Chapter

Design Approaches for Safety Increasing and Risk Decreasing for the Civil Aircraft's Operation

Dmytro Tiniakov

Abstract

The safety and risks of civil aircraft operation depend on a lot of factors. One of them is the structural features of an aircraft. In aviation history, there are examples when "non-rational" design solution was the reason for crashes, but there are examples about successful civil aircraft that have "rational" structure and long operational time without critical incidents. So, how can a designer provide high safety of level and decrease incidents' risks in time of a regular aircraft operation? This chapter partly can help to understand some reasons and approaches for providing "rational" aircraft structure. Design solutions can be divided into some groups by some common features and requirements. They are maintainability, serviceability, accessibility, labor effort decreasing, weather requirements, transportation, etc. All these groups depend on engineers' structural solutions. They are interdependent and often contradictory. In other words, if one of the features will be better, another will be worse at the same time. And, a designer must remember all the time about this and try to find compromise between different requirements. The successful commercial aircraft is composed of a set of rational design solutions for these specific tasks.

Keywords: aircraft, design solutions, maintainability, serviceability, safety, risk

1. Introduction

In the processes of civil aircraft operation, there is a need to solve the problems of ensuring safety and reducing risks, taking into account environmental factors, human factors, etc. [1]. Two ways to solve such problems are by decreasing number of risks and increasing reliability on the basis of the deep risk analysis [2–4]. In both cases, risk analysis must be.

The problem of risk control is prevalent nowadays. Risk is a complex issue.

A continuous improvement in safety is due to several factors, and aircraft have become more reliable.

Safety systems have been developed significantly. A number of design solutions had a significant impact on decreasing accident rate, including improving the aerodynamic characteristics and design of the liner, improving the criteria for fault tolerance of the structure, improving the cockpit instruments, and increasing the number of aircraft with automatic control flight.

Scientific advances have also enabled the aviation industry to understand better how the human factor affects flight safety. At the same time, significant

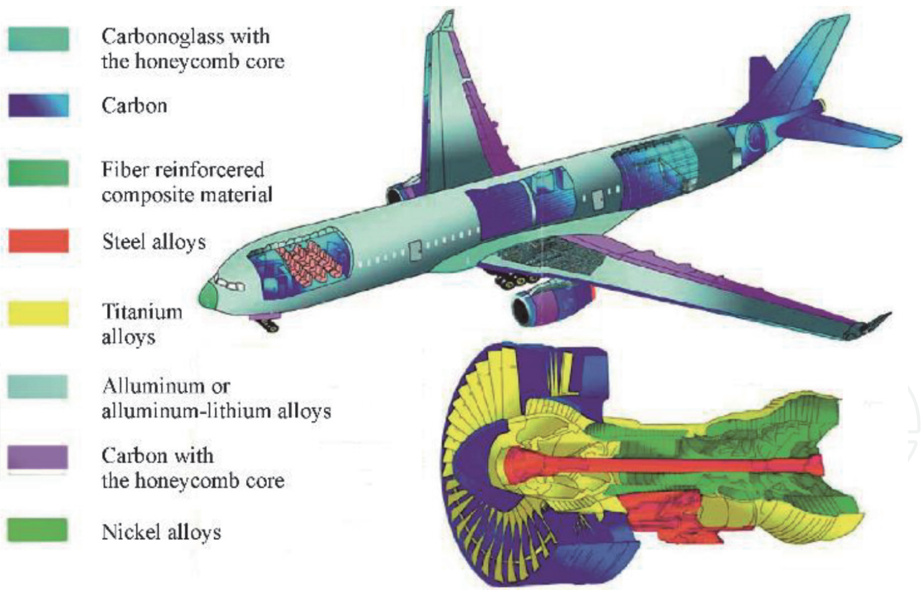

Figure 1.
Structural material application in airframe and engine.

improvements were also achieved in manufacturing processes, aircraft operations, and regulations.

All of these factors, synonymously, have effect on the safety level. But, they also have an opposite effect on the risk number. For example, in modern engines there are composite material structural members (**Figure 1**), as carbon fiber fan blades, or newest structural solution, composite ceramic turbine blades, etc. [5, 6]. This solution provides higher aviation engine efficiency. But, in case of damage, they require more complex, expensive, and longer repair procedures. At this time, the probability of mistake will be higher, and as a result, risks will be higher too than for traditional metallic structure. Another example of electrical systems is high automation of the flight control. It is possible only by applying computer-controlled electrical system and units, although it is complex. Boeing 787 Dreamliner in 2013 had some problems with the electrical system [7]. Solving these problems, the Boeing Company stopped their servicing for about half a year. The Boeing 737 Max had serious problems also with automation computer control system. We see that more complex solution also creates additional risks.

Environmental effect of the aircraft operation is very high. According to the FAA, in 2018, there were about 14,600 collisions between aircraft and animals [8].

Considering risks in aircraft maintenance is an important factor. Modern airline companies have a great number of different airplane types, which require different maintenance approaches, including refueling, recharging, servicing, etc. Mistakes by the ground staff create real conditions for the expansive damage or crash.

Although the incidents in flights become more seldom, a number of incidents in airports are high, and in the nearest future, they can increase [9]. Airport equipment is expensive, and making changes in aircraft structure features, their numbers, and safety requirement needs is not easy.

So, deep risk analysis allows us to find rational solution for aircraft structure, maintenance approaches, logistic ways, etc. that can provide a decrease in risks and an increase in safety level.

2. Safety and risks as functions of structural features

Safety and risk have deep interconnection [4]. Increasing the safety level directly relates with aspects of risk analysis and risk control. Risk control is a set of

DOI: http://dx.doi.org/10.5772/intechopen.92560

systematic procedures for achieving a risk value within specified limits. Procedures of the risk control involve activities related to overcoming uncertainty in a situation of inevitable choice, in the process of which it is possible to quantitatively and qualitatively assess the probability of achieving the intended result, failure, and deviation from the goal. Risk control depends on two factors: the air transport system and its main tool—aircraft.

The air transport system has the following features [10]:

1. Extreme complexity of the system itself and its main components (aircraft, etc.), due to the diversity of its subsystems and elements, the multiplicity of their relationships, and interdependencies

2. A high level of uncertainty of the impact of external hazardous factors, both natural and artificial

3. The special and diverse role of man at different stages of the designing, manufacturing, organization, preparation, and implementation of air transportation

Artificial hazard factors also depend on the complexity of structural components of air transport system and aircraft.

Human factors directly depend on human specifics, but rational or non-rational structural features can influence on their effect.

Structural aircraft features depend on a lot of factors (**Figure 2**):

1. Market requirements such us passenger capacity, flying speed, fuel consumption, etc.

2. Design process specifics such us traditions, structural materials, equipment contents, etc.

3. Manufacturing process limits such us aircraft number production per year, structural materials, labor conditions, etc.

