 (A95-19551 04-26), Warrendale, PA, Minerals, Metals and Materials Society, 1994, pp. 807–816. 19 Refs. Documents available from Aeroplus Dispatch.

Tensile property and fatigue crack growth of Alloy 718, which was solution-annealed at 1223–1323 K and aged, were investigated in high-pressure hydrogen of 1.1–19.7 MPa and argon at room temperature up to 773 K. The effect of gaseous inhibitors added to hydrogen atmosphere on the fatigue crack growth was also investigated to prevent hydrogen assisted fatigue crack growth. Hydrogen environment embrittlement (HEE) increased with increasing delta phase and with decreasing testing temperature. HEE still occurred at 773 K. Delayed fracture was found predominantly in fatigue crack growth in hydrogen. The crack initiation occurred at carbide, then the crack propagated along the interface between delta phase and gamma matrix of the alloy with delta phase or along the grain boundary of the alloy without delta phase. It was observed that oxygen or carbon monoxide added to hydrogen atmosphere greatly hampered hydrogen assisted fatigue crack growth. (Author)

A95-18723 Effect of grain size on cyclic fatigue and static fatigue behaviour of sintered Al_2O_3. H. N. KO (Nakanihon Automotive College, Gifu, Japan), *Journal of Materials Science Letters* (ISSN 0261-8028), Vol. 14, No. 1, 1995, pp. 56–59. 10 Refs. Documents available from Aeroplus Dispatch.

The effect of grain size on the static and cyclic behavior of a sintered Al_2O_3 material, fabricated with SiO_2, MgO, and other additives, was investigated by performing rotary bending and static fatigue tests on specimens containing grains sized 5 or 19 μ in diameter. Microscopic examinations showed that the fatigue fracture occurred mainly as a transgranular process; the observations of finer-grained material were similar to those on larger-grained material. Microscopic observations on the fractured surface after two fatigue tests were similar to those after the static test, and no differences in the crack growth behavior were found.

A95-17210 Acoustic imaging of plate thickness and sound velocity during tensile testing at low temperature. H. SATO, O. V. KOLOSOV, Y. NAGATA, and T. KODA, *Japanese Journal of Applied Physics, Part 1* (ISSN 0021-4922), Vol. 33, No. 11, 1994, pp. 6373–6378. 8 Refs. Documents available from Aeroplus Dispatch.

In many procedures important in engineering and science, such as plastic working, tensile, bending, creep, and fatigue tests, both the geometrical shape and material properties of objects change simultaneously. In this paper, we present a novel method for simultaneous imaging of the thickness of and sound velocity in a plate. After evaluating the accuracy of this method in a low-temperature acoustic microscope, it was applied to a stainless steel plate that underwent the stress-induced martensitic transformation, and thickness and sound velocity images around a notch in the plate were obtained. Since the thickness and velocity images differ slightly, the possibility of independent but simultaneous imaging of plate thickness and sound velocity was confirmed. (Author)