UDK: 629.725.025:614.84
COSATI: 01-03

Repair of G4 Aircraft Heavily Damaged by Fire

Milutin Martinović, BSc (Eng)[1)]

Extensive airframe and system damage caused by fire in oxygen installations on two Super Galeb G-4 aircraft is discussed in this paper. The assessment of the damage extent along with the damage inspection and repair possibility are also presented. Fixation of the fuselage structure to maintain the original geometry during repair is described. The repair project, the production of necessary tools and the structure repair realization with the final aircraft testing for the first after-repair flight are shown. Finally, an attempt to establish possible causes of fire is made.

Key words: **aircraft, training aircraft, fighter, aircraft structure, fuselage, structural damage, fire, repair.**

Introduction

TWO G4 aircraft based at two different airfields had the same type of accident over a short period of time, which put these aircraft out of service [1]. During the refill of oxygen tanks on the ground, an explosion occurred in the area of the tank valve, which led to a huge fire that was extinguished by the ground personnel. These dramatic accidents were aggravated by the fact that one of the aircraft was armed and fully refuelled. But awareness of the situation and readiness of the ground crew enabled the fire to be localized and finally extinguished without casualties. This kind of accident has never happened during the long service of G4 aircraft, since its first takeoff in 1978. Representatives of the VTI analyzed the conditions of both aircraft on the site and found out that load carrying structures and systems had suffered serious damage. One of the aircraft, although heavily damaged, had good repairing possibilities. The other aircraft was so severely damaged that it was possibly beyond repair and the cost-effectiveness of the repair was questionable. Since both aircraft were highly expensive and they had arrived shortly before from the general overhaul, necessity for bringing them back to service was evident. An aircraft which has undergone an overhaul could be considered as a new one. Since a considerable amount of money was already spent, an additional investment in its repair was justified. That investment would be negligible compared to the basic value of the overhauled aircraft.

The type and extent of damage were of such proportions (Fig.1), that standard repair procedures and instructions were useless. It was necessary to comprehensively assess the extent of the damage and define an original repair project for each aircraft depending on the damage. Due to the seriousness of the damage on the load carrying structures and systems, it was decided that the project of repair [2] for both aircraft would be done by the VTI Aircraft Division while the UTVA Pancevo Aircraft Industry would carry out the repair of structures and systems. In order to reduce costs to the minimum, it was decided that the Air base at the airfield would carry out a considerable part of aircraft preparation for repair and the final tests as well. Both aircraft were transferred from their units to the Air base, where they were disassembled and the equipment from the front aircraft section was dismounted. Thus prepared, the front fuselage parts were transferred to the UTVA Pancevo AI for further repair. In order to make the work faster, it was decided that the aircraft with a smaller extent of damage would be repaired first (first aircraft), and then the aircraft with considerable damage (second aircraft). This would allow the experience gained during the work on the first aircraft to be used on the second one.

Figure 1. Damaged structure after the fire

Analysis of possible fire causes

A comprehensive investigation was conducted to find out the cause of fire. Besides the VTI (Aircraft System Division), the Aeronautical Plant “Moma Stanojlović” and the Faculty of Technology of Belgrade University took part

1) Military Technical Institute (VTI), Ratka Resanovića 1, 11132 Belgrade, SERBIA

in it. The oxygen system elements were stripped down from the damaged aircraft and submitted to rigorous testing as well as compared to the same class of elements on aircraft not involved in accidents. The fire broke out on a special 5-port valve, so the valve was submitted to a detailed scheduled endoscope examination. Certain deviations were found on the valve elements, also some thread damage, presence of sawdust, some dirt, but not in quantities sufficient to cause the fire. Laboratory examinations were also conducted on oxygen bottle parts. All gaskets were examined. They showed the signs of deterioration at temperatures over 400^{o} C, which is higher than working temperatures. The tests were executed by “Moma Stanojlović” and the Faculty of Technology.