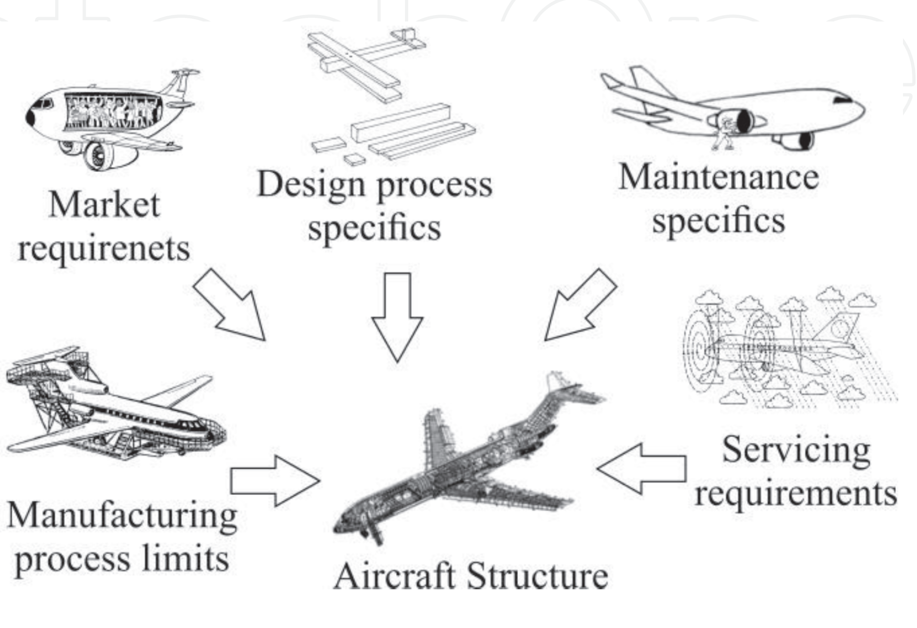

Figure 2.
Structural aircraft specifics and their dependencies.

4. Servicing requirements like the weather and environment conditions, traffic intensity, pilot training, etc.

5. Maintenance specifics like maintenance time limit, environmental conditions, staff training, ground equipment, etc.

All of these features have direct relation to the structural specifics of related aircraft.

So, as we see, structural specifics are important to all factors that influence risk and safety. Researchers make an analysis of these dependencies.

3. Civil aircraft maintainability specifics

Aircraft maintainability is one of the important factors that influence safety. The more complex the maintenance process is, the higher the possibility of ground staff making mistakes and it poses higher risk.

Aircraft maintenance consists of operation, servicing, repair, etc. (**Figure 3**). It takes into account the following specifics:

1. Safety requirements

2. Structural materials' specific properties that are applied in an airframe (corrosion resistance, combustibility, ability to absorb moisture, ability to destruction, etc.)

3. Ergonomic requirements for the servicing simplification

4. Accessibility of aircraft systems and units for their checking and servicing

5. Application in an aircraft structure of the systems and units that are unattended or not demanding frequent servicing

6. High labor-out ratio and time limits of servicing and repairing

7. Fatigue and service life requirements

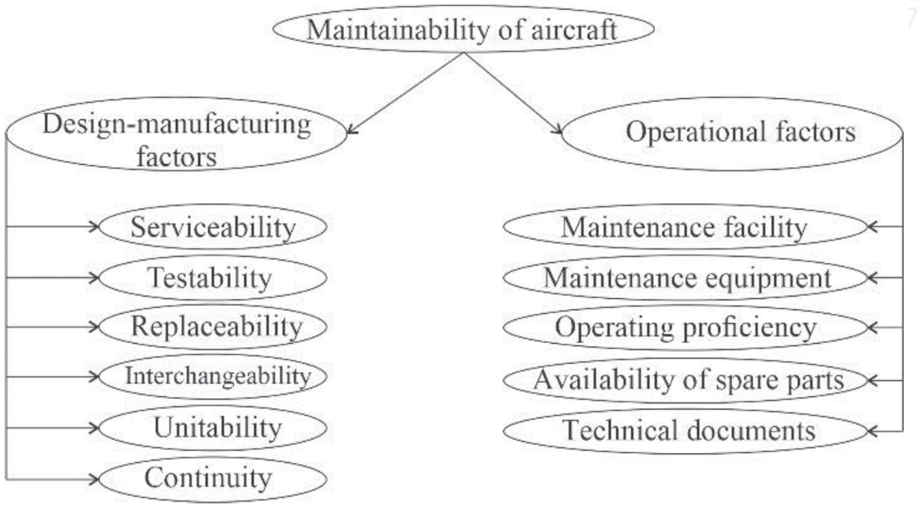

Figure 3.
Maintainability contents.

A designer can take into account all of these specific features at the time of the designing process and can improve them by applying rational structural solution. Moreover, it can decrease the risks in servicing process.

4. Aircraft structure adjustment for the progressive servicing and repair methods

Aircraft structure has developed for more than 100 years (**Figure 4**). One of the factors that influence on this process is the servicing way. With technic development, the processes of servicing and repairs undergo changes. New ideas and approaches provide a decrease in process time and increased efficiency. But, to provide new servicing approaches, the aircraft structure must have changes too.

4.1 Aircraft structural features

For the required safety level, providing aircraft structure must have the following properties:

1. Repair modular method.

2. Aircraft technical condition is the main factor for replacement and repair of units and systems.

3. Units and systems' periodic check without access removal.

4. Possibility for these specialized equipment (**Figures 5–12**).

Specialized equipment really decreases the risk level. It has the main function of simplifying servicing procedures and decreasing maintenance time.

These structural properties can be provided by the following ways:

1. Applying the "fail-safe" principle in the structure. It means that a single element or a subsystem failure does not lead to emergency. It can be provided by redundancy.

2. Applying easily dismountable joints and panels.

3. Applying built-in indicators and equipment access connectors (**Figure 13**).

4. Applying interchangeable systems, unit's structural members, etc.

The specialized ground equipment from the one side adjusts maintenance safety, and from the other side special knowledge can be required from the staff. So, the ground staff must have required level of knowledge and skills.

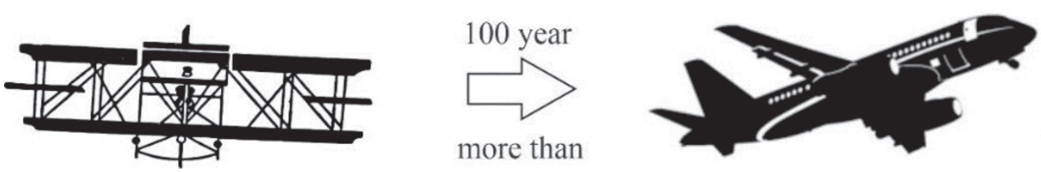

Figure 4.
More than 100 years from Wright brother's aircraft to modern airliner.

