

## Japanese Aerospace Literature This month: Aluminum Alloys

**A90-14696 Crack propagation behavior under low-cycle corrosion fatigue of A7003-T6 aluminum alloy.** KAZUAKI SHIOZAWA, KAZUYU MIYAO, and TORU ASAMOTO, *JSME International Journal, Series I* (ISSN 0914-8809), Vol. 32, Oct. 1989, pp. 572-580. 12 Refs.

Crack propagation behavior has been observed in A7003-T6 aluminum alloy under low cyclic loading with hold time over the frequency range .004-1 Hz in 3.0 pct saline solution. From the experimental results, the effect of cyclic frequency on crack propagation rates was found to be exemplified by two different regimes. One has a positive dependency on the frequency below a critical frequency, at which point maximum environmental attack occurs in terms of da/dN, and the other is negative above the critical frequency. The number and depth of secondary cracks occurring under the fracture surface were measured by metallographic examination, and the actual crack tip stress intensity factor was estimated.

**A90-11928 Improvement of fracture toughness in 7475 aluminum alloy by the RRA (Retrogression and Re-Aging) process.** TADAKAZU OHNISHI, TAICHIRO ITO, and YOSHIKI IBARAKI, *JIM, Materials Transactions* (ISSN 0916-1821), Vol. 30, Aug. 1989, pp. 601-607. Research supported by the Light Metals Educational Foundation, Inc. 13 Refs.

In order to improve fracture toughness and SCC properties with retention of the high strength of T6 level, a three-step aging process (RRA) was investigated for the 7475 aluminum alloy. The usual T6 condition was suitable for the first-step aging. For the second-step aging (retrogression), the improvement of the properties became more remarkable with increasing temperature and time. However, the strength decreased in the case of over-aging of the retrogression. For the final-step aging (reaging), it was preferable to increase the aging temperature and time to an extent within the permissible range of loss in strength. The results suggest that the retention of high strength and the improvements in fracture toughness and SCC resistance can be simultaneously effected by an optimum RRA process, and that the conventional over-aged treatments such as T76 and T73 which accompany a loss of strength may be replaced by the RRA process.

**A90-10417 Grain refinement and mechanical characteristics at elevated temperatures in 7475 aluminum alloy sheets.** YOON-EUI HONG, NAOKUNI MURAMATSU, and TAKAO ENDO, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 39, Aug. 1989, pp. 541-549. 29 Refs.

The effects of testing temperature, imposed strain rate, heating rate up to testing temperature, and holding time before stretching on the total plastic strain have been investigated in warm-rolled 7475 Al-alloy sheets. The value of the strain-rate sensitivity parameter,  $m$ , and apparent activation energy for plastic flow were also measured. Mechanical-characteristic and optical-microscopic observations showed that, in order to obtain large superplastic elongation, the specimens should be heated quickly up to the optimum testing temperature and be stretched just before the advent of static recrystallization. The value of  $m$  was about 0.2 at 583-650 K; however, it increased with increasing temperature and reached about 0.55 above 770 K. The apparent activation energy for plastic flow was 358 kJ/mol in the temperature range of superplastic flow. Compensating by the change in grain size and elastic modulus at testing temperature, the activation energy reduced to 160 kJ/mol. This suggests that the grain accommodation during superplastic flow is controlled by the bulk diffusion.

**A89-48774 Mechanical properties of aluminum alloy composites reinforced with new continuous Si-Ti-C-O fibers.** Y. WAKU, T. YAMAMOTO, M. SUZUKI, M. TOKUSE, T. NAGASAWA et al., *SAMPE Quarterly* (ISSN 0036-0821), Vol. 20, July 1989, pp. 47-54. 6 Refs.

The mechanical properties of an aluminum metal matrix composite reinforced with a continuous inorganic Si-Ti-C-O fiber which has fine ceramic SiC powder attached to its surface were studied. The aluminum metal matrix composite was produced by a vertical squeeze casting process capable of low-cost mass production. The Si-Ti-C-O fiber is distributed uniformly in the matrix free of contact between fibers, and also is high in compatibility with the matrix, making it possible to produce an aluminum matrix composite with superior mechanical properties.

