THERMOPLASTIC COMPOSITE AIRCRAFT STRUCTURE REPAIR METHODOLOGY

On the stage of the repair project, repairing and operating the repaired object arises a number of issues in material science and technology cases. Addressing these issues depends on the type of polymer composite material (PCM), the type of defect or damage, the chosen method of repair, repair conditions and requirements to restore the original characteristics of the product. The significance of the problems of material science knowledge for PCM parts repair can increase the reduction of bearing capacity critical components, particularly aircraft. In general, over the implementation of a quality PCM parts repair not only material scientists work, but also technological staff, educated in matters of connections and the designers of products.

To eliminate defects and damage to PCM parts adhesive compound is preferably used, which include adhesives, molded and welded connections. They can be combined with mechanical fastening, designed to relieve some of the disadvantages of adhesive joints.

For the repair parts come from PCM received during molding and product assembly optimal structure and properties. These structures and properties in detail are allowed to repair in such a level that they should retain as much as possible. Composition and structure of PCM because of their heterogeneity and heterophase often need to consider a greater extent than in the repair parts and products made from other materials

Applied to repair using adhesive joints is necessary, first, to consider multicomponent of PCM. Composition and properties of the components affect the occurrence of PCM defects in materials from them and in the compounds of these details. PCM components have different effects on preparation of the repair area, variously behave as in the repair process and the operation of the repaired details area. Knowledge of the composition of PM facilitates the analysis of the surface of the repaired parts wetted by some repair glue. In general, the polymers have a lower surface energy than, for example, metals, and therefore experience repairing metal parts using glue joints may not always be transferred to the case of the repair parts PM. If the surface is PCM "varnish" polymer layer, the condition of wetting it with glue:

$$\gamma_{pcm} > \gamma_g$$

(γ_{pcm} – critical surface tension of PCM, $\gamma_к$ – critical surface tension of glue) can't always be performed.

Preliminary assessment of the properties of the components of PCM located on its surface may narrow search for the most suitable adhesive for joining lining or can immediately indicate the need for purposeful preparation by modifying the surface to increase its energy. With the presence of a significant proportion of PCM composition of low molecular weight substances to be reckoned also in predicting behavior is reconditioned parts, for example, using glue or molded compounds. Migration of these substances from being repaired in PCM adhesive layer or overlay may change their properties and thus weaken the reinforcing effect attached to defective patches.

For low molecular weight substances in the PCM moisture can be attributed. If the repair items from PCM-based thermoplastic welding is carried out using a melt, it is necessary to assess the possible presence in the repaired parts of moisture adsorbed during storage or use of products. It is especially actual if the repair exposed parts, such as polyamide 6 and 66, which moisture absorption in air at 23 º C to saturation may reach 2.5-3.4%, or polycarbonate. Detection of moisture such products may require drying them before repair welding.

Due to the presence of fiberglass filler covered on the workpiece surface "lacquer layer" can be considered an effective removal of it by one of the types of machining. As a result, this can happen denudation of glass fiber and can create more favorable conditions for surface wetting glue or PCM to achieve intimate contact of bonded prepreg for the critical surface tension γs, for example, fibers of E - glass is much higher (γs = 425 mN / m) than γs thermoplastics (for example, PA 6 γs = 44 mN / m). However, it is hardly useful treatment for aramid-plastic as the surface energy polymeric filler (eg, fiber type HM-aramid γs = 30-40 mN / m), nestled film matrix, close to the surface energy of matrix. Simple as "deployment" of the surface in this case, as well as in the processing of non-polar thermoplastic can even give a negative result due to the imperfections of filling glue fleecy surface microrelief (Fig. 1.). The presence of fillers in the PCM that can exert an

abrasive effect on the cutting tool during machining allow the defective area, in particular when drilling holes inhibiting crack propagation at its ends or holes for injecting the adhesive into the bundle locations when finalizing the edges of holes, etc.

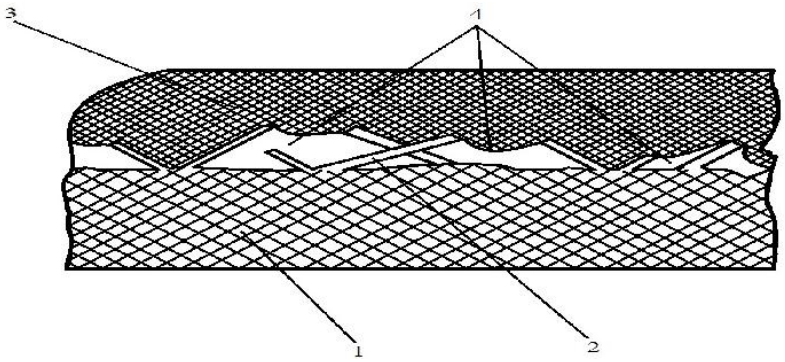

Fig.1. - Scheme of surface topography aramid-plastic treated sandpaper before applying the adhesive: 1 - aramid-plastic; 2 - loosened layer; 3 - Clay 4 - adhesive unfilled cavities.

Evaluation of the properties of the filler can significantly affect the choice of technology of repair PM. If a filler, such as carbon fiber is electrically conductive, the repair parts can be made of carbon fiber is not typical for the PM method (induction or electric resistance welding).

Because of the low content of the matrix in the surface layers of thermoplastic CM compared to unfilled thermoplastics possibility of defect-free weld joint is limited. To form the compound of the repaired parts of TCM and welded overlays may require the introduction of laying between the unfilled polymer. But all the problems of producing high-quality repair weld joint increase in the volume involved in the formation of the weld PM can’t be solved. When welding parts of TCM with an overlay with summing up the heat from the heated tool from the patch may be in breach of the reinforcing fibers laying scheme in detail, and in the patch. It is desirable that the above gasket was more fusible than the matrix of the repaired parts and linings, and still be uniform or consistent with them.