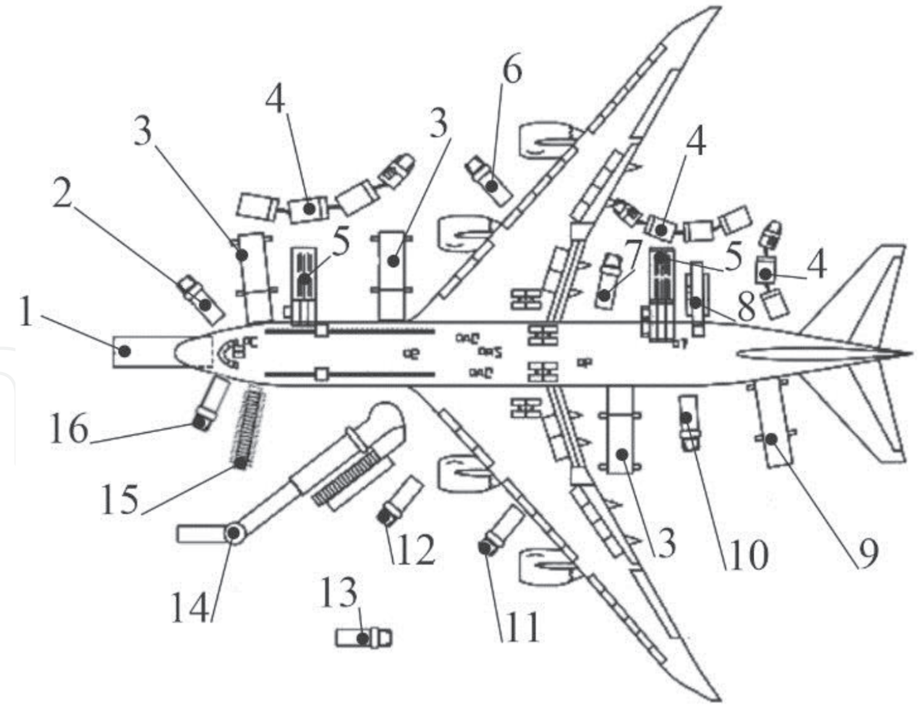

Figure 5.
*Arrangement of the special equipment for airport passenger aircraft B747 servicing [11]: 1, tow tag; 2, electrical power; 3, galley truck; 4, baggage train; 5, lower lobe loader (**Figure 6**); 6, hydrant fuel truck (**Figures 9 and 10**); 7, potable water truck; 8, belt loader (**Figure 7**); 9, cabin cleaning truck; 10, lavatory truck; 11, hydraulic power (**Figure 8**); 12, conditioned air truck (**Figures 11 and 12**); 13, air start truck; 14, passenger boarding bridge; 15, passenger stairs; 16, waste servicing truck.*

Figure 6.
Special luggage elevator.

Sometimes aircraft fuel valves have special control handle for correct identifying the position (**Figure 13**).

4.2 Aircraft servicing specifics

For service availability, the following are the recommendations:

1. Access to subsystems and units (especially of a power plant), their built-in indicators, and connectors by cowls and covers for their free checking and servicing (**Figure 14**, **Example 3** and **Figure 17**) should be provided.

2. The systems and units should be grouped in easily mounting panels. Deep analysis of the checking and servicing procedures can show what kinds of structural members required check and access more frequently (**Example 1** and **Figure 15**).

3. Separate units dismounting for access and servicing of others (**Example 2** and **Figure 16**) should be excluded.

Figure 7.
Belt luggage loader.

Figure 8.
Special equipment for hydraulic system checking.

Figure 9.
Fuel tank truck.

Figure 10.
Centralized underground fuel system and hydrant fuel truck.

Figure 11.
Conditioned air truck.

4. Removable hatches without the need for breaking the main structure integrity for access bolt joints should be provided.

5. Joint elements at non-pressurized part should be located in case pressurized compartments are present.

Figure 12.
Some airports have passenger boarding bridges that supply air-conditioning, ground power, potable water, etc.

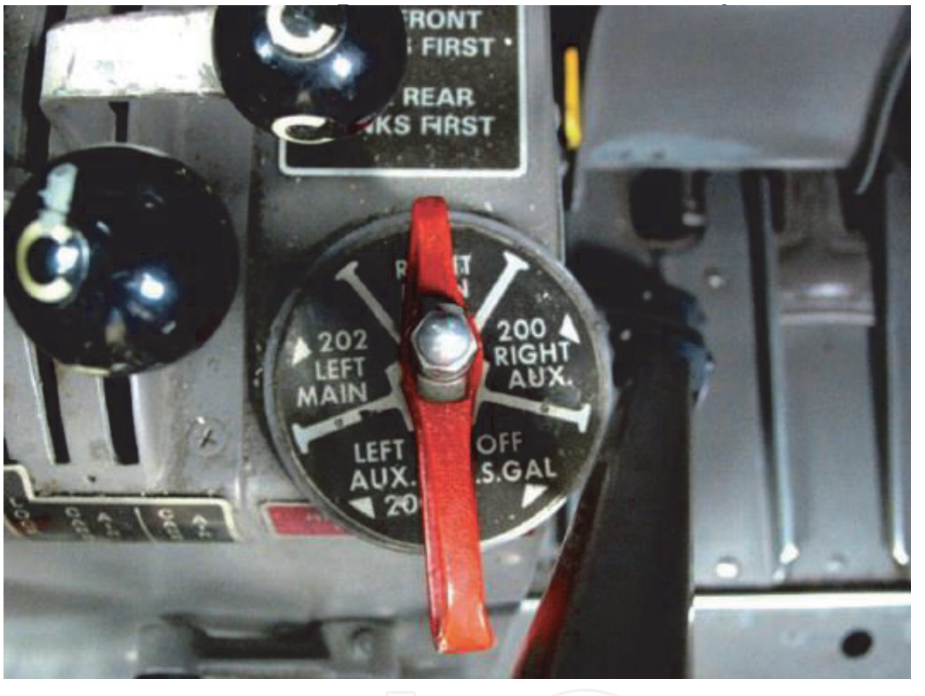

Figure 13.
Fuel valve with detents and the indicating handle for each position.

6. Access to hatches or easily removable panels for periodic checking and servicing of the units' attachment fitting and their load-carry elements should be provided.

7. Access to control system of structural members (rods, bell cranks, brackets, rollers, cables, actuators, etc.) for their checking and servicing should be provided.

8. Bearing servicing (control surfaces, high-lift devices, etc.) without dismounting them should be provided.

9. All movable attachments by lubrication, especially for a landing gear parts for extension configuration, should be provided.

10. Availability of special equipment at an airport (**Figures 6–12**) should be taken into account.

Figure 14.
Providing free access to power plant systems.

4.2.1 Example 1

Different kinds of servicing structural members' location are shown in **Figure 15**.

All of these structural elements have one aim—to provide good access for different systems and units' check points.