**A89-41202 Fabrication and properties of ceramic dispersed aluminum alloy composites by powder liquid forming technique.** HIDEO WATANABE and HIROSHI SAITOH, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 39, April 1989, pp. 255-261. 33 Refs.

A new type fabrication process for particle dispersed composites, powder liquid forming technique, was proposed. In this process, first compacts blended of air atomized aluminum alloy powders and ceramic particles were produced by cold press. The obtained compacts were heated up to the melting point of matrix aluminum alloy and pressed in the mold in order to wet between the molten metal and the ceramic particles, and then formed under pressure. The fabrication conditions of this process were investigated mainly from the density and Vickers hardness of Al<sub>2</sub>O<sub>3</sub> particles/6061 powder composites. The forming temperature needed over the melting point of matrix and the forming pressure over 80 MPa. 0.2 percent proof stress increased with volume fraction of Al<sub>2</sub>O<sub>3</sub> particles.

**A89-45923 Fabrication of silicon nitride whisker/aluminum alloy composites and some of their properties.** HIROMI MATSUBARA, YOSHINORI NISHIDA, ITARU SHIRAYANAGI, and MAMORU YAMADA, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 39, May 1989, pp. 338-343. 6 Refs.

The Si<sub>3</sub>N<sub>4</sub>-whisker-reinforced aluminum and 6061, 7075, and AC8A alloy composites were fabricated by squeeze casting. Tensile and wear tests and micrography of the composites were carried out. The composites are easy to fabricate in spite of a large contact angle of Si<sub>3</sub>N<sub>4</sub> with molten aluminum. Though preforms have been produced by the aspiration method, whiskers distribute in the composites in the indefinite preferential direction. The tensile strength of the composites is nearly equal to that of SiC-whisker-reinforced aluminum alloys, and lowers at elevated temperatures in a similar manner to matrices. The composites are superior in wear resistance and also superior to some degree to SiC-whisker-reinforced aluminum alloys in machinability.

**A89-45925 Mechanism of particle dispersion into liquid aluminum alloys and wear resistance of composites.** TAKAO CHOH, ZIRO EBIHARA, and TAKEO OKI, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 39, May 1989, pp. 356-360.

Dispersion behaviors of Al<sub>2</sub>O<sub>3</sub>, alpha-SiC, beta-SiC, and SiO<sub>2</sub> particles in aluminum alloys were studied. Wear resistance of the composites containing these particles was examined. The time required for dispersion of Al<sub>2</sub>O<sub>3</sub> and alpha-SiC particles into liquid aluminum alloys is prolonged with increasing volume fraction of the particles and decreasing particle diameter. By vacuum degassing heat treatment of the particles at 1273 K, the dispersion time for Al<sub>2</sub>O<sub>3</sub> shortens to some degree, and SiO<sub>2</sub> particles become dispersive into pure aluminum. In the first half of dispersion time, introduced particles agglomerate with liquid aluminum. Alumina particles in the agglomerates increase in ratio and then rapidly disperse in the metal matrix through the maximum ratio during agitation. The ratio of particles in the powder phase, on the other hand, decreases with prolonged agitation. Wear resistance of the composites is improved by dispersing alpha-SiC 10 microns or more and 7 percent or more in diameter and volume fraction of particles, respectively.

**A89-41205 Effect of temperature on tear fracture strength of 5083 aluminum alloy.** TETSUYA TAKAAI and YOSHIHIRO NAKAYAMA, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 39, April 1989, pp. 293-299. 13 Refs.

Tear fracture strength of 5083 aluminum alloy plate was studied experimentally for the test temperatures ranging from 4 k to 473 k. The total absorbed energy during the tear fracture shows N-letter type changes with respect to the test temperatures indicating the presence of three distinct temperature regions. In the higher and lower temperature regions, the temperature dependences of the total absorbed energy are negative, while they are positive in the medium temperature region. The temperature dependence of the absorbed energy for the crack propagation is substantially the same as that of the total absorbed energy.

**A89-33179 Mechanical properties of SiC whisker reinforced aluminum alloys fabricated by pressure casting method.** TOSHIRO KOBAYASHI, MASAKI YOSINO, HIROYOSHI IWANARI, MITSUO NINOMI, and KUNJI YAMAMOTO, *Cast reinforced metal composites; Proceedings of the International Symposium on Advances in Cast Reinforced Metal Composites*, Chicago, IL, Sept. 26-30, 1988 (A89-33151 13-24). Metals Park, OH, ASM International, 1988, pp. 205-210. 10 Refs.