The oxygen and nitrogen stations were also tested. These stations could not precisely control the difference in pressures between the refilling pressure and the pressure in bottles, so operators had to rely on their skill and experience. The pressures are simultaneously monitored, both at the station and on the cockpit instruments. The pressure difference must be less than 15 bar. Even the maximum allowed pressure difference cannot raise the temperature in the valve and cause spontaneous ignition. A large number of simulations in experimental, real-life conditions of oxygen refilling not in one case gave the ignition as a result. All these examinations did not give any undoubted cause of fire during oxygen refill.

In the future, it will be necessary to increase safety measures, the level of following the existing instructions and the level of technological discipline. Furthermore, additional measures were issued in order to prevent or diminish risks: the process of filling is slowed down to reduce the oxygen flow rate through the 5-port valve. Better equipment maintenance and strict following of the procedure of oxygen station handling are insisted upon as well.

Aircraft mounting on the assembling JIG

Aircraft mounting had to be solved before the beginning of damage detection and repairs. The first aircraft was placed on the JIG with four cranes for hoisting the aircraft at fuselage frames No.10 and No.26, as shown in Fig2. This JIG was formerly used during the G-4 serial production. It was not possible to implement the same procedure to the second aircraft, since the whole section of joints for hoisting the aircraft at the starboard of frame No.10 was destroyed and had to be reconstructed.

Figure 2. Mounting assembly for the first aircraft

For the mounting of the second aircraft an assembling JIG (haling) was used, shown in Fig.3, the same assembly structure that was used during the aircraft production for the assembly of the cockpit section and the fuselage central section. This tool was modified in order to reduce static loads of the aircraft during repair. The aircraft was connected to the tool at frames Nos.5 and 21, which was a relatively wide range for an aircraft as damaged as this one, since 50 percent of the fuselage cross-section was missing. To prevent bending and twisting of the fuselage during repair, new mounts were added to the tool at the position of No.10 frame, both left and right ones. The left mount was used during the whole period of repair, whereas the right one was just a temporary solution, since its role was taken over by a permanent mount at the position of frame No.8. This assembly tool provided a high quality repair with full comfort.

Figure 3. Assembly tool for aircraft mounting

Owing to its complexity and quality, this tool satisfied all demands for the repair. If this tool had not been available, it would have been necessary to design and produce it. This would have put the whole repair project in question, since its cost would have jeopardized the cost-effectiveness.

Damage detection

The fuselage structure damage was inflicted by simultaneous mechanical and thermal effects (explosion and intensive heat). Mechanical damage comprised structural destruction, bending and twisting, wrinkled sheet structure, cracks, etc. These types of damage are easily detected, but damage caused by high thermal strains, very hard to detect, represented the main problem.

The basic load carrying material is duralumin with a melting point of 660°C. Since some parts of the support structure were completely destroyed by fire, the temperature in the fire center must have been higher. As a consequence, the heat-affected zone shifted from the fire center. For damage detection of heat-affected aircraft structures, visual inspection is of utmost importance. It enables establishing the correlation between the damage extent and the temperature, on the basis of the change in colour of the damaged structure exposed to high level temperatures. In order to determine the boundaries of the heat-affected zones, it is necessary to monitor the structure color changes (burnt, blistered, black, dark brown, slightly darkened and base color). Every change in color represents a different heat effect on the load capacity of the structure.

A slightly darkened base color indicates that the structure was exposed to a temperature of around 150°C in a short period of time, which does not significantly affect the load capacity; it, however, increases the future corrosion probability. If an element with a similar color remains on the aircraft, it has to be repainted and protected. On this aircraft, all heat-affected elements were replaced in order to prevent corrosion during future service. Temperatures of 250°C and higher significantly affect load capacity of the structure and resistance to corrosion. Table 1 shows the changes of the base color of the damaged elements and the 7075-T6 duralumin properties [8].