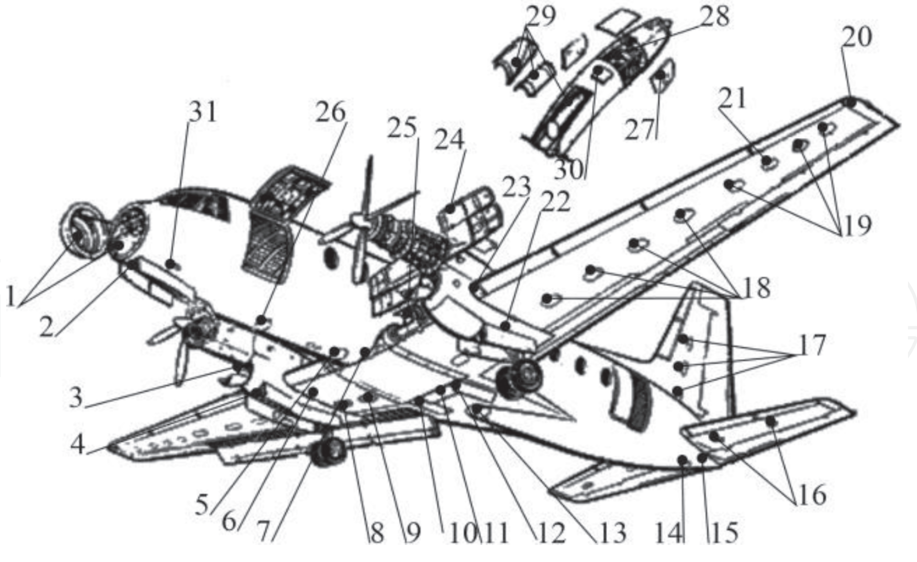

Figure 15.
The example of location of hatches, covers, and doors for service, check and repair of units, and systems and elements of the airplane: 1, battery; 2, members of hydraulic system; 3, socket of hydraulic system check; 4, hydro tank and filter; 5, electrical equipment and equipment of the air-conditioning system; 6, access to center wing section; 7, electric connectors; 8, fuel precipitation tank; 9, access to wing root; 10, actuator and gear of flap; 11, transmission and shaft of flap system; 12, cable tension adjuster of aileron control system; 13, gyroscopic sensors of autopilot; 14, servo actuators of elevators; 15, tail cone; 16, access for stabilizer servicing; 17, access for fin servicing; 18, access for fuel tank servicing; 19, access for wing servicing; 20, removable wing tip; 21, landing light; 22, doors of the main landing gear leg; 23, filter of anti-icing system; 24, the cowls; 25, access to engine control system; 26, electrical equipment and air-conditioning members; 27, filter of the air pressure blower; 28, accessory gearbox drive; 29, exhaust pipe; 30, valve and balloon of fire protection system; 31, members of attachment flaps; 32, the socket of fueling.

4.2.2 Example 2

In **Figure 16**, the variants of joint structure of two elements are given: not checkable and checkable from the point of view of visual detection of fatigue cracks and bolt joints.

4.2.3 Example 3

The variants of placement of detachable section of wing attachment to center section and fairing. In the first variant, attachment is closed by fairing (**Figure 17a**). Speaking about the requirements of aerodynamic perfection, such option is rational, but as for checkable variants, it is not convenient. Fatigue damages of attachment in operation are possible. But, it is not possible to determine the external visual servicing because the attachment is closed by fairing.

The second variant of structure (**Figure 17b**) is more checkable because of the visual servicing.

4.3 Interchangeability properties

Interchangeability at servicing and repair is the way of simplifying the maintenance and decreasing risk ability.

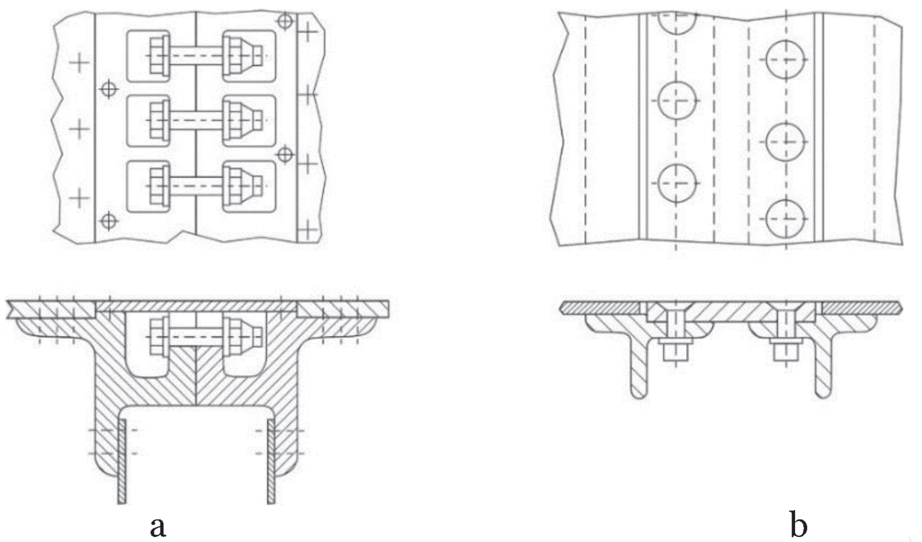

Figure 16.
Variants of a joint structure: (a) good check ability; (b) bad check ability.

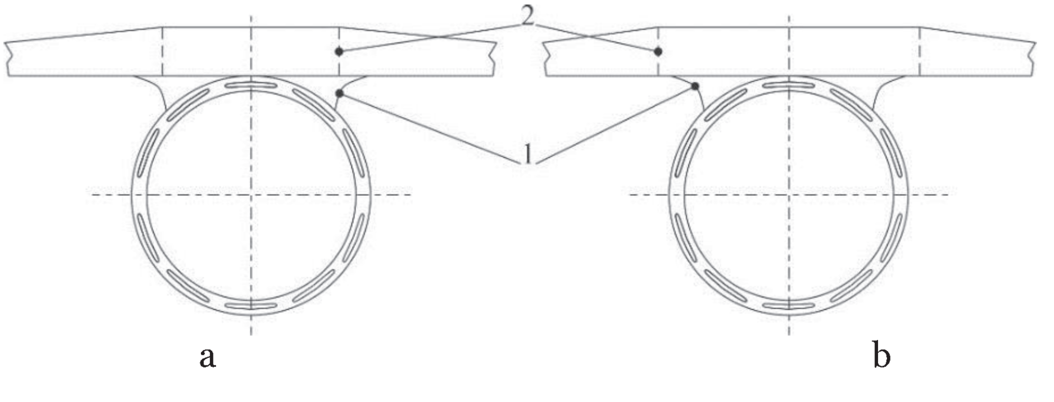

Figure 17.
Variants of a structure: (a) bad check ability; (b) good check ability (1, fairing; 2, joint).

1. The units, systems, and elements are removed and replaced by new (or repaired) at servicing and repair. It will have the functional and geometrical interchangeability. It especially belongs to such units, systems, and elements which most often are required for replacement or repair. Examples of such are the following:

   a. Moveable units—control surfaces (ailerons, elevators, rudders), flaps, slats, interceptors, spoilers, trimmer-tabs, and also their members of attachment

   b. Removable panels, covers, hatches, and fairings

   c. Cowls of engines and engine attachment elements

   d. Entrance and cargo doors, cargo compartment shutters and gates, and their locks

   e. Landing gear legs, their locks, and doors of landing gear compartment

   f. Control system components (rods, bell cranks, rollers, cables, actuators) and sealed lead-outs

   g. Nose section of wing and tail, air intakes, and nose and rear fairing of fuselage

   h. Glasses of windows of passenger compartment and cockpit.

2. Units, members, and elements of systems and the equipment also will have to complete functional and geometrical interchangeability (see **Example 4** and **Figure 18**).

3. The modified units, members, and elements will have opportunity to replace older variants of members at all aircraft types where they are installed.

4.3.1 Example 4

Bolt joints are important structural solutions applied at the high-loaded structural members. However, there can be some differences in aviation bolts and general engineering bolts (**Figure 18**).

One of the differences is as follows: aviation bolt body consists of two parts—grip has length t_{ag} and thread has length t_{bt}. In the general engineering bolt structure, there is only one-part thread that has length t_{bt}. So, the thickness of the jointed elements for the aviation bolt must be equal to the length of the thread:

$$t_{e1} + t_{e2} = t_{bt}. \tag{1}$$

For the general engineering bolt, it may be equal or smaller than the thread:

$$t_{e1} + t_{e2} = t_{bt} – t_{wnf}, \tag{2}$$

where the t_{wnf} is the total thickness of washer, nut, and bolt free tip that is usually equal to 2–3 screw pitch.