Microstructures and mechanical properties of SiC whisker (SiCw) reinforced aluminum alloys fabricated by pressure casting method are investigated. The SiCw-reinforced aluminum alloys fabricated under the pressure of 90 MPa are superior to those fabricated under lower pressure conditions in mechanical properties. The fracture of SiCw-reinforced aluminum alloys is associated with the failure of SiCw and the interface decohesion between whiskers and matrix. It is shown that these composites are strengthened by increasing interface bonding between SiCw and matrix, i.e., the interface cohesion is strengthened by accelerating the interface reaction adequately. The addition of the highly reactive lithium to aluminum matrix makes the interface cohesion tight and results in lower density and greater strength composites.

**A89-25892 Boron/magnesium-aluminum sintered composite alloy.** E. HORIKOSHI, T. IKAWA, and T. SATO, *Modern developments in powder metallurgy; Proceedings of the International Powder Metallurgy Conference*, Orlando, FL, June 5-10, 1988. Volume 19 (A89-25876 09-26). Princeton, NJ, Metal Powder Industries Federation, 1988, pp. 579-590. 5 Refs.

The effect of the sintering conditions and the composite composition on the mechanical properties of Mg-Al alloy reinforced with boron particles were investigated. It was found that sintering in Ar atmosphere at 600 C was optimum for the Mg-Al alloy. The addition of boron increases the tensile strength and the modulus of elasticity of Mg-Al alloys, up to a certain level of B, after which the mechanical properties of the alloy deteriorate. A Mg-9 wt pct Al-10 vol pct B alloy was found to exhibit a maximal modulus of elasticity of 63 GPa, which is 1.4 times greater than that of the cast Mg-Al alloy.

**A89-33168 Mechanical properties of aluminum alloys reinforced with continuous fibers and dispersoids.** SEN-ICHI YAMADA, SIN-ICHI TOWATA, and HAJIME IKUNO, *Cast reinforced metal composites; Proceedings of the International Symposium on Advances in Cast Reinforced Metal Composites*, Chicago, IL, Sept. 26-30, 1988 (A89-33151 13-24. Metals Park, OH, ASM International, 1988, pp. 109-114. 5 Refs.

A hybrid technique, which can solve problems encountered during MMCs' fabrication by squeeze casting, is developed. The addition of dispersoids improved the strength of multifilament-type fiber-reinforced composites in the longitudinal and transverse directions. Several hybrid effects on the composite strength are investigated.

**A89-23197 Finite element analysis aided fracture toughness evaluation in tear test of aluminum alloys.** TOSHIRO KOBAYASHI, MITSUO NINOMI, YUKIO TAKABAYASHI, and SHIGERU KOHMURA, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, Nov. 1988, pp. 723-730. 12 Refs.

A rather good correlation between fracture properties obtained from tear tests and the fracture toughness value  $J(IC)$  has already been reported previously; here, an FEM technique for estimating fracture toughness parameters directly from the tear test is presented. Tear test is carried out using specimen with a deep notch ratio of  $a/W = 0.3$  which is recommended from the result of finite-element analysis, while its other geometry is held same as that of the standard tear test. In such test, load-load line deflection curve and crack initiation point are recorded. Then,  $J(IC)$  can be successfully evaluated by putting the area under the load-deflection curve up to the crack initiation point into Rice's simple  $J$  integral estimation formula.

**A89-20938 Influence of whisker volume fraction on the mechanical properties of SiC whisker reinforced aluminum alloy composites.** HIROYUKI MORIMOTO and KEN-ICHIRO OHUCHI, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, Oct. 1988, pp. 658-664. 12 Refs.

A powder metallurgical method was used to fabricate SiC whisker reinforced aluminum alloy composites with a whisker volume fraction ( $V_f$ ) ranging from 0 to 40 percent. The elastic modulus increases with increasing  $V_f$  and is in good agreement with the value calculated with Cox's (1952) equation, assuming that the elastic modulus of the whiskers is 43,000 kgf/sq mm. The whisker orientation factors of the three-dimensional array composites for the strength and the elastic modulus are 0.38 and 0.68, respectively.

