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OPERATIONAL DURABILITY OF AIRFRAME STRUCTURES

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Abstract

Requirements for intense operational utilization over long periods of time have stretched the design life objectives for modern aircraft considerably. Operational lives of 20 years are for certain military aircraft not abnormal anymore. For short haul commercial transport aircraft extremely high figures, such as an expected operational life of 25 years and/or 90.000 flights are quoted.

In this paper ways and means are discussed to achieve such goals. In addition to the selection of materials and airframe structures, that by their nature will guarantee a high degree of operational durability, such extreme objectives can be met only by integration of the latter with those concerning other airframe structural design requirements.

The durability aspects shall be controlled equally well during the design development as those concerning other aspects of the airframe such as strength, stiffness and weight.

Introduction

Two different editions of Webster's Dictionairy give respectively the following definitions of the word "durability":

- "Ability to exist a long time without significant deterioration". (1)
- "Lasting inspite of hard wear or frequent use". (2)

The first mentioned definition is very well applicable to military aircraft. These, as compared with civil airliners, make only a rather small number of flights and spend the rest of their lives on the ground and exposed to the influences of the atmos-

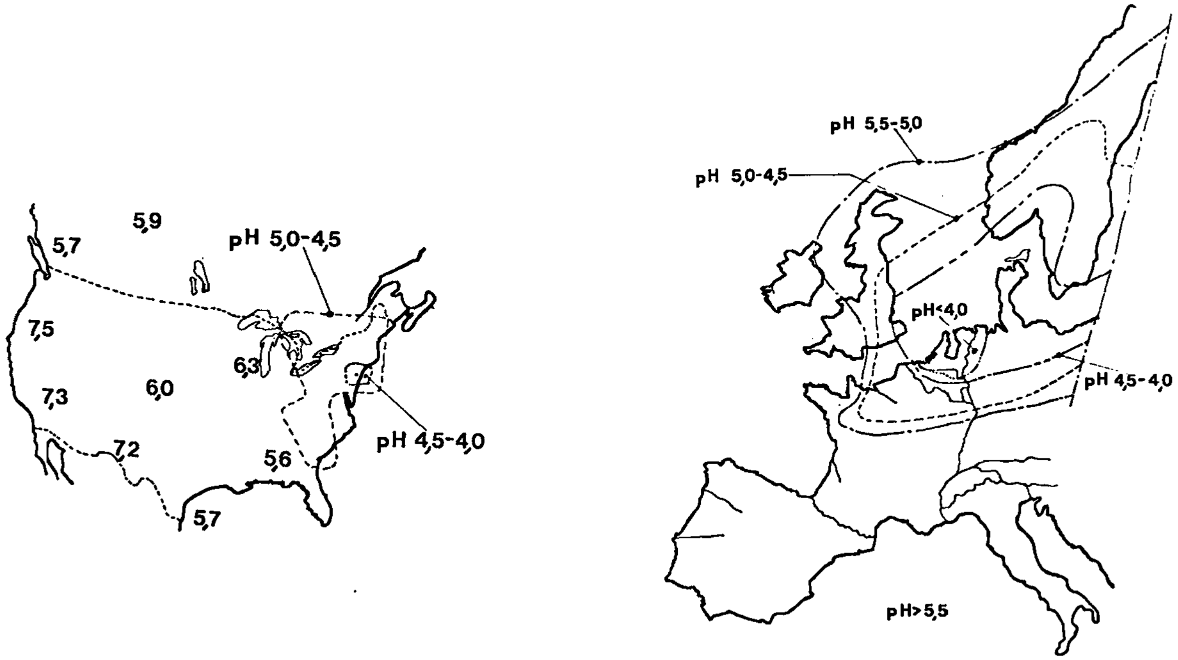

Fig. 1 The degree of acidity of rain as measured in North America and in Western Europe. Regions with pH values between 4.0 and 5.0 can be found in the eastern part of the U.S.A. and in Europe covering the eastern part of England, North France, Belgium, The Netherlands, the northern half of the Federal Republic of Germany, Danmark, south Norway and Sweden.
pH Values lower than 4.0 have been found in the Netherlands and the German Ruhr area (3a and b).