As we can see, the general engineering bolt has more universal applications than aviation bolt, because the aviation bolt, we can apply only at one place or at place

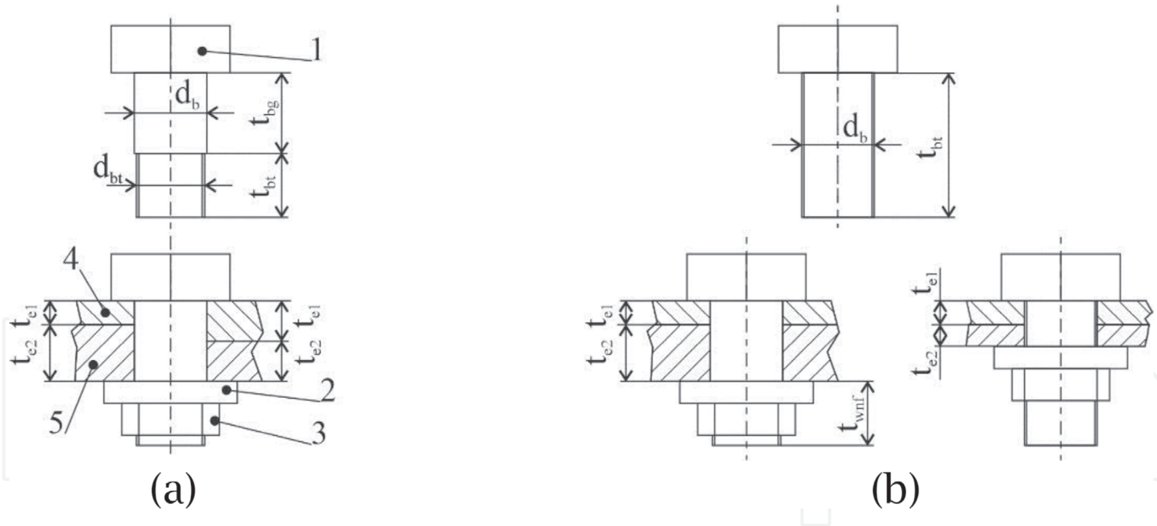

Figure 18.
Aviation bolt joint (a) and general engineering bolt joints (b): 1, bolt; 2, washer; 3, nut; 4, 1st jointed element; 5, 2nd jointed element.

with the similar thickness of the jointed elements. For the general engineering bolt, this strict is softer.

Usually, joints in an aircraft structure have low interchangeability features, and designers should try to adjust to this feature.

4.4 Aircraft repair specifics

Repairing the units depends on the following:

1. Interchangeability of parts, members, and units.

2. Capability of replacing parts without disassembling members located nearby.

3. Development of block (modular) structures (**Figure 19**).

4. With failure, the inoperative module (block) is replaced by a serviceable one and forwarded for repair to the specialized site.

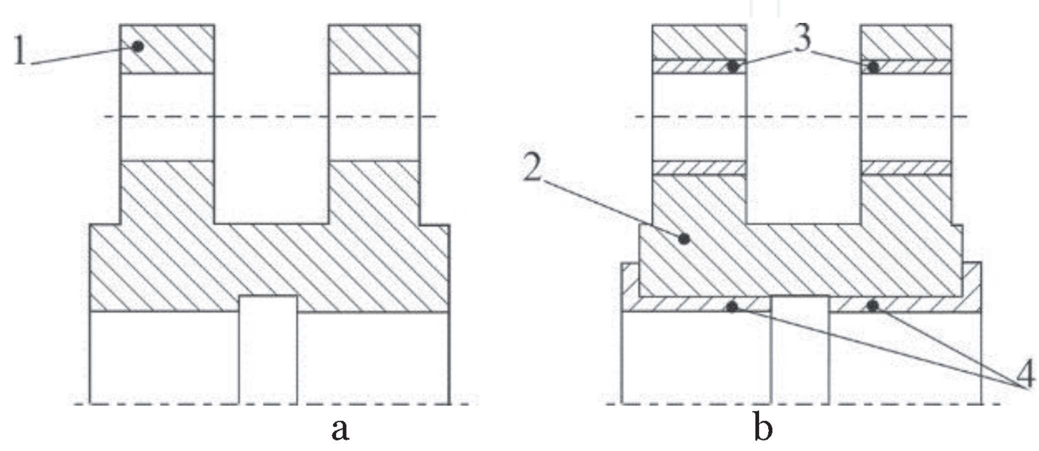

Figure 19.
Variants of structures: (a) is discouraged; (b) is recommended.

5. Removing the necessity of developing all units, searching for the inoperative member under field conditions.

6. Utilization of widely standardized and unified parts and units.

It is necessary to develop a structure that allows for its simple and quick removal and replacement. For example, the replacement of the engine on AH-56A helicopter is made for 30 min [12].

4.4.1 Example 5

Complex and hard-load element must have modular structure. In **Figure 19a**, there is monolithic flange. In **Figure 19b**, there is an assembler flange with the same functions. Elements 3 and 4 are presented at hard-load zones that transfer the main loads. So, they have a short service life compared with body 2. Fast changes of elements 3 and 4 provide simpler repair and cheaper reserve elements.

It is a rational way to apply such structures that could be removed with the help of ground equipment and strength of the maintenance personnel.

5. Requirements of simplicity of performance of fueling, oil servicing, and adjusting works

Refueling, recharging, oil servicing, etc. are important and dangerous operations for the aircraft maintenance. They create many risks.

For this purpose, an aircraft structure must have the following properties:

1. Minimization of quantity and unification of fuel and oil types, fueling, and oil servicing devices.

2. Easy access to threaded joints which demand in using periodic check of tightening torque.

3. Decreased standard sizes of the used fasteners.

4. Unification of the turnkey sizes for bolts and nut heads.

5. Unification of connectors for measuring checking equipment.

6. Unification of connectors for filling operations.

7. The structure of fillers should exclude getting fuel (or oil) in the airplane during spillage passage. That is why it is better to apply the system of filling having jointers in the bottom parts of the airplane (**Figures 20–23**).

Figures 20–22 show the regular refueling procedures at the airport. It may be directly from the ground (**Figure 20**), and this way requires minimum possible time. It may be completed by the special stairs, and in this case, it will be more complex and longer.

In **Figure 23**, there are situations when the airfield has not specialized on refueling equipment and ground staff is done by manual mode. On the one hand, it is good, when an airplane can be refueled without specialized equipment. On the other hand, the risk of the emergency situation in time of procedure or after that is very high.

