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REPAIR TECHNOLOGY OF THE COMPOSITE WING OF A LIGHT PLANE DAMAGED DURING AN AIRCRAFT CRASH

Summary. The increasing use of composite structures in aircraft constructions has made it necessary to develop repair methods that will restore the component's original design strength without compromising its structural integrity. In this paper**,** the complex repair technology of the composite wing of a light plane, which was damaged during an aircraft crash, is described. The applied repair scheme should meet all the original design requirements for the plane structure.
Keywords: light plane; composites; damage repair; wing.

1. INTRODUCTION

In Poland in recent years, following the experience of other countries in the EU, it has been observed that sporting activities based on the use of ultralight (UL) planes have been developing rapidly.

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In accordance with the Ordinance of the Minister of Transport, Construction and Maritime Economy of 26 March 2013, the class of UL planes is constituted in terms of machines intended to be used by amateur pilots, of which the stall speed or minimum horizontal flying speed in the landing configuration should not exceed 65 km/h, while the take-off weight should not exceed 450 kg (or 495 kg in the case of hydroplanes).

In accordance with the available data, there are currently more than 2,000 UL-class planes registered in Poland, of which the vast majority are mostly made from composite materials [1]. Alongside the increase in the number of planes in operation is the rise in the number of breakdowns.

Apart from ever more complex plane constructions, this situation makes it necessary to develop repair technologies in order to restore the initial structure of the construction, as well as its design strength. This issue is becoming more significant, particularly with regard to the difference between the technological level represented by the manufacturers of the planes of this type and that represented by the original equipment manufacturers (OEMs), as well as the methods applied in the course of repairing and operating them, especially as far as composite structures are concerned [2].

As a result, taking into consideration the still unsatisfactory level of the standardization of these methods, there is a need to collect the experience connected with them and generalize the data in question as far as possible.

2. IDENTIFICATION OF DAMAGE TO THE PLANE CONSTRUCTION AFTER A BREAKDOWN

In the course of an emergency landing of a two-seat UL plane (a low-wing monoplane), its structure sustained major damage.

The damage in question affected the front part of the fuselage (manufactured entirely of fibreglass and carbon fibres with the application of "sandwich" technology and possessing a honeycomb structure core), the front undercarriage and the wings on a 9 m wingspan. The left wing, of which 1,760 mm was burnt together with the main spar, and the aileron could no longer be repaired (Fig. 1).

Fig. 1. View of the fragments of the left wing of a UL plane burnt in an aircraft crash involving another UL plane (irreparable)

The reason for this was that it was impossible to reconstruct the main spar in such a way that its initial design strength would be restored.

After a detailed analysis, however, it was found that such a repair may be conducted on the right wing, in which the boom ribs were broken, while the Fowler flap protracting mechanism, which contained the right high-lift device, as well as the end of the wing, was destroyed.

3. REPAIR TECHNOLOGY OF THE WING

3.1 Construction of the wing

The section of the construction of the wing is presented in Figure 2.

A wing, made entirely of carbon fibres, has a rectangular outline with trapezoidal endings, the final parts of which are winglets. In the rear part of the wing, there is an electrically controlled high-lift Fowler flap[4], which is able to move on aluminium rollers fastened to the boom ribs. In the wing, there is an also a 39-litre fuel tank.

3.2 Description of the wing repair

The objective of the repair to the right aerofoil of the plane was to restore its initial structure and rigidity of it, together with the ability to carry design loads, while simultaneously maintaining aerodynamic parameters and restrictions, which result from the mass balance.