Table 1. Dependence of color and material properties

	Rockwell hardness	Color	σ_m daN/mm^2	σ_{02} daN/mm^2
1	B38-40	black	30.0	14.7
2	B52-56	black	37.5	18.5
3	B61-64	brown	39.5	29.5
4	B72-80	light brown	44.0	33.5
5	B80-82	base color	52.3	45.0
minimum values for duralumin 7075-T6			50.5	43.5

High temperature effects are closely connected to the geometry of structural elements, e.g.: sheet metal aircraft structures are highly susceptible due to their low thickness compared to massive elements such as mounts, etc.

Heat effects on the structure caused total burnout of duralumin, melting, bending, wrinkling, and change in material structure. A characteristic duralumin aircraft structure exposed to high temperatures is shown in Fig.4.

Visual inspection was performed for a rough damage estimation and the damaged elements were removed (cracks, buckling, torn connecting elements, structural breaks, burnt elements, melted material, and elements with burnt and deformed paint).

Figure 4. Burnt duralumin structure

After the removal of the damaged elements, the repair zone boundaries were determined in order to determine which structural elements would be repaired and which would not. The basic requirement that had to be met was to determine the locations of the basic load carrying material with intact mechanical characteristics, bearing in mind that it was necessary to take into account technical specifications for exact determination of repair boundaries. Mechanical properties were tested by testing hardness and tensile strength at the boundaries of repair zones.

Material hardness of dismantled structural elements and parts around the zone assumingly affected by the accidents were tested in a classic way. Disassembled for inspection and cleaning, particular structural elements were tested by the same method (mostly control elements, mounting brackets, etc.). These tests were done by the UTVA Pancevo AI with the assistance of the VTI.

A portable device was used for testing hardness of the structural material left on the aircraft repair zone boundaries. This device was a property of the Aeronautical Plant Moma Stanojlović. The applied non-destructive method was Leeb-testing, named after its author Dietmar Leeb.

Testing was done at sixty points on the aircraft structure on the repair zone boundaries. During the testing of affected structures, a certain number of control points (check points) at a safe distance from the destroyed structure were selected. The results obtained at the control points showed a high level of dissipation and did not satisfy the project requirements. The measurements taken at the control points also showed considerable deviations from the undamaged material properties. The tests pointed out to a strong influence of the surface elasticity (thin sheet structures), which made the results unreliable. Applied to bulk elements, this method gave more accurate test results. The general conclusion was that the applied test method was not suitable for the considered structure types.

In order to obtain accurate results for the boundary zone, it was decided to do direct material testing for tensile strength. Thirty four mini samples were taken from the boundary zone and tested on a tensile machine in the laboratories of the MTI. The analysis of the results indicated that the tensile strength values were between 42.5 and 47.4 daN/mm^2, which corresponds to the values for the 3.1364-T42 material.

Table 2. Tensile test results

Sample No.	Braking force F (N)	Tensile strength (daN/mm^2)	Sample thickness (mm)	Material type
6	5298	44.2	1.2	3.1364.T3
8	5104	42.5	1.2	3.1364.T3
15	5210	43.4	1.2	3.1364.T3
19	5712	47.6	1.2	3.1364.T3
27	6980	43.6	1.6	3.1364.T42
28	7345	45.9	1.6	3.1364.T42
31	4750	47.5	1.0	3.1364.T42

This confirmed that only the undamaged material was within the repair zone. It was also needed to take under consideration the design and technological issues when deciding where the boundaries of the repair zone would be.

Damage description

In both aircraft, the damaged structure was located only on the starboard fuselage, the second cockpit section. Since the damage of the second aircraft was much more severe than the first one, the following description will mostly refer to the second aircraft. The detection of damaged structure and systems was done by degrees, in order to gradually reach the undamaged structure. The center of the structural damage was detected below the floor of the second cockpit, between the starboard of the keel and the skin panels, and in the direction of the longitudinal axes between frames Nos.11 and 13. The cross-section of the fuselage structure, after the fire, is shown in Fig.5. It is evident that the fire damaged approximately 50% of the structure.