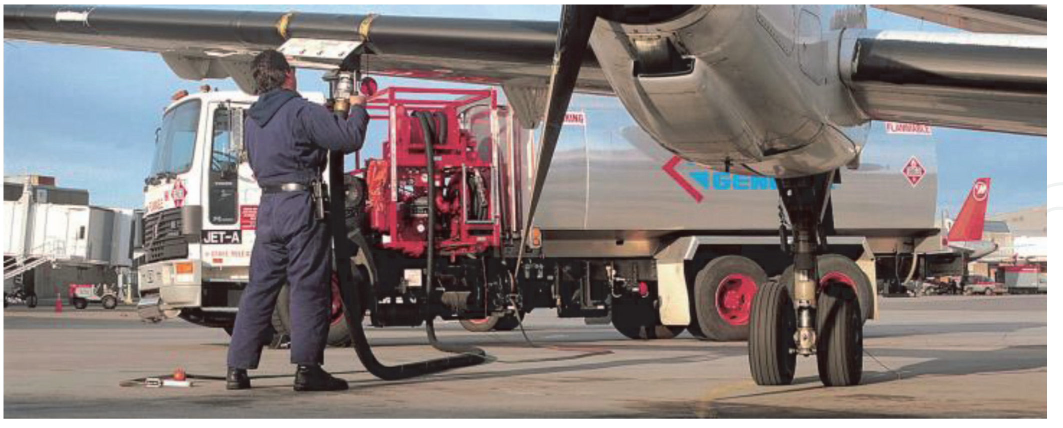

Figure 20.
Arrangement of the fueling connectors at the bottom wing surface.

Figure 21.
Airplane fueling from the service car—non-rational.

Figure 22.
Airplane fueling from the ground stairs.

a b

Figure 23.
Handle refueling aircraft: (a) Antonov An-26 in Africa; (b) Beechcraft 300 at the Antarctic Air Base Pot. E. Frei M.

6. Requirements ensuring reduction of labor input of carrying out loading and discharging

There are risks for the aircraft during the loading-unloading procedures. To provide this requirement, we use the following design solutions:

1. Cargo compartments must have the equipment for loading-unloading (door stairs, cat crane, lift), the device for cargo fastening (**Figures 24** and **25**).

2. Cargo compartments will have to be located as possible near to the runway. It simplifies loading-unloading process. For example, the landing gear with the possibility of squatting the nose and main legs are used for airplanes (**Figures 26–32**).

In **Figures 25–27**, there is Antonov An-124 supercargo airplane that has nose and rear cargo door, special lift equipment that is built in its cargo compartment, light system for the night conditions, etc. All of these features provide successful airplane applications.

Figures 28 and **29** show cargo airplanes Boeing Company Dreamlifter and Airbus Company Beluga. Both of them require specialized loading-unloading equipment, and they cannot be applied at the airports without these tools.

Cargo door side location (**Figure 30**) has more easy structural solution, but the dimensions of a cargo must be smaller than the previous examples.

Figure 24.
Floor of the airplane B747 cargo compartment with the devices for moving and fastening of cargo.

DOI: http://dx.doi.org/10.5772/intechopen.92560

Figure 25.
Cargo compartment with the built-in hoist of the cargo aircraft Antonov An-124.

Figure 26.
Nose cargo door of the heavy cargo airplane Antonov An-124.

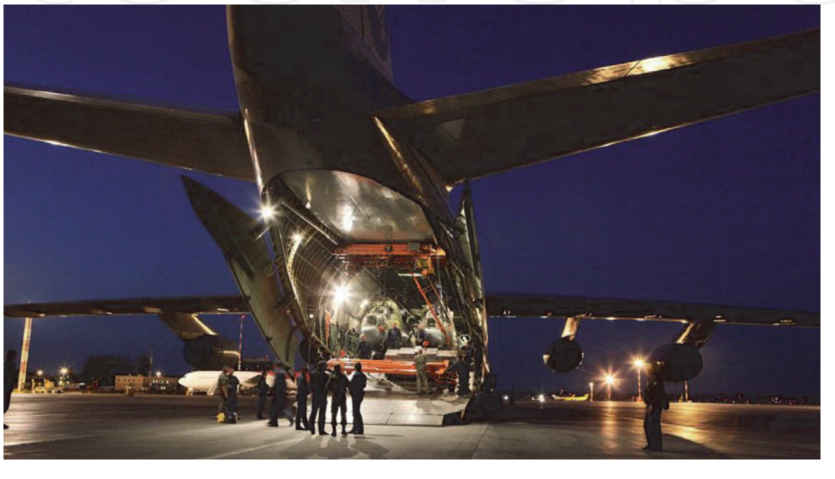

Figure 27.
The rear cargo door of the heavy cargo airplane Antonov An-124, night loading procedure.

Figure 28.
Rear cargo door of "Dreamlifter" B747.

Figure 29.
Loading cargo into Airbus beluga cargo plane from nose cargo door.

For the passenger aircraft there is a task of passenger stairs location selection. In bigger airplanes, usually car drive stairs (**Figure 31**) or passenger boarding bridges (**Figure 12**) are used. For small airplanes (**Figure 32a**) or regional airplanes (**Figure 32b**) that can land on the unpaved runways at airports without special stairs tools and the built-in passenger stairs (**Figure 32**), there is rational solution.

Figure 30.
The side location of cargo door in the Ilyushin-114T cargo airplane.

Figure 31.
Passenger stairs.

a b

Figure 32.
The door stairs at passenger airplanes: (a) side location for Bombardier Challenger 300; (b) rear location for Yakovlev Yak-42.

7. Requirements for operating capability in various weather conditions and storages out of doors

External factors, like the weather conditions, have negative effects on the aircraft maintenance, related to risks and its safety. Hot and cold temperatures both have a negative influence on the staff activity, aircraft's structural member, tools, etc. Not only temperature has this feature, extreme humidity, strong wind, solar radiation, etc. also have the same effect.

7.1 Design solutions

A designer on the base of the deep analysis of operational conditions, a customer requirement, engineering solution database, etc. can influence on the risk factors.

7.1.1 Example 6

There is a retractable nose leg of landing gear and its compartment. If an airplane can be used on unpaved runways, then it is necessary to minimize the possibility of getting in landing gear compartment of different dangerous foreign objects, especially dirt and snow.

Some baseline arrangement solutions are possible:

1. After retraction of the landing gear leg, the landing gear compartment must be closed again (**Figure 33**); however, it complicates the structure of the gear in opening and closing of the landing gear compartment door.

2. Rational using the direction of a leg ejection: a, front ejection (**Figure 34a**), full values of dirt, snow, and stones get in the landing gear compartment; b, backward ejection (**Figure 34b**), all dirt put on the bottom (closed) section of fuselage; c, non-retractable landing gear (extreme variant).

Front ejection has other advantages compared with backward ejection. One of them is as follows: wheel is more easy to locate at the variant because in this case it will be arranged at the bigger fuselage cross section.

So, collisions between some of the operational requirements are a possibility, and the designer-engineer must find a compromise between all of these requirements taking into account aircraft's operational limits, required safety level, etc.

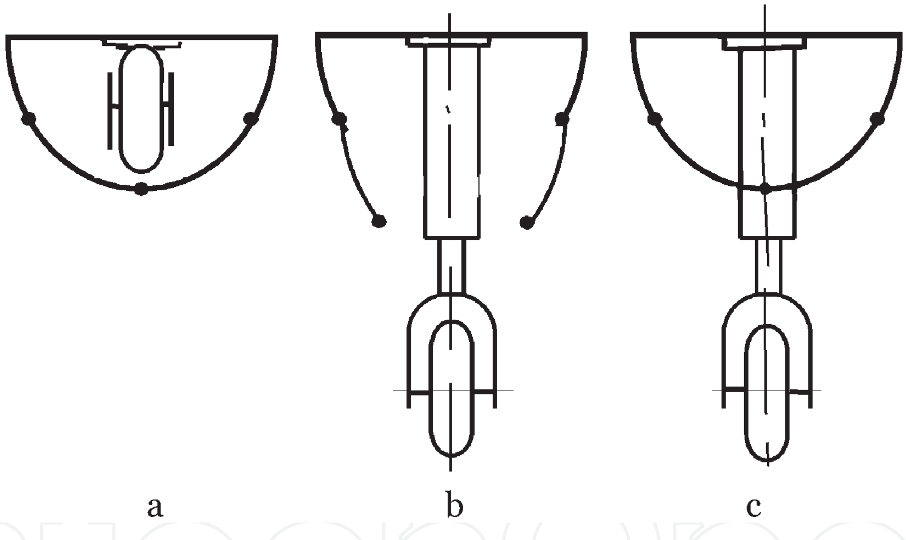

Figure 33.
The arrangement variant of landing gear for an airplane with the take-off and landing at soft surface runway: (a) base position (retract); (b) eject of the landing gear leg; (c) final eject position.

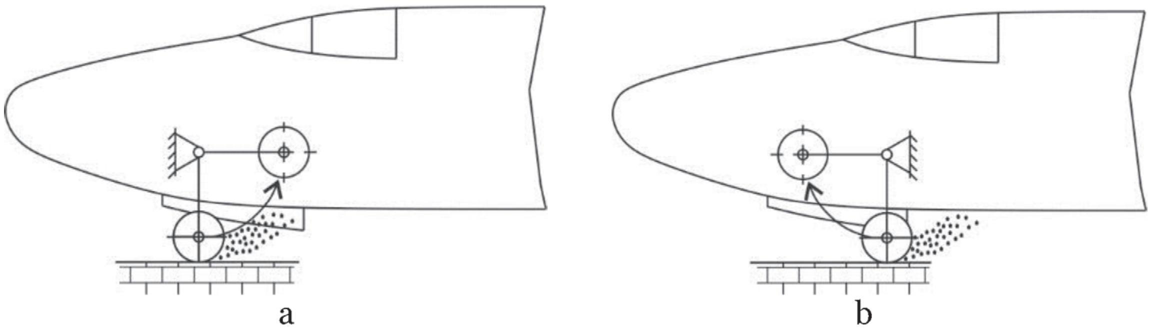

Figure 34.
Diagrams of retraction-ejection of nose landing gear leg of regional airplane which operates at soft surface runway: (a) non-rational; (b) rational.

7.2 Manufacturing solutions

1. To apply materials, proof to environment.

2. To use open but not closed-loop sections in which moisture can be collected (in places of probable accumulation of moisture on the lower surfaces, the drain holes must be provided) (**Figure 35**).

3. To carry out anticorrosive procedures.

Structural materials that are widely applied in modern aircraft are as follows:

1. Artificial thickening of protective oxide coating with the help of anodic treatment (**Figure 36**) and chemical oxidizing for metallic structural materials like aluminum alloys, steel, etc.

2. Metal coatings (plating, metal spraying) (**Figure 37**)

3. Protection with protectors (for aluminum alloys, zinc is more often applied)

4. Paint coatings (**Figure 38**)

7.2.1 Example 7

Metals and alloys with more positive potential, when contacting with aluminum alloys, increase their corrosion. They are copper, and its alloys, nickel, tin, alloys of

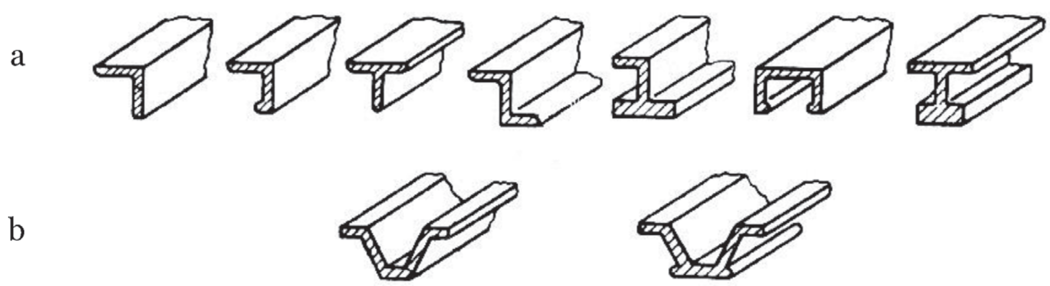

Figure 35.
Open (a) and closed-loop (b) structural elements for stringers.

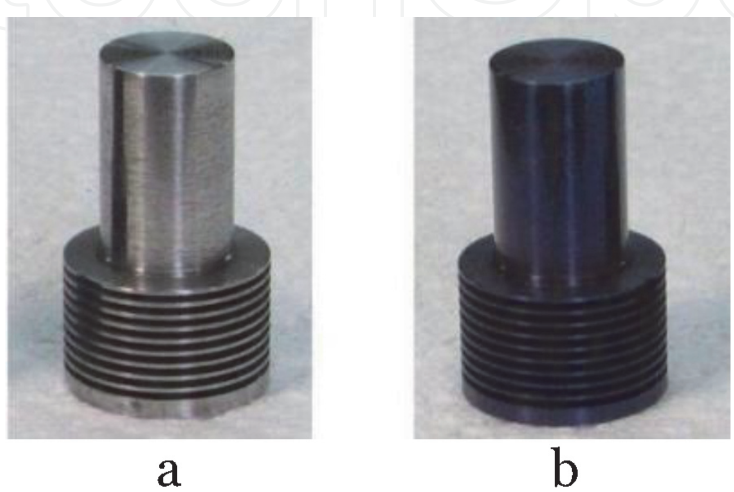

Figure 36.
Steel element: (a) before anodizing; (b) after anodizing.

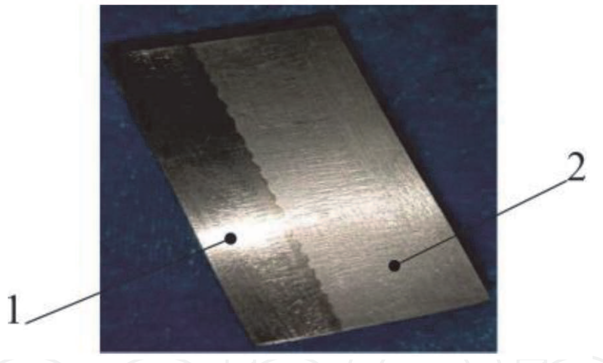

Figure 37.
Cladding for the aluminum alloys by steel: 1, steel layer; 2, aluminum layer.

Figure 38.
Aircraft painting.

nickel, steel, and lead, are considered as noble metals. Without special protection, contact of these metals with aluminum alloys is not allowed. For example, riveting is impossible by copper rivets. If contact is necessary, then special gaskets should be applied (**Figure 39**).

If the materials have the same potential, contact can be allowed. These are alloys on a basis of zinc and cadmium: any materials covered with zinc, cadmium, and aluminum.

7.3 Servicing solutions

The weather factor can be solved by the solutions for airports. Applying special building for the aircraft is necessary to keep its high efficiency (**Figure 40**).

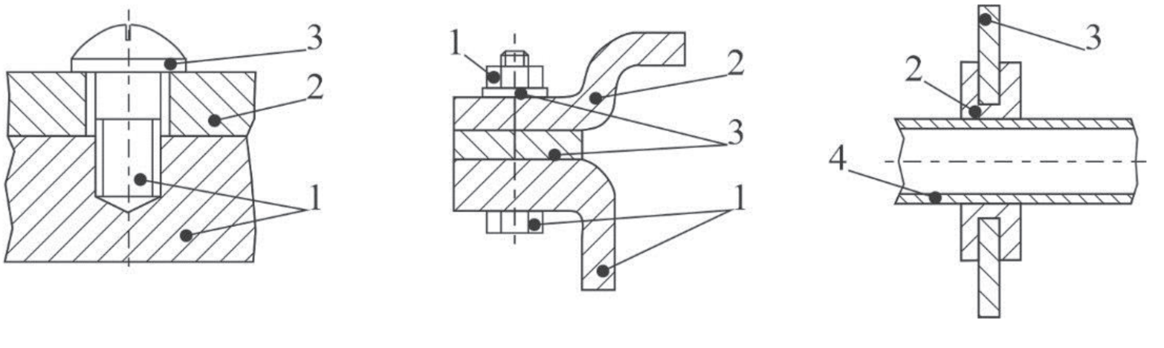

Figure 39.
Protection of metals at contact: 1, steel; 2, aluminum alloy; 3, cadmium; 4, copper alloy.

Figure 40.
Boeing 747 in the special aircraft shed.

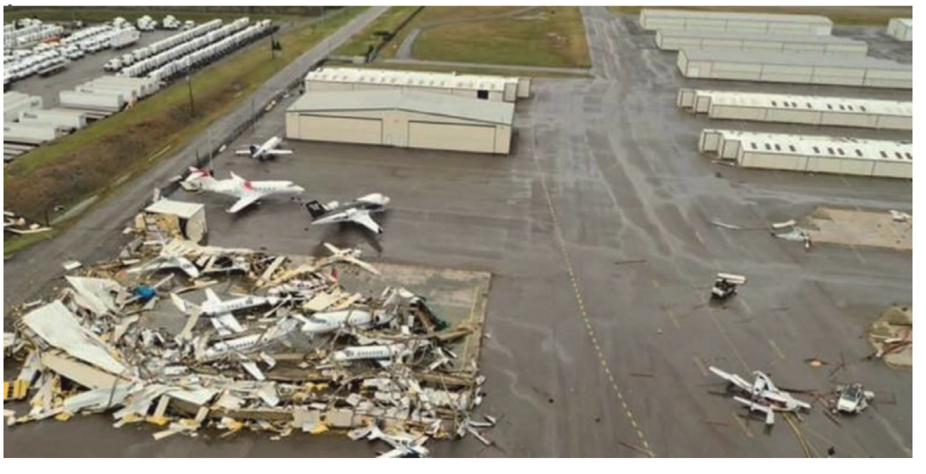

Figure 41.
The impact of tornado in the West Nashville John C Tune Airport on March 03, 2020.

Some of their advantages are as follows:

1. It keeps an airplane from long parking caused by weather.

2. It provides good conditions for the ground staff in time maintenance or repair: temperature, light, etc.

The results of the environment negative affect are shown in **Figure 41**. There you can surely see that airport buildings are good, but some airplanes were destroyed after tornado.

8. The requirements for transportation

It implies that the units of the airplane are to be no more than certain established sizes and also have attachment capability.

The possibility of an airplane or its separate units transportation depends on specifics of rail-way, ships, highways and soft-roads (**Figure 42** [13]).

a

b

Figure 42.
Transportation of Airbus A380 section: (a) fuselage by river ship; (b) fuselage by road.

One of the reasons for the high cost of the aircraft A380 project is the complex logistics of its units to the final assembly place. During transportation, it is necessary to provide the required safety level at all stages. It is a complex and expensive task.

9. Afterword

As it is shown in this chapter, the different stages of maintenance, servicing, etc. are important and mission-critical for decreasing risk and providing safety. Rational structural solution that can provide convenient maintenance procedures, simpler repair, which can compensate environmental effect, etc. can be developed (implement at the designing stage).

However, they require from designer-engineers deep and wide knowledge in the engineering sciences. Also, often, they are facing challenges in economic requirements for manufacturing or minimal weight requirements, etc., and a designer together with a customer should take a balanced decision that can provide the highest possible economic efficiency with the required safety level.

Author details

Dmytro Tiniakov
Nanjing University of Aeronautics and Astronautics, Nanjing, China

*Address all correspondence to: tiniakov_d@nuaa.edu.cn

References

[1] Krause S. Aircraft Safety. 2nd ed. New York, US: The McGraw-Hill Companies Inc.; 2003. p. 498

[2] Kritzinger D. Aircraft System Safety. Cambridge, England: Woodhead Publishing Limited; 2006. p. 367

[3] Zubkov V, Minaev E. Flight Safety Base. Moscow: Transport; 1987. p. 144

[4] Risk Management Handbook. U.S. Department of Transportation, FAA, Flight Standards Service, Change 1; 2009. p. 112. Available from: www.Militarybookshop.Co.UK

[5] Baker A, Dutton S, Kelly D. Composite Materials for Aircraft Structures. 2nd ed. Reston, Virginia: American Institute of Aeronautics and Astronautics, Inc.; 2004. p. 602

[6] Pourhashemi A. Engineering Materials. Toronto, New Jersey: Apple Academic Press; 2015. p. 286

[7] Boeing 787 Dreamliner battery problems [Internet]. Wikipedia. 2013. Available from: https://en.wikipedia.org/wiki/Boeing_787_Dreamliner_battery_problems

[8] Wildlife Strikes to Civil Aircraft in the USA 1990–2018. Serial Report Number 25. U.S. Department of Transportation FAA [Internet]. 2019. p. 123. Available from: https://www.faa.gov/airports/airport_safety/wildlife/media/Wildlife-Strike-Report-1990-2018.pdf

[9] Statistical Summary of Commercial Jet Airplane Accidents Worldwide Operations|1959–2018. 50th ed. Boeing Company; 2018. p. 28. Available from: https://www.boeing.com/resources/boeingdotcom/company/about_bca/pdf/statsum.pdf

[10] Mahitko VP, Dmitrienko GV, Gavrilova EA. Estimation of risks and factors of danger in the system of safety of flights of airships. Bulletin of the Samara Scientific Center of the Russian Academy of Sciences. 2017;**4**(19):192-197

[11] Eggink R, Bateman P. 747-8 offers operational improvements and cross-model commonality. AeroMagazine, Boeing Company. 2010;**03**(39):5-15

[12] Velichko I. Mi-28 vs AH-64 Apache. Catching up always lagging behind? Nauka and Technika Journal. International Space Station; 2015;**9**(112):52-62. Available from: https://naukatehnika.com/mi-28-protiv-ah-64-apach-dogonyayushhij-vsegda-otstaet-chast-1.html

[13] Newton J. The amazing story of the A380 told through incredible pictures. MailOnline. 2019. Available from: https://www.dailymail.co.uk/travel/travel_news/article-6700789/The-amazing-story-A380-told-incredible-pictures.html?ico=embedded