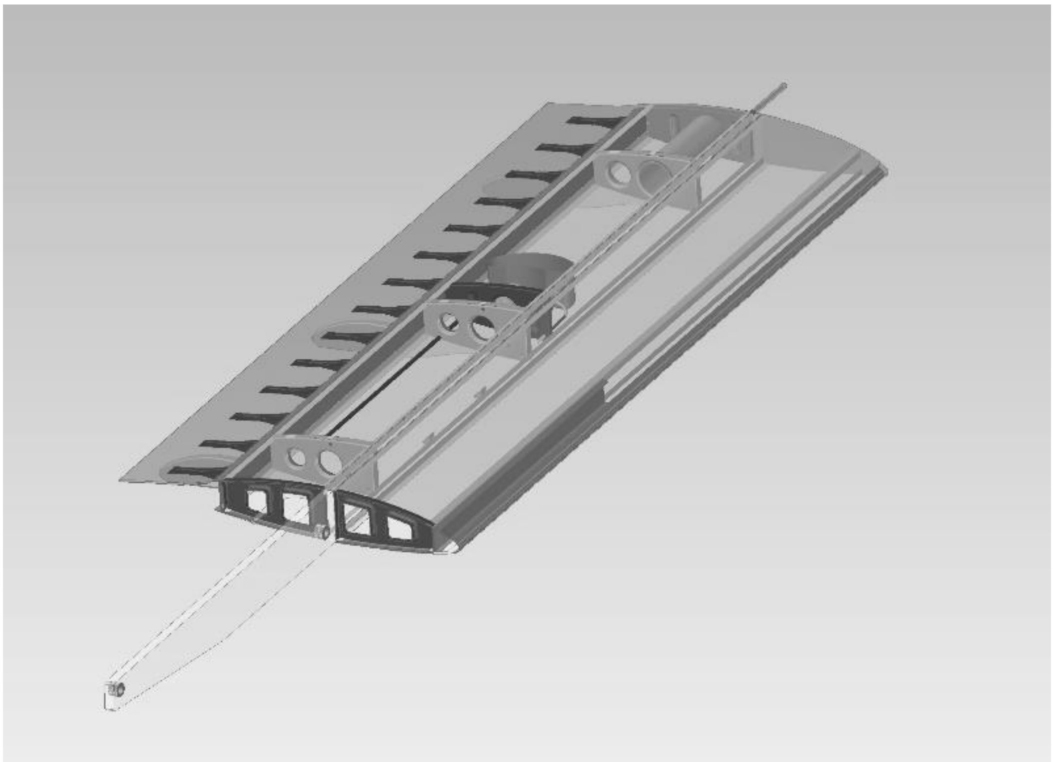
Fulfilling those requirements results in adopting the algorithm of subsequent operations in the way presented in Figure 3.

The wing repair was commenced by cutting out a fragment from its bottom shell plating, which was 120 mm on each side of the damaged rib no. 1, in order that it could be cut out with the application of a rotary saw.

This operation was repeated on ribs nos. 2 and 3 (Fig. 4), although there was an additional difficulty due to the fact that those ribs constituted the side panels of the fuel tank, which was inseparably connected to the construction of the wing, as show in Figure 5.

After removing the remnants of the cut-out ribs and grinding down the layer of the old adhesive, it was ascertained whether the new ribs could be located in their proper places in the structure of a wing, as well as whether there was sufficient clearance value to make it possible to correct the ribs' arrangement if that was needed.

[4] Fowler flaps are mounted on the rear part of the aerofoil and considered to be the most effective mechanical elements of it. Apart from the properties of slotted flaps (preventing air streams from detaching), they protract backwards as well, increasing the surface of an aerofoil, and, ipso facto, its lift. At the same time, in the case of a significant increase in the lift coefficient, Fowler flaps cause least resistance.



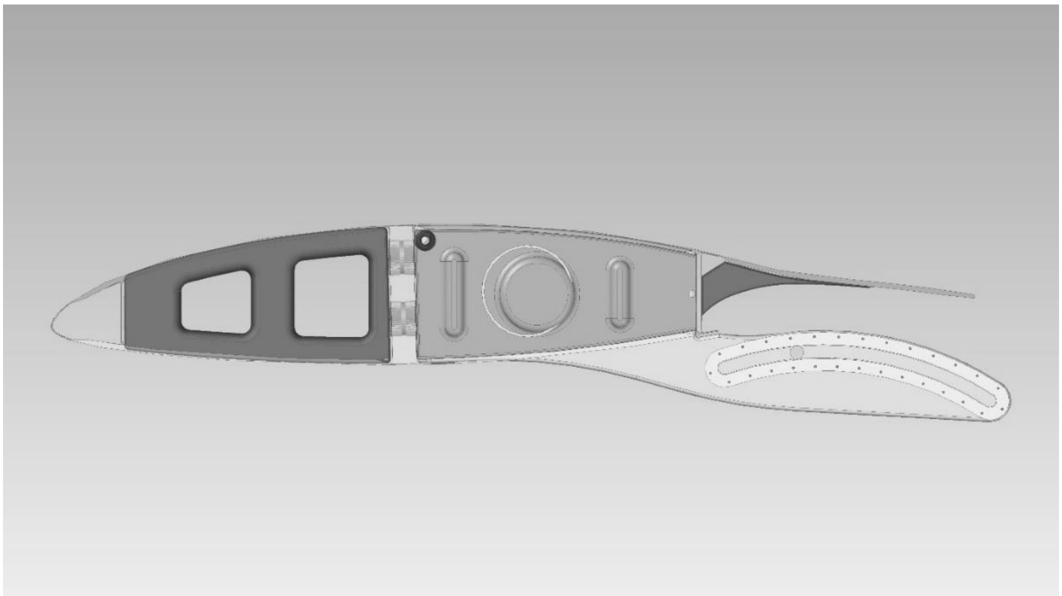


Fig. 2. Construction of the wing

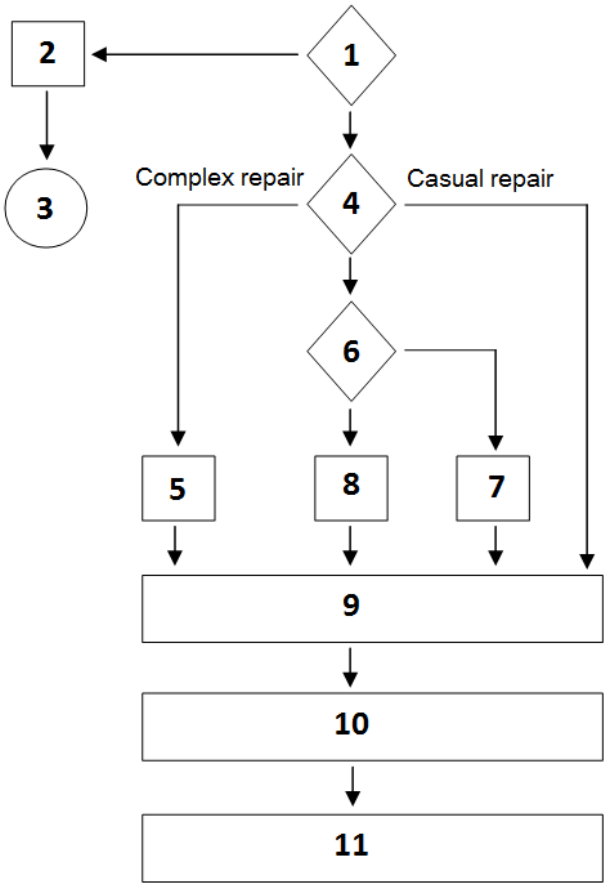


Fig. 3. Algorithm of the subsequent wing repair operations: (1) identifying the kind and scope of the damage; (2) irreparable damage; (3) taking the aerofoil out of service; (4) making a decision concerning the kind of repair; (5) together with the producer (or an OEM), establishing the repair scope and technology, as well as approving the repair; (6) determining the provisional repair scope; (7) establishing and accepting the provisional repair quality; (8) performing the provisional (airfield) repair in the period before handing the item over to a specialized workshop; (9) performing a permanent comprehensive repair in accordance with the adopted guidelines and the conditions of the producer; (10) controlling the quality of the performed repair; (11) putting the aerofoil into service again and mounting it on the plane

After finishing that work, a Fowler flap was mounted and fitted to the ribs in such a way as to guarantee its seamless movement on the rollers.

Subsequently, after the wing and ribs shell plating have holes drilled into them, these elements were initially joined with the application of connectors (so-called “hefts”). Once again, the control of the flap movement’s seamlessness was performed, together with that of the dimensions of the slot between the flap and the wing shell plating. Finally, the flap and the ribs were dismounted.

Fig. 4. View of the wing in the course of repair work

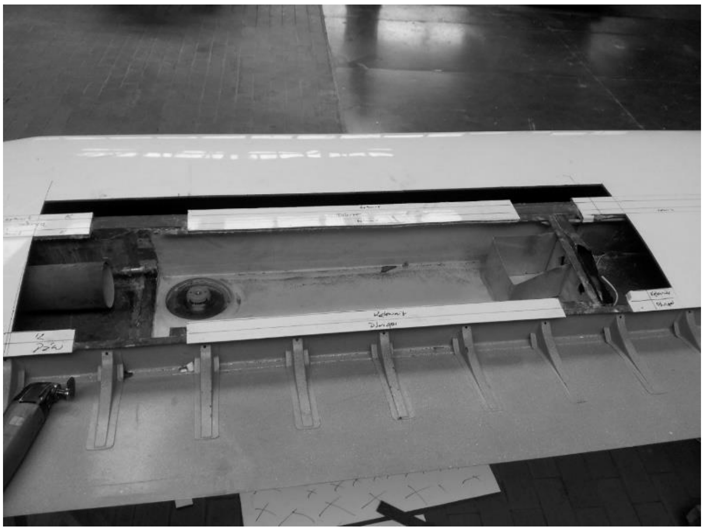


Fig. 5. Fragment of a fuel tank constituting the inseparable part of the wing construction

Subsequently, the parts along the rib edges, which were previously prepared and degreased with the application of acetone, while epoxy resin, thickened beforehand with cotton flakes, was applied to the places where they join the wing shell plating, were clamped with "hefts" after the application of adhesive. Any excessive quantity of the adhesive was also removed.

The high-lift device was fitted again and it was ascertained that the flaps could move seamlessly, which confirmed that the resin had dried and that the positions of the ribs, mounted with the use of the adhesive, were correct.

After gelling, the flap was dismounted. In the places of connection between the ribs and the wing shell plating, angle sections made of composite, based upon carbon fibre, were laminated in [3] in order to strengthen the connection.

The side surfaces of ribs nos. 2 and 3, constituting the side surfaces of the fuel tank (Fig. 5), were subjected to lamination. For that purpose, a composite based upon a fibre made of S-type glass, impregnated with epoxy resin, whose tensile strength amounts to σ_r = 882 MPa, and fuel resistant was applied. This step was also repeated on the remaining surface of the tank, with the surface in question subsequently covered with the TAPOX 2-k Epoxy sealant, made by Fertan.

The subsequent stage of the work involved making the new fragments of the wing shell plating.

For that purpose, in the place of connection between the old and new elements of the wing shell plating (at a width of 40 mm), the layer of the composite made of carbon fibre was removed, as was the Nomex[5]. The purpose here was to make it possible to conduct "overlap" fastening with the adhesive of the new shell plating bands, which were adjusted to the holes cut out of the wing (Fig. 6).

The new fragment of the fuselage shell plating, which was situated where the fuel tank was, was additionally painted with the TAPOX 2-k Epoxy sealant.

In the course of the work, particular attention was devoted to removing the excessive quantity of the adhesive (flashes) in the place of connection between the shell plating (Fig. 6), which, after the resin has dried, facilitates grinding and preparing 60 mm surface bands, on which the strengthening elements of those edges are laminated.

Subsequently, the surfaces being joined with the application of the adhesive were cleaned, then filled with the first layer of putty to cover the larger uneven areas, while defects on the surfaces were repaired.

Fig. 6. Shell plating mounting operation with the application of the adhesive, as well as the view of the right wing after its new fragment was mounted with the use of the adhesive

Mounting work was concluded by ascertaining the tightness of the fuel tank[6].

Having reconstructed the wing in such a way, it was then soaked in a furnace for a period of 16 h and at a temperature of 56 ^{o}C.

After the repair was completed as described above, it was possible to commence the subsequent stage of the work, which was the initial mounting (the so-called semi-mounting) of the wing.

[5] Nomex is a polymer from the Aramis group, which is characterized by simultaneously high mechanical and thermal resistance. Nomex is a registered trademark of DuPont.