The mechanical properties are reflected on the technology of repair and restoration of the bearing capacity of the part or assembly.

Stiffening of patch, for example, by increasing the degree of filling or the orientation of the filler along the loading direction according to equation Folkersena:

$$\tau_m = \tau_{max}/(\Delta/2)^{1/2},$$

τ_m и τ_{max} – middle and maximum shear stress along the length l of the defective area of overlap overlay details; $\Delta = Gl^2 / E\ \delta\ d$, where G - shear modulus of the adhesive layer; E - tensile modulus of patch; δ - thickness of the patch; d - thickness of the adhesive layer, and equation:

$$L = K\,[(E_p / E_a)\cdot\delta^3\cdot d]^{1/4},$$

where L - length of the zone that receives the peel force of the bond patch on the repaired part; E_p - tensile modulus of patch; E_a - the modulus of elasticity of the material of the adhesive layer in tension; δ - thickness of the patch; d - thickness of the adhesive layer, K – factor favorably coefficient affecting the state of stress of a lap or T-shaped adhesive joints of the shear and peel, and leads to improvement of strength, and consequently the feasibility of the material properties of the repaired parts.

High strength of fiber also presents a challenge to restore it.

Because of characteristics of the mechanical properties based on the of unidirectional fibers should be borne in mind their anisotropy, and that strength and modulus of significantly higher than the polymer matrix.

Most attention for materials scientists, designers, and technicians in addressing repair, as well as assembly, it is necessary to pay the negative mechanical properties PCM such as low strength interlayer shear and wrinkling, low hardness, greater than that of metals, sensitivity to stress concentrators, creep under constant load.

Low strength in PCM crumpling when exposed to a concentrated load from the metal fasteners, tools or other items that have higher strength when damp, requires taking into account at all stages of repair work: the design, choice of materials, equipment and installation modes reinforcing patches , to repair work.

You can't overlook when repairing parts from PCM that the hardness of the polymers is much lower than the hardness of metals, ceramics, inorganic building materials. Precautions must be taken during repair work, to avoid the appearance of surface scratches and dents PCM serving as stress concentrators. How sensitive to certain types of stress concentrators PCM according to data tables.

Table - Tensile strength (MPa) and the stress concentration factor Kn for unidirectional CM based on different fibers and epoxy matrix

Sample	Reinforcement type		
	Kevlar 49	*E-glass*	Carbon
unnotched[1)]	394	287	427
notched[2)]	338	201	156
Kn	1,16	1,43	2,73

[1)]Width 25,4 mm; [2)] Side slit width 6,4 mm.

Because of the sensitivity to stress concentrators TCM recommended for repair welding to achieve a monolithic material in the weld zone and smooth transition from the weld to the base material.

If repair is necessary to avoid the formation of bonding is not filled adhesive sites between the insert and the workpiece or plate.

This is facilitated by techniques such as the application of a low-viscosity filling uneven ground, apply sufficient for the occurrence of rheological processes of glue, and on both surfaces: details and patch, creating a pressure higher than the pressure of volatile products formed during the curing reaction of the reactive adhesive, etc.

To eliminate the stress concentrators in the form of abrupt changes of cross sections in the repair area, it is necessary, for example, create, prepreg layers by molding patch segmental cross-sectional shape.

Lack of normal temperature plastic deformation in PCM does not allow them to edit and fit during repair. Manifesting forced elastic deformation during

subsequent operation of PCM can "show memory" and restore the original shape. Consequences of such a shape recovery is easy to imagine.

Some repair processes of products from PCM accompanied by heating or repaired material (for example, repair welding, drilling holes for the fastener in the result of heat cutting), or adhesive layer for repair melt adhesives, or both of them in the repair of reactive adhesives hot curing. Exposed to temperature extremes and repaired products during their operation. In this regard, knowledge of the characteristics heat - physical properties PCM is important for both the design process of repair, and to predict the behavior of the repaired area.

To solve the problem requiring repair summing heat from PCM products with low thermal conductivity is possible, using heating methods, which are based on the conversion of heat into other forms of energy, such as mechanical or electrical energy, or when using the repair welding providing heat from the tool, the heated gas, IR - emitter directly to mating parts and lining.

Thermal expansion characteristics are taken into account especially when repairing polymer parts using metal patch pasted or repair welding of parts from a local TCM summing heat (to the seam). Thermal shrinkage of the adhesive layer or weld material may cause residual tensile stress on the boundaries, respectively, "adhesive layer - metallic substrate" or "weld - basic material" which, in turn, can cause warping of the article or the emergence of cracks. Decides to consider the problem of convergence of values thermal expansion coefficient adhesive layer and connected material, as well as longer (if possible) the maintenance of the adhesive layer in an easily deformable state for a more complete relaxation of residual stresses. With the introduction of butt welding insert into the hole sheet metal thermoplastic preference should be given to the symmetric X-shaped seam, rather than V-shaped to create a symmetrical field of thermal stresses. It is also recommended to preheat the parts, and after repair welding weld annealing to produce products with the aim of stress relaxation.

On the processes of repair products and to restore them to the carrying capacity reflects the specific chemical properties of the PM and the ability to resist the effects of the environment.

In many cases, repairs in practice have to give a comprehensive assessment of the maintainability of the PCM. The greater the number of factors will be considered material science at the design and development of its repair process, the more reason to wait for restoration of bearing capacity from PCM products.