**A89-20933 Fabrication of particle dispersed aluminum alloy composites by compocasting process and their properties.** AKIRA WATANABE, HIDEO WATANABE, KOICHI OHORI, and YO TAKEUCHI, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, Oct. 1988, pp. 626-632. 8 Refs.

Compocasting was used to fabricate particle dispersed Al-4 mass pct Cu alloy composites. The recovery of particles introduced in the molten metal is found to be dependent on the particle size, the fraction solid of the metal and the Mg concentration in the metal. It is shown that 0.5 mass pct of Mg is required in the metal to ensure the homogeneous dispersion of SiC particles which are 40 microns in size in the molten metal.

**A89-20934 Effects of hot extrusion and rolling on the tensile strength of SiC whisker reinforced aluminum alloy composites.** HIDEO WATANABE, KOICHI OHORI, and YO TAKEUCHI, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, Oct. 1988, pp. 633-639. 15 Refs.

SiC whisker/Al composites fabricated by high pressure infiltration were extruded and rolled at high temperatures. Measurements were taken of the strength and working ratio of the composites. It is found that the tensile properties of extruded composites are strongly dependent on the whisker orientation. The elastic modulus of SiC whisker/6061 composites is expressed as  $E = 255 V_f + 72$  (GPa).

**A89-20932 Aluminum alloy matrix composites with discontinuous fibers oriented uniaxially by electrostatic method.** TOMOHITO ITOH, HIDETOSHI HIRAI, and REN-ICHI ISOMURA, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, Oct. 1988, pp. 620-625. 10 Refs.

An electrostatic method for fabricating uniaxially oriented ceramic discontinuous fiber preforms was developed. Short fibers of alumina suspended in an insulating liquid were aligned to form long agglomerates and sedimented to form a preform in the dc field. SiC whiskers form similar agglomerates in the a field. It is found that a uniaxially oriented FRM has a higher bending strength than an FRM with two) and three-dimensionally random orientations at the same volume fraction of short fibers or whiskers.

**A88-52977 Effects of precipitate particles on structure evolution during hot rolling of 3003 aluminum alloy.** TAKEYOSHI DOKO, SHIGENORI ASAMI, and KEISUKE YAGI, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, July 1988, pp. 386-393. 23 Refs.

Direct chill-cast ingots of 3003 Al alloy were homogenized in two conditions and subsequently submitted to single-pass hot rolling, and the rolled plates were held at exit temperature. The precipitation by homogenization and the structural change during the holding were investigated by means of TEM. Homogenization at 450 C results in fine dispersion of small alpha Al(Fe, Mn-Si precipitate particles; on the contrary, two-step homogenization at 600-450 C brings about coarse dispersion of relatively larger particles.

**A88-42126 Aluminum-based amorphous alloys with tensile strength above 980 MPa (100 kg/sq mm).** AKIHISA INOUE, KATSUMASA OHTERA, AN-PANG TSAI, and TSUYOSHI MASUMOTO, *Japanese Journal of Applied Physics, Part 2* (ISSN 0021-4922), Vol. 27, April 1988, pp. L479-L482. 26 Refs.

Al-Y-Ni mixtures containing 2-25 at. pct Y and 2-30 at. pct Ni were melted in an arc furnace, and 30-micron-thick 1.5-mm-wide ribbon samples of amorphous alloys were produced by liquid quenching in a single-roller melt-spinning apparatus and subjected to extensive mechanical testing and microstructural analysis. The results are presented in tables and graphs, and it is demonstrated that ductile amorphous alloys are produced only in compositions with Al greater than 80 at. pct. The highest tensile fracture strength (1.14 GPa) is found in an Al87Y8Ni5 alloy with Young's modulus 71.2 GPa and Vickers hardness 300 DPN. The ratio of specific strength to density in these alloys is shown to reach 38, much greater than that of conventional alloy steels.

**A89-15062 Void formation and its effect on post-formed mechanical properties in superplastic 7475 aluminum alloy.** TAKEHIKO ETO, MASAKAZU HIRANO, MITSUO HINO, and YOSHIMITSU MIYAGI, *Superplasticity in aerospace; Proceedings of the Topical Symposium*, Phoenix, AZ, Jan. 25-28, 1988 (A89-15051 03-26. Warrendale, PA, Metallurgical Society, Inc., 1988, pp. 199-207. 9 Refs.