pherical environment. An environment that in certain western european countries must be considered as highly agressive, like in the Netherlands where the rain has a very high acid content, demonstrated by a pH value of 4 (3) figure 1. Time is passing that fast that for many of us, members of the aeronautical community, it is hard to believe that the earliest F104 "Starfighter" aircraft came into operation as early as 1962 (4). Being the same year in which the last built B52 Bomber of the U.S.A.F. left the production line (5). Both aircraft types are still operational. Insiders are well aware, however, of the fact that this could be achieved only by means of considerable efforts in costly modifications, repair and replacements of major airframe components. In this light it is understandable that the design objectives for the U.S.A.F. B-1 Bomber included an operational life objective of 15 to 20 years.

Last mentioned Webster-definition is very well applicable to civil airliners, in particular those used for short-haul operations. Per example Fokker F-27 "Friendship" aircraft are in operation since 1958. To-day early aircraft of that type are still in airline use, some of them after a life of more than 60.000 flights (fleet maximum to-day about 63.000 flights) (6) Fig. 2. This is at a moment in time that Fokker engineers study the feasibility to extend that operational life to 90.000 flights without important modifications (7). What the meaning is of such a high utilization, can often be easily explained to aeronautical outsiders by pointing out that each flight begins by a 2000 meters long taxi- and take-off roll on, sometimes, poorely paved, runways, including an acceleration to a speed of some 185 km/hour. That same flight is ended by a landing- and taxi run over a similar distance, including again fast rolling with a speed of some 165 km/hour and heavy braking. An operational life of 90.000 flights thus would mean 360.000 km rolling on the ground, which is an achievement, that only few of our present day motorcars would be able to duplicate.

It will be clear that such extraordinary operational lives will be achievable only when two important conditions are fulfilled:

- The aircraft has been designed such that prolonged use will not create hazards as a result of fatigue failures in major structural components.
- The aircraft is subject of a continuous and well organized maintenance activity, that will a.e. detect and repair any major effects of environmental degradation.

One of the main reasons for replacements of military aircraft has been in the past a degeneration of its military value in relation to strongly developed mission requirements. A very important second reason, however, has been the necessity for replacements due to the fact that the airframes simply were not resistant enough to the environment and maintenance and repair could not keep up anymore with the rapid deterioration, that finally would lead to structural failures and fatal accidents. Fig. 3. During the fiscal year 1975 the total costs of the USAF maintenance operations was $ 10 billion of which about 25% concerned costs directly associated with corrosion. This included the costs of inspection and repair of corroded components.

Fig. 2 Fokker F27 "Friendship", of which the operational life may be extended to 90.000 flights, operating from a typical poorely paved airstrip.

