ISSN 1070-3632, Russian Journal of General Chemistry, 2011, Vol. 81, No. 5, pp. 1022–1024. © Pleiades Publishing, Ltd., 2011.
Original Russian Text © N.F. Lukina, L.A. Dement'eva, A.A. Serezhenkov, E.V. Kotova, O.G. Senatorova, V.V. Sidel'nikov, K.E. Kutsevich, 2010, published in Rossiiskii Khimicheskii Zhurnal, 2010, Vol. 54, No. 1, pp. 53–56.

Adhesive Prepregs and Composite Materials on Their Basis

N. F. Lukina, L. A. Dement'eva, A. A. Serezhenkov, E. V. Kotova, O. G. Senatorova, V. V. Sidel'nikov, K. E. Kutsevich

All-Russian Scientific Research Institute of Aviation Materials Federal State Unitary Enterprise, State Research Center of the Russian Federation (RIAM), ul. Radio 17, Moscow, 105005 Russia
e-mail: admin@viam.ru

Received December 1, 2009

Abstract—The properties of high-strength and high-elasticity film-forming adhesives, high-strength cold- and hot-setting adhesive pastes, functional adhesives for metals, and various nonmetal and composite materials are reviewed. The properties of self-adhesive materials of different grades used for temporary repair of airframe surfaces are also described.

DOI: 10.1134/S1070363211050343

The improvement of aerodynamic characteristics of airframes and provision of weight efficiency are largely reached due to composite materials (CMs). The RIAM's researchers have pioneered a complex of theoretical and experimental investigations on the strength and viscoelastic properties of multicomponent polymer compositions. The results of these investigations have formed the basis for development of high-strength and high-elasticity film adhesives for structural applications, which compare with the best foreign analogs in strength, deformation, and processing properties and meet severe requirements to components for aviation industry.

Structural adhesives have acquired still greater importance in view of the demand for development of polymer composite materials (PCMs) with new properties. High-strength adhesives are used as the base for adhesive binders with controlled characteristics (viscoelastic, strength, deformation, and temperature). These materials have been used to develop, for the first time in domestic practice, long-lived prepregs with fillers made of carbon fiber strips and yarns (KMKU brand materials) and glass fibers, including those on the basis of high-modulus fibers (KMKS brand materials).

A characteristic feature of adhesive prepregs is that they allow realization of a high-efficiency technology of assembling for high-load nonmetal structures of single and complex curvature: laminar, integral, and honeycomb, when cladding is formed and glued on the honeycomb filler in a single technological operation. This feature of adhesive prepregs is employed in the development of PCM items combining integral and honeycomb elements which are formed simultaneously, in a single technological cycle. The efficiency of adhesive composite materials (ACMs) of KMKU and KMKS brands in such applications has been confirmed by successful pilot tests.

The use of ACMs allow the production cycle of items to be decreased 2–3 times and the labor consumption for production of honeycomb structures, by 40–50% compared with standard lamellar panels. Therewith, the number of technological operations decreases 3 times, the number of accessories, 1.5–2 times, and item weight (especially with a honeycomb filler), by 30–50%. Therewith, atmospheric emissions decrease 10–15 times, since adhesive prepregs and items on their basis are produced by a solution-free technology. Furthermore, ACMs also allow to enhance hermeticity of PCM constructions by an order of magnitude, crack resistance by 40–50%, and interlaminar shear stress by 20–35%.

The first stage of works in this direction involved the development of composite materials with the working temperature 80°C (KMKS-1.80 and KMKU-1.80 brands). By directed modification of the formulation of the adhesive matrix the thermal stability of the adhesive prepregs from 80°C to 120°C (KMKS-2.120, KMKS-2m.120, and KMKU-2m.120), 150°C (KMKU-3.150), and 175°C (KMKS-4.175 and KMKU-4m.175). The service life of ACMs is long at

Table 1. Properties of adhesive composite materials on the basis of various fillers

Parameter	Carbon fillers		Glass fillers
	ELUR-P strip, brand KP	Porsher fabric article 4510	T-10, T-15, and T-60 fabrics (VMP)
Tensile strength, σ_t, MPa	900	1800	560–1250
Compression strength, σ_{-t}, MПa	1020	1000	450–900
Elastic modulus E, GPa	130	130	22–50

120 and 150°C and short at 175°C. The properties of ACMs could be varied over a wide range by using a variety of glass and carbon fillers, including imported (Porsher, France) ones, in the formulations of adhesive prepregs [1, 2].

Table 1 lists the properties of certain ACMs with different fillers.

Presently, ACMs belong to the most perspective polymer materials. They are involved in virtually all designs of aircraft and space vehicles and have been widely and successfully tested in PCM components of new flight vehicles, including Super Jet-100. They will also be used in the design of the short-haul aircraft MS -21.

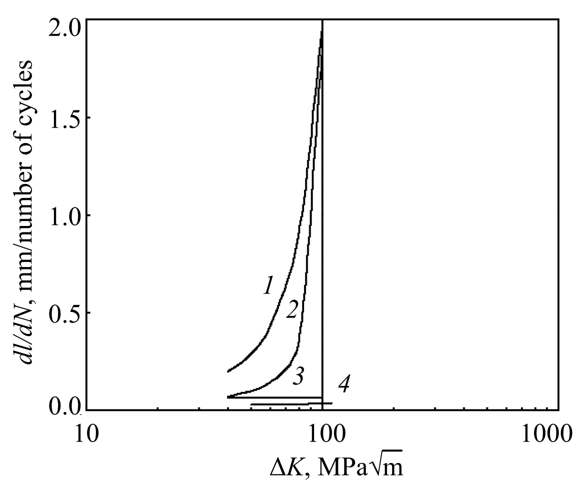
With new adhesive prepregs, a new composite aluminum glass plastic (SIAL) was developed, which is a lamellar hybrid of thin aluminum sheets made of structural alloys with interlayers made of glass plastics with various reinforcement structures. The combination of these materials provides a unique combination of characteristics of this class materials, promising candidates for application in new-generation flight vehicles, which endows the latter with enhanced reliability and endurance [3–4].