[6] After closing the fuel cap and blocking the tank ventilation pipe by the pipe, which feeds fuel from the tank to the engine of the plane, we pumped air into the tank under low pressure. If air did not leak from the tank, the system was found to be tight.

This stage consisted of joining separate parts and sub-assemblies of the wing in order to ascertain the correctness of fitting and mounting, as well as the functioning of the control systems.

The initial mounting included the following activities (in the order given):

- mounting the aileron after previously covering the fittings with a lubricant and securing the pin with locking pins, followed by connecting its control system inside a wing
- ascertaining the correctness of mounting the aileron by controlling the clearance values, as well as the seamlessness and easiness of the movement of the entire system
- mounting the end of the wing, together with the navigation lights, as well as installing electric cables to them
- installing the dynamic air pipe to the pitot tube
- mounting a rotameter on the tank mounting, together with connecting electrical cables to it
- mounting the fuel pipe, which feeds fuel from the tank to the engine, the fuel cap and the special fuel in the lowest point of the tank
- mounting the electrical mechanism of protracting a Fowler flap from the wing and mounting the flap itself, as well as connecting the mechanism and the flap
- ascertaining the correctness of mounting the flap by controlling clearance values, as well as its seamless protraction

The wing prepared in such a way was initially mounted on the fuselage, after which the correctness and seamlessness of the functioning of the system was checked, followed by closing the main pins of the wing, as well as the auxiliary pins (front and rear). The dimension of the slot between the wing and the fuselage was also checked. The control systems were connected to the instrumental panel in the fuselage.

Afterwards, the wing was dismounted and handed over for lacquering. In order to limit the increase in the mass resulting from the repair, the old lacquer was grounded. The surfaces being repaired were filled with putty, then painted with a filling primer. Finally, the wing was painted with an acryl lacquer. The entire preparation process for the painting, as well as the painting itself, was conducted manually.

After concluding the painting process, the wing was again mounted on the fuselage in the course of the final plane mounting.

The following were also performed:

- mounting the plane anchoring handle
- controlling the tightness of the fuel tank when it is 100% filled
- mounting the peephole cover on the wing
- installing a special “platform” for standing on the wing, together with the call signs of the plane, which were cut out of high-quality decorative foil

The assembled airframe was set in the position for horizontal flight, the purpose of which was to level the airframe, which involved checking its geometry in accordance with the levelling sheets at our disposal. Afterwards, with the use of a special protractor, the inclination angles of the ailerons and the flaps were checked, regulating their inclination values on pushers or limiters in the control system.

4. SUMMARY

Upon the basis of the experiences collected in the course of repairing the wing of an UL airframe with a composite structure, it is possible to indicate that what seems to be the essential problem is the assessment of the character of damage and the possibility of removing it, so as to restore the design parameters of the structure in full. Such an assessment is relevant in terms of both technical (the selection of repair technology) and financial aspects. It is possible to estimate that, as in the described case of using conventional methods of repairing composite structures, the cost of restoring the structure of the right aerofoil alone constitutes approximately 35-45% of the purchase cost of a new element. However, this is dependent upon the degree of damage. This paper describes all the processes for repairing a plane, commencing with its delivery to the workshop to inspecting the entire airframe, repairing the airframe sub-assemblies, painting the plane, and mounting the airframe for the purpose of conducting tests on the ground and in the air.

After checking the geometry of the plane in such a way, we may be sure that the plane will be flying as it should, will maintain its handling qualities.

References

1. Kelly Tony, Bill Clyne. 1999. "Composite materials: reflections on the first half century". *Physics Today* 52(11): 37-41. ISSN 0031-9228. DOI: 10.1063/1.882882.
2. Katnam Kali-Babu, Lucas Da Silva, Trevor Young. 2013. "Bonded repair of composite aircraft structures: a review of scientific challenges and opportunities". *Progress in Aerospace Sciences* 61(2): 26-42. ISSN 0376-0421. DOI: 10.1016/j.paerosci.2013.03.003.
3. Soutis Constantinos. 2005. "Fibre reinforced composites in aircraft construction". *Progress in Aerospace Sciences* 41(2): 143-151. ISSN 0376-0421. DOI: 10.1016/j.paerosci.2005.02.004.

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