Superplastically deformable 7475 Al alloy samples with a fine, 10-micron grain and 500-percent elongation at 516 C is presently studied to characterize the effect of cavitation on postformation properties in the T6, T76, and T73 conditions, after either water quenching or distortionless polymer quenching. Cavitation is noted to be greater in uniaxial-tensile than in biaxial deformation; voids were formed primarily at the triple point of grain boundaries, due to sliding-induced decohesion during deformation. Postformed mechanical properties were adequate, and the T76 and T73 conditions were found to exhibit good corrosion resistance, as required for aerospace applications.

**A89-16499 Effects of copper and magnesium additions on tensile deformation behaviour at elevated temperatures of aluminum PM-alloys containing Fe and Zr.** ANDERS P. SODERGREN, JUN SHIMIZU, and OSAMU IWAO, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, Sept. 1988, pp. 540-545. 9 Refs.

Tensile tests at temperatures from 25 C and 490 C and initial strain rates from 0.0001/s to 0.1/s were carried out on Al (3 pct. Fe) 1.5 pct. Zr alloys to which Cu and Mg had been added by 1.5 percent, respectively. The strength increases at low temperatures below 200 C and decreases at high temperatures above 370 C, and the ductility is improved over a range of elevated temperatures. These effects are attributed to differences in work hardening rate, recovery rate, and necking behavior among the alloys. The tensile elongation at high temperatures and low strain rates is governed by the formation and growth of voids.

**A89-41203 Properties of alumina particles dispersed aluminum alloy composites fabricated by powder liquid forming technique.** HIDEO WATANABE and TAKASHI SAITOH, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 39, April 1989, pp. 262-268. 27 Refs.

Aluminum alloy matrix composites containing Al<sub>2</sub>O<sub>3</sub> particles were fabricated by the powder liquid forming technique. Tensile properties of composites depended on the size of alumina particles, and tensile strength showed 550 MPa for 30 wt pct Al<sub>2</sub>O<sub>3</sub> (average d = 0.5 micron-/6061 aluminum alloy composites. Aging sequence of composites was accelerated by the presence of alumina particles compared with the matrix alloy. Thermal expansion coefficients of 6061 and AC8A alloy composites containing 30 wt pct Al<sub>2</sub>O<sub>3</sub> particles, respectively, were reduced about 20 percent compared with the matrix alloys.

**A88-49932 CO<sub>2</sub> laser light absorptivities of cast aluminum alloys.** HIROSHI SAKUTA, YASUNORI MIYATA, YUKIO ICHINOSE, TOSHIO SUZUKI, and JUN KUROBE, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, Aug. 1988, pp. 468-472. 7 Refs.

Absorptivities of cast aluminum alloys for CO<sub>2</sub> laser light were determined by two different methods, by measuring the power reflected from the surface of the alloys and by measuring temperature rise of the alloys during irradiation. When the surface of an alloy is fine, absorptivities determined by the two methods are nearly equal to each other. The absorptivity of the alloys depends on the surface roughness and the contents of alloying elements. Roughening of the surface and the increase of alloying elements cause an increase in absorptivity.

**A88-52979 Behavior of silicon in intermetallic compounds during ingot heating and annealing in 1050 aluminum alloy.** MAMORU MATSUO, TOSHIKI MURAMATSU, AKIRA ASANUMA, TSUYOSHI KAJIYAMA, and MASASHI FUKUDA, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 38, July 1988, pp. 400-406. 15 Refs.

The behavior of Si in constituents of 1050 Al alloy were investigated by chemical analysis of extracted residue with phenol (phenol residue method). The constituents of the ingot are transformed from Al<sub>6</sub>Fe to beta-Al<sub>3</sub>Fe and finally to stable Al<sub>3</sub>Fe by ingot heating. Si moves to the constituents from matrix at 350-450 C then dissolves into the matrix again at higher temperatures according to the transformation. The maximum Si content in constituents is 33 percent of total Si at 350 C. In case of the annealing of the rolled sheet, the behavior depends on the phase of the constituents before annealing.