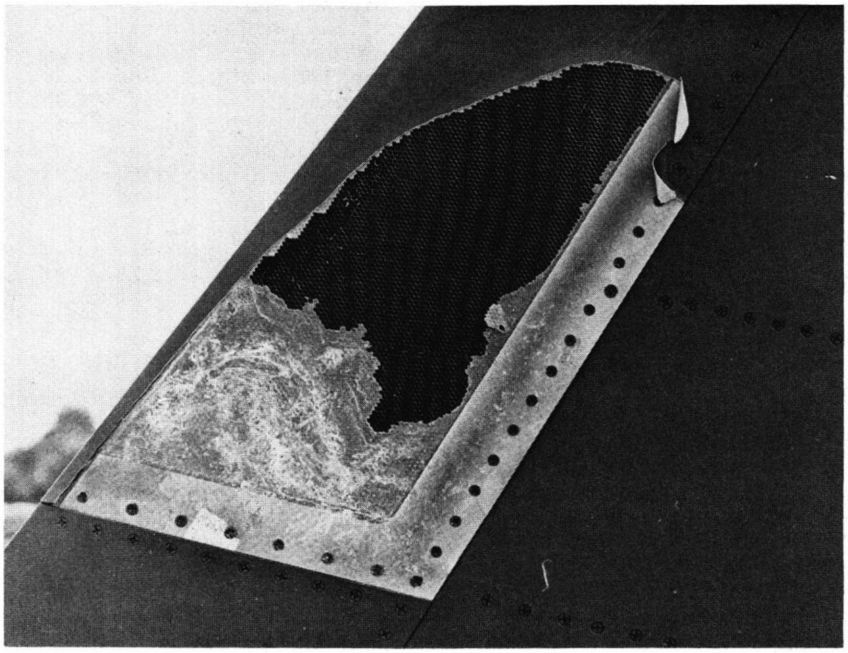

Fig. 3 Tailplane leading edge after losing skin during flight due to corrosion (15)

The quoted figure over 1975 was twice as high as the 1965 figure, while over the same period procurement costs did not change significantly (8).

The reasons for replacement of civil transport aircraft have been primarily economical. It is well understandable that the profit earning capability of the aircraft in the fleet of an airline company determines whether that company will be able to stay in bussiness or not. The percentage of the seat and/or freight capacity, that has to be filled in order to cover the operational costs of the aircraft on a given route in comparison to the obtainable load factor on that route will determine the profitability of the operation. When that margin becomes too small, the operation has either to be stopped or more suitable fleet equipment has to be brought into action.
In addition to the economical aspects nowadays acceptability of the equipment by the public is of growing importance. Public, that may be the non-flying inhabitants of homes in the vicinity of airfields, for which the noise characteristics of an aircraft are of prime importance, but equally well the flying public that without any doubt desires to enjoy the best travelling comfort for a given ticket price. In recent years the first mentioned noise problem has been of such an importance, that it has led airworthiness and airport authorities to formulate stringent requirements and operational limitations for civil aircraft on the basis of their environmental noise characteristics, inspite of their serious impact on the economy of the operation (9).

The operational economy of an aircraft is determined by a complex of factors of which the structural characteristics of the airframe is only one of them.

Relation between airframe structure and operational costs

The Direct Operational Costs (D.O.C.) of a civil transport aircraft are generally calculated according standardized methods (10). Per flying hour (or block hour) cost factors such as: depreciation of the invested capital, interest, insurance and cockpit crew costs are calculated in addition to the costs for maintenance inspection and repair and .... last but not least: the fuel costs. The structural aspects appear in these calculations primarily, but not exclusively, in the factor maintaince costs. However, the structural efficiency and the resultant factor structural weight determine the load carrying capacity for a given maximum take-off weight. With other words: the structural weight influences the amount of fuel required to transport a given load over a given distance. The The structural properties of the airframe are also a hidden factor in the capital costs of the aircraft. The depreciation cost element of the direct operating costs is based on the assumption of a certain economical life and residual value of the aircraft.

When selecting new aircraft types for their fleets, the airline companies in the past have used such standard rules of comparison, that the aircraft with the lowest initial costs and the lightest structure as well as the lowest fuel consumption would win. By calculating the depreciation period and the maintaince costs regardless of the structural features and the corrosion resistance of the airframe, they did not offer an incentive to the airframe manufacturers to develop products with a long fatigue life and high corrosion resistance.