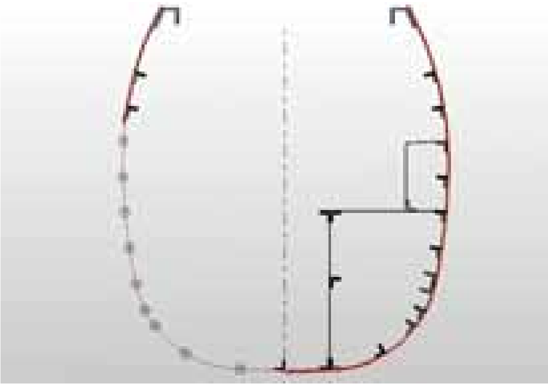

Figure 5. Undamaged fuselage structure in the zone of fire (bolded)

The damaged fuselage load carrying structure is listed below:

1. six frames (frames Nos.9, 10, 10a, 11, 12, 13);
2. side and ventral skin (between frames Nos.9 and 14, and from stringer No.5 till the central line of the aircraft on the ventral side);
3. steel skin in the gun section;
4. right wall of the keel between frames Nos.10 and 14
5. floor of the second cockpit from the left wall of the keel to the right skin panel and a part of the first cockpit floor
6. right side skin panel stringers Nos.6, 7, 8, 9, 10, 11, 12 and 13;
7. lower, upper and middle keel stringers (four stringers in total);
8. right side floor stringers;
9. three keel webs, Nos.11, 12 and 13;
10. all hatch doors and covers;
11. all other load carrying and non bearing structure in this section;
12. right panel in the second cockpit and a part of the right panel in the first cockpit.

The extent of the damaged structures was 1500 mm in length, 900 mm in height and 650 mm in width. Some damaged and partially cleaned basic structure parts are shown in Figures 6 and 7.

Figure 6. Partially cleaned aircraft after the fire

Since the damaged structure was under the second cockpit where a number of aircraft systems are located, most of these systems were damaged in the accident. The systems with substantial damage were:

1. Primary aircraft controls (aileron, elevator and rudder control);
2. Secondary command controls (parking, mechanical unlocking of the landing gear, mechanical rejection of under–carrying loads and locking of cockpit hatches);
3. Electric system in the front part of the fuselage (48 parts, including 37 bunches of conductors);
4. Electronic system (42 beams of conductors and 7 co-axial cables);
5. Complete oxygen system;
6. Cockpit pressure and air-conditioning system;
7. Parts of the anti-g pressure suit system;
8. Ejection system;
9. Part of the hydraulic system.

All the facts presented, it is evident that structural and system damage was severe and that it was necessary to make a very detail repair plan, to do the repair with utmost precision and to do the final aircraft testing before the first flight.

Figure 7. Damaged structure after the fire

Project of repairs

After doing a comprehensive identification of all aspects of the damage as a consequence of fire, the next step was to prepare a detailed project of repairs. Since the project of G4 aircraft was done by a standard method (on paper), it was decided to use the same method for a repair project with the maximum use of UNIGRAPHICS design computer software. The silhouette and the analysis needed for the project development were done using this software. The imperative was that the repairs to be done must not restrict the aircraft structure or systems during the exploitation in the future. The project for system repair instructed that all system elements that were destroyed or damaged had to be replaced with new elements according to the original documentation of the aircraft. Some elements allowed to be dismantled, repaired, and returned to the aircraft. The procedures of system repairs had all required documentation attached. After the repair all systems had to fulfill the requirements defined by the Product Quality Regulations (PQR).