The wide variety of structures and properties of lamellar hybrid materials allows for a designer to choose a material best meeting his goals. The number, thickness, and ratio of layers, structure of the glass plastic layer, structure and state of the surface of aluminum sheets all affect the properties of the lamellar material. The most typical are 3-layer (2 aluminum sheets + 1 glass plastic layer) and 5-layer structures (3 aluminum sheets + 2 glass plastic layers). The anisotropy degree required by the operating conditions of the construction is controlled by the cross-linked reinforcement of the plastic layers. In SIAL-1, glass fibers are arranged in one direction (0/0), in SIAL-2 about ~ 70% are arranged in one direction and ~30% in the transversal direction, and in SIAL-3, 50% and 50%, respectively (0/90) [5].

SIAL materials bypass in fatigue, crack, impact, and flame resistance and static mechanical properties the monolithic sheets of traditional aluminum alloys presently applied in aviation. Lamellar materials are also characterized by decreased density.

The most important advantage SIAL-type lamellar composites offer over monolithic aluminum sheets is their very high crack resistance, especially an extremely high resistance to fatigue crack growth, which predetermined the reliability and endurance of aircraft constructions (see figure).

Over the past years the range of SIAL materials has extended. The previously developed SIAL materials on the basis of the aluminum alloy D16chAT and adhesive prepreg KMKS 1.80.T60 with the working temperature 80°C exhibited enhanced (by a factor of 1.5–2.0) strength and other advantages compared with the monolithic sheets of D16chAT alloy, but, at the



Fatigue crack growth rate vs. stress intensity coefficient (ΔK) for monolithic aluminum sheets and SIALs: (*1*) D16chAT; (*2*) 1441; (*3*) SIAL-3-1 in 3% NaCI; and (*4*) SIAL-3-1, SIAL-3.

Table 2. Principal characteristics of five-layer SIAL materials

Brand	SIAL composition		σ_t, MPa	E, GPa	d, kg m^{-3}
	alloy brand	basis of glass plastic			
SIAL-1	D16chAT	Adhesive prepreg on the basis of cord fabric T-60 (VMP)	900	60	2470
SIAL-3	D16chAT	Adhesive prepreg on the basis of cord fabric T-60 (VMP)	600	55	2470
SIAL-1-1	1441 RDT11	Adhesive prepreg on the basis of cord fabric T-60 (VMP)	900	68	2360
SIAL-3-1	1441 RDT11	Adhesive prepreg on the basis of cord fabric T-60 (VMP)	600	64	2360
SIAL-1-1R	1441 RDT11	Adhesive prepreg on the basis of high-modulus glass fiber roving	990	70	2350
SIAL-3-1R	1441 RDT11	Adhesive prepreg on the basis of high-modulus glass fiber roving	630	64,5	2350
Aluminum alloy	D16chAT	–	430	70	2780
Aluminum–lithium alloy	1441 RDT11	–	404	76–77	2590

same time, they had a lower (by 10–30%) elastic modulus. In this connection, an urgent problem was to develop a SIAL material on the basis of the aluminum–lithium alloy 1441 possessing, compared with D16chAT, increased elastic modulus (E ~ 76–77 GPa), decreased density (d~2590 kg m^{-3}), and higher working temperature.

SIAL materials comprising alloy 1441 sheets (thickness 0.3–0.4 mm) and thermostable prepreg KMKS 2.120.T60 on the basis of T-60 cord fabric made of VMP high-modulus fiber, can be exploited at temperatures of up to 120°C.

The next stage was the development of materials SIAL-1-1R and SIAL-3-1R on the basis of alloy 1441 and thermostable (up to 120°C) adhesive prepreg with a high-modulus glass fiber roving filler (66–68 vol %), which allowed to enhance the strength and rigidity and decrease the weight of lamellar constructions. Table 2 shows comparative characteristics of this class materials.

The SIAL materials of the basis of alloy 1441 exhibit a high crack resistance, specific strength, fatigue resistance, corrosion resistance, and decreased density. The use such materials as components of structural elements of flight vehicles will allow solution of the key problem: To increase strength, reliability, and service life and simultaneously decrease weight, thereby providing high performance characteristics.

REFERENCES

1. Dement'eva, L.A., Serezhenkov, A.A., Bocharova, L.I., and Anikhovskaya, L.I.., *Klei. Germetiki. Tekhnol.*, 2008, no. 1, pp. 14–16.
2. Lukina, N.F., Anikhovskaya, L.I., Dement'eva, et al., *Svar. Proizv.*, 2007, no. 5, pp. 19–27.
3. Fridlyander, I.N., Anikhovskaya, L.I., Senatorova, O.G., et al., *Sb. tr. mezhd. konf. "Sloistye kompozitsionnye materialy-98"* (Proc. Int. Conf. "Lamellar Composite Materials-98"), Volgograd, 1998, pp. 30–32, 86–88, 131–133.
4. Fridlyander, I.N., Senatorova, O.G., Lukina, N.F., et al., *Klei. Germetiki. Tekhnol.*, 2007, no. 5, pp. 15–17.
5. Senatorova, O.G., Antipov, V.V., Lukina, N.F., et al., *Tekhnol. Legkikh Splavov*, 2009, no. 2, pp. 28–31.