Aircraft manufacturers specializing in airframes with high durability in the form of a long crack free life and high corrosion resistance were seldomly given credit in such comparitive studies by a rearranging of depreciation periods or maintenance costs. That policy has led to the current generation of civil transport aircraft of which during the period 1979-1980 the maintenance costs varied between 15 and 19% of the direct operating costs. This included medium- to long-range narrow body as well as long-range wide body transport aircraft (11). That are aircraft of a generation of which the operators seriously complain, that the corrosion phenomenon is responsible for 30% of all maintenance manhours during major checks. These require periodical clearing out the whole cabin interior and stripping the exterior paint protection for subsequent preventive inspection on corrosion as well as corrective and corrosion preventive activities. Such thorough programs are required in order to reduce non-scheduled down-time and repair due to structural corrosion damage to a minimum. Corrosion has only in recent years been recognized by the operators as a major cost factor. It was estimated that the costs due to corrosion damage to the members of the International Air Transport Association (IATA) has been in 1976 about $ 100 million (12). The energy crises in the last years and subsequent increase in fuel prices has led to a sharp increase in operational costs and reduction of profit margins for the airline companies. An increased effort by the airline companies to cut costs as much as possible has been a result of this. On the other hand it also changed the relative importance of the elements of the direct operational costs. The share of the fuel costs in the total operational costs reduced the relative importance of elements such as the maintenance costs. Were the maintenance costs for a certain group of airplanes in the period 1979-1980 between 15 and 19% of the D.O.C., for the same fleet they were estimated for the period 1980-1981 to be between 11 and 15% of the increased D.O.C. due to the rising fuel costs.

Under present circumstances, however, the urgent need to cut unnecessary costs due to lack of durability is of prime importance. Therefore it is well-understandable that the airline companies made a common effort to avoid in the new generation of transport aircraft the mistakes that have been made in the past, by formulating a number of ground rules for the design and finish of these aircraft. In the following some aspects of the IATA guidelines for design and maintenance against aircraft corrosion will be discussed. Before doing so the impact of corrosion and airframe durability on the total cost picture of civil transport aircraft will be discussed in more detail. Fig. 4 shows a typical break-down of the D.O.C. for a well-known medium range transport aircraft of the 1970 generation, based on a stage length of 350 nautical miles (approx. 650 km).

COST ELEMENTS	U.S.$ PER BLOCK HOUR	%
DEPRECIATION	350.7	12.1
INTEREST	245.5	8.4
INSURANCE	41.6	1.4
FUEL	901.4	31.0
COCKPIT CREW	377.5	13.0
CABIN CREW	185.3	6.4
MAINTENANCE:		
AIRFRAME, MATERIALS	71.0	2.4
AIRFRAME, LABOUR	223.1	7.7
ENGINES, MATERIALS	38.8	1.3
ENGINES, LABOUR	49.6	1.7
NAVIGATION CHARGES	177.2	6.1
LANDING FEES	248.2	8.5
	$ 2909.9	100.00

Fig. 4 Break-down of Direct Operation Costs for medium range twin engined jet-airliner,used on stage length of 350 n.m. (approx. 650 km) based on fuel price $ 1/U.S. gallon, price level Jan. 1, 1980 and calculated according the AEA-method (10).

and a fuel price of 1 $/U.S. gallon, being the economical condition of Jan. 1, 1980 and calculated according the A.E.A. method. It appears that the airframe maintenance cost, materials plus labour amount to 10.3% of the D.O.C. According to Schoevers (13) and Parkins (14) the costs of corrosion repair of contemporary aircraft average upto 8% and may be even 13% of the direct airframe maintenance costs. These figures are exclusive any costs created by unscheduled down-time at both the main bases or at route stations.
Such high corrosion damage figures indicate insufficient measures for corrosion prevention during the design stage. For the given aircraft in fig. 4 8% corrosion costs of airframe maintenance cost would mean 0,82% of the D.O.C. Experience with other aircraft models that during the design stage were subject of intense studies and measures for corrosion prevention, have learned that upto 90% of these corrosion costs can be avoided. That means that for the example aircraft 7.2% of the airframe maintenance cost ($ 21.10/block hour) can be saved. Expressed as fuel costs that would mean an equivalence of a fuel saving of 2,35%. Taking into account that fairly certain the total fuel costs of the new generation of airliners will be 25 to 30% lower than those of the present generation, this would mean an equivalence of a fuel saving of 3 to 3.3%. This is exclusive any costs from unscheduled down-time. It is clear that corrosion prevention has an important impact on the D.O.C. of the aircraft operation.
Indirectly the prevention of corrosion has a much greater influence. In many cases corrosion is the beginning of fatigue cracking and therefore is an important factor for the depreciation life of the aircraft. According to the calculation method of A.E.A. that life is assumed to be 14 years and a residual value of 0. When due to better corrosion protection the depreciation life of the aircraft could be 1 year longer than this assumption, which is rather pessimistic, the financial burden due to depreciation and interest could be 7% lower per block hour ($ 41.7). This is equivalent to 6.6% fuel saving for the new generation of aircraft. Depreciation periods longer than 15 years and higher residual values are certainly feasible for aircraft that have enjoyed more attention to the durability aspects during their design.