The project of structural repairs [6] was much more complex that the one for system repairs. The basic principle that had to be implemented during repairs was that aerodynamics had to be intact. Therefore, repairs had to be done in such a way that after them it would not be possible to notice that any work was done on the aircraft, without detailed inspection. All new elements that were used had to be integrated into the aircraft original silhouette. This principle was neglected in one case, while joining steel skin panels to the ventral side of the aircraft, in order to avoid major complications. In order to keep the repairing process as simple as possible and to keep costs at the minimum, the connections between old and new skin panels were done outside the silhouette in the air intake panel section. These procedures allowed aerodynamic characteristics of the aircraft fuselage to be completely preserved. The design of new elements was done according to the original documentation, with no regard to possible discrepancies that happened during manufacturing of this aircraft. All inconsistencies, if any, were solved during the repair. Two types of structural elements were considered: those built in according to the original documentation (75 elements) and new designed elements (87 elements). The new elements, used to connect the original structure with the new one, were thus designed to sustain at least as much load as the original elements or slightly more. Simplicity of solutions in order to achieve an easy repair process was a must. The overall mass of the aircraft was insignificantly increased due to a great number of joints, without any consequences. During the design process it was necessary to solve approximately 40 knots. The length of joints on the skin panels and floors was about 8000 mm. More than 160 new structural elements were built into the aircraft. The repair documentation was exhaustive and consisted of approximately 80 blueprints, 10 of which were of A0 format or larger. The documentation that backed up the design was also relatively large (defect identification lists, instructions, etc.)

Static calculation of repairs

A standard static calculation for the aircraft was carried out. It was logical to do the calculation for the repair in the same way. The detailed calculation of load capacity was done separately for each element which connected the new and the old structure followed by the inspection of all standard elements that were connected [7]. Loads used in this calculation were not the same ones as for the aircraft as a whole. It was considered that each new element had to resist the same stress as the original element (before repair). For each element, the stress considered in the calculation should be determined regarding the position of that element in the overall structure (frame, stringer, skin panel, wall, mount, etc.) and the kind of stress (pressure, tension, torsion, bending). This approach allowed staying on the safe side, because some of the original construction elements were never under the maximum stress. The new structure could at least resist the same, if not probably even higher stresses as the original ones.

Repair realization

The aircraft repair was done in the UTVA Pančevo AI. Since the factory did not produce the cockpit section for the serial G4 aircraft, it lacked the tools.

In order to start with repair, it was necessary to design and produce a large number of tools for manufacturing structural elements. Tools for manufacturing frames, diaphragms, stringers, hatches, enforcements and all elements that were used to connect structural elements were manufactured. It was necessary to design and manufacture 55 different tools. The only original tool that could be used was the assembly tool (haling) for the assembly of cockpit and central fuselage section, Fig.3. Since this tool originally had entirely different use, it was repaired and modified in order to fulfill all the requirements and it was used for mounting the fuselage during the repair.

Figure 8. Prepared structure for the integration of elements

The cost of the modification of this tool was higher than the cost of the manufacture of all other tools together; it was, however, significantly lower than the cost of design and manufacture of this tool from scratch. This tool allowed for a considerable reduction of repair costs. For tool design and manufacture and haling modification, 2556 man hours were needed.

Since the aircraft was covered with dirt from fire and fire extinguishing foam, detailed cleaning, vacuuming and washing with appropriate agents was necessary in order to prepare the structure for further work. Conveniently, the applied foam was not corrosive.

Figure 9. Forming of the keel structure

The repair process was very complex and demanded precise and comprehensive technical preparations in order to achieve high-quality results. All elements, during the assembly, had to be fitted with utmost precision due to very strict tolerances. Separating riveted elements of the structure and disassembling had to be done very carefully, since it was imperative not to widen holes of connecting elements. The elements to be built into the structure were supplied with required additions in order to be compatible with the aircraft structure. The port wall of the keel (Figures 8 and 9), was first assembled and then the starboard wall. The new keel was thus formed as a compact unit. In the keel interior, mounts for the control stick and other control commands were installed. The next phase included the assembly of new ribs and their connection with the existing structure. The net of stringers was then formed (Fig.10) and joined with the existed ones. The method used allowed for

Figure 10. New formed fuselage structure

forming highly compact fuselage structure as a whole (Figures 10 and 11). The next phase was the assembly of the skin panels (Fig.12) and the cockpit floor and their final installation. As many parts of skin and floor were damaged and it was necessary to join and bridge several dozens of structural elements, the problem of hermetization of cockpit space emerged. Because of that, adequate procedures had to be foreseen to realize efficient sealing. Since the producer did not have the cockpit at his disposal, the test of hermetization had to be conducted only after the aircraft assembly in the air base. PRC polymerized mixture was used for hermetization. This mixture was applied to each contact surface between two elements as well as to upper parts of all connecting elements, as recommended by SNO 4604 Standard. The complex structural repairs were successfully performed, with high quality, by the UTVA Pančevo AI. These repairs are shown on a series of photos taken during the repair.

The whole repair process was recorded on a large number of digital photos, which were also used for quality control. Digital photos proved valuable in capturing hardly accessible areas.

The system repair was the next step after structural repairs. Utmost concentration was necessary in separating the undamaged system parts from the damaged components, deciding on what had to be discarded and what had to be revitalized and put back onto the aircraft.

Major difficulty was to install cables, since almost all of them were damaged by fire, and they had to be replaced in full. All cables from the front fuselage section were replaced. Bundles of wires with connectors were formed on workbenches and then built in, which was very difficult due to many hardly accessible zones. Complexity of this task could be seen in Fig.13. After the installation of cables, complete testing followed. Hundreds of cables had to be tested and each of them had dozens of wires. All other systems have also been installed and tested. The repair of the first aircraft took 5000 man hours, the second one took 16802 man hours and the design and manufacturing of tools took 2556 man hours.

Figure 11. New formed structure of the second cockpit

Figure. 12. Precise integration of a skin panel on the side of the second cockpit

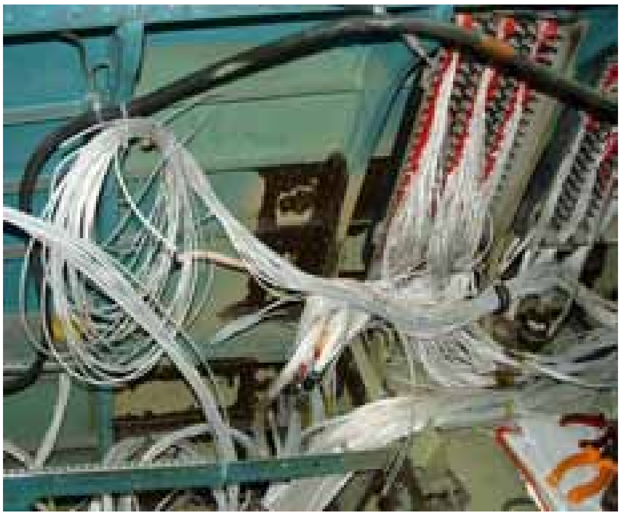

Figure13. Wiring installation into the cockpit sides.

Final aircraft tests

After the successful repair, the front fuselage section was returned to the Air base, where the aircraft was reassembled. The program of the final testing was defined as follows:

1. Electronic tests of all command circuits were done (calibration, deflection, stiffness). All tests results were within the required ranges. The tests were performed by the AP Moma Stanojlović;
2. All tests of aircraft geometry, silhouette and position of the landing gear were done, and all the results met the requirements. The front fuselage section remained of the same shape, geometry and dimensions although extensive repairs were done. The external silhouette of the aircraft in the area of the repair was identical to the original silhouette, presented in Fig.14, owing to adequate measures and good mounting tool (haling). These tests were done by the Flight Test Institute (FTI);
3. Being out of service for a considerable period of time, the aircraft had to have maintenance inspections after 300 hours of flight. This is the most comprehensive inspection of an aircraft with the most extensive work, except for general overhaul. This work was done by the Air base;
4. Testing of the hermetically connected elements was necessary since the major part of the fuselage side and the cockpit floor were replaced according to the relevant Product Quality Regulation. This was done by the Air base.
5. Testing of oxygen installations will be done by the UTVA Pancevo AI.
6. After the completion of all activities, the mass and C.G. position were measured. It was found that the mass increase and C.G. movement were negligible.
7. All the work was crowned by the first flight, performed smoothly by a FTI test pilot, without a single complaint about such a complex work.

The VTI had a considerable part in final testing since it defined the testing program and then significantly contributed to the control and verification of the results. The test flight, requested by higher instances, was performed by a test pilot from the FTI, after repairs and ground testing due to the extent of repairs.

Figure14. Aircraft at the end of structural repairs

Conclusion

The above described repairs have been performed very effectively on both aircraft and they subsequently returned into the service. The repairing costs were reasonable, taking into consideration that both aircraft had had general overhaul some time before the accident, and they justified all the work performed. The repair of these two aircraft depicts high potentials of technical staff of Serbia's aircraft industry.

References

[1] MARTINOVIĆ,M.: Possibilities of heavy fire damage repair on G4 aircraft", OTEH-2005, Belgrade, SERBIA, 2005.

[2] *Project of the repair of G4 aircraft damaged by fire*, Military Technical Institute, Belgrade, SERBIA, 2004.

[3] *Report on results of examination of oxygen bottles explosions on N62 plane* V6-0911-I024, Military Technical Institute, Belgrade, SERBIA.

[4] *Endoscopic diagnostics of the five lead valve assembly and high pressure oxygen bottles* DC/GŠVJ-TU-1/I-03, VZ Моме Stanojlović.

[5] Manual for F-86 SABRE T.O.1F-86A-3"

[6] *Manual for the repair ORAO aircraft*, Military Technical Institute, Belgrade, SERBIA, 1988.

[7] *Calculation for the repair of an aircraft damaged by fire*, Bogdan Bogdanovic, MITT publication, 2004.

[8] *Acceptable Methods, Techniques, and Practices-Aircraft Inspection and Repair*, Federal Aviation Administration FAA AC No.43.13-1A, 1988.

Received: 25.05.2007.

Veliki požari na avionu G4 i sanacija

U ovom radu dat je prikaz velikih oštećenja strukture i sistema na dva aviona G4, kao posledice požara na kiseoničkoj instalaciji. Daje se prikaz procene stepena oštećenja sa defektažom i mogućnostima opravke. Predstavljeno je rešenje prihvatanja strukture trupa u toku opravke rada očuvanja geometrije aviona. Prikazan je projekat opravke, izrada neophodnih alata, realizacija opravke strukture sa završnim ispitivanjima aviona za prvi let. Izvršeno je sagledavanje mogućih uzroka požara.

Ključne reči: **avion, školski avion, borbeni avion, struktura letelice, trup aviona, oštećenje konstrukcije, požar, opravka.**

Большие пожары на самолёте Г4 и ремонт

В настоящей работе показаны большие повреждения конструкций и систем на двух самолётах Г4 как последствие пожара на кислородном устройстве (оборудовании). Здесь приведены оценки степени повреждения с отыскиванием отказов и с возможностями ремонта. Тоже представлено решение закрепления планера фюзеляжа в течении ремонта с целью сохранения геометрии самолёта. Затем приведён проект ремонта, выработка необходимого инструментария, реализация ремонта планера со конечными исследованиями самолёта для первого полёта. Тоже сделано рассматривание возможных причин пожара.

Ключевые слова: учебный самолёт, боевой самолёт, нланер самолёта, фюзеляж самолёта, повреждение конструкции, пожар, ремонт.

Grands incendies sur l'avion G4 et réparation des dégâts

Dans ce papier on a présenté les dégâts importants sur les structures et systèmes de deux avions G4, comme conséquence d'un incendie sur l'in- stallation d'oxygène. On a donné aussi le tableau d'estimation du degrès des dégâts avec défection et les possibilités de réparations. Une solution pour la fixation du fuselage pendant la réparation est proposée dans le but de sauver la géométrie de l'avion. Le projet de réparation, fabrication des outils néces- saires, réalisation de la réparation de la structure avec les essais finals des avions pour le premier vol, ont été présentés aussi .Les causes possibles de l'incendie ont été examinés.

Mots clés: **avion, avion école, avion de combat, structure de l'aéronef, fuselage, endommagement de construction, incendie, réparation.**