Design for Durability

During the design stage an effort must be made to create an aircraft that not only is strong enough to bear all possible external and internal loads on its structure without important damage and risks to the safety of the airframe and the people on board. In addition strong efforts must be directed as well towards the prevention of damage to that structure by these operating loads as well as environmental influences either separate or in combination, such that excessive inspection, untimely repair or replacement of components is avoided during the envisaged operating life.

The following basic problems have to be considered. The metal alloys that generally are chosen for airframe structures for reason of their favourable strength/stiffness/weight ratio's use to have such a composition that they are sensitive to stress concentration and subsequently prone to fatigue damage. These materials by themselves unfortunately are insufficiently resistant to environmental attack and subsequent corrosion and require special measures to prevent this. It must be taken into account that small initial corrosion damage can form starting points for dangerous fatigue phenomena. Fig. 5. Provision for sufficient resistance against both the operating loading as well as the atmospherical environment

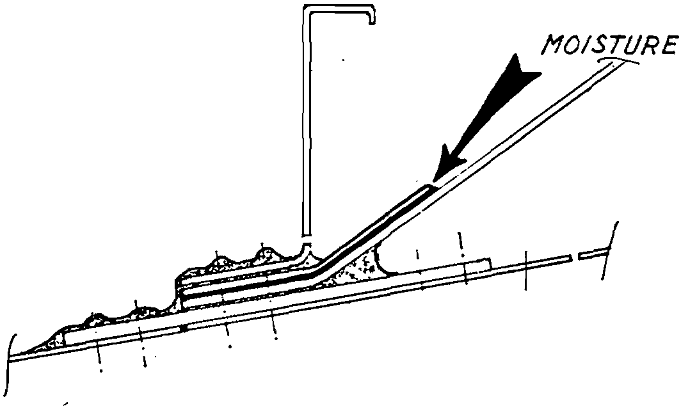

Fig. 5 Cross section of pressure bulkhead-skin joint where moisture penetration in bondline at the location of arrow created the initiation of a fatal explosive fuselage decompression (15).

can not be done for individual structural components, but requires a systematic approach. The following phases must be recognized therein:

- Definition of structural concepts.
- Selection of primary structural materials and definition of their means of protection against environmental influences.
- Definition of joining methods.
- Integration.

Definition of Structural Concepts

During this phase a compromise has to be found for the optimal geometry of the structure and its components for fulfilment of its load-carrying requirements through the projected aircraft life as well as production at the lowest possible costs and utilization of the available means of production. From the structural point of view the designer looks for the best possible fit of the geometry to the pattern of loads in order to keep the stresses as evenly distributed as possible. From the cost point of view, there is the requirement to keep the amount of individual components, the so-called "parts count", as small as possible. The latter will lead to lowest costs for drafting and production administrative activities, the indirect production costs. Modern numerically controlled manufacturing equipment nowadays offers facilities to fulfil these ideals "by sculpture" machining intrigate components from large solid planks of materials or preformed forgings. Undoubtedly this approach will see large scale application in the next generation of civil transport aircraft. However, this method has certain limitations that still leave openings for the more "old-fashioned" methods of design and manufacture. These limitations concern a number of durability aspects. These large integral components must have the highest possible material properties, which is not always possible due to the fact that they start as thick rolled planks of material that is not that homogeneous as thin rolled material. Inspite of the application of new heat treatments and alloying modifications, these materials have a certain directional sensitivity, as well for stresses perpendicular to the main rolling direction as for environmental attack. Also crack propagation in thick sections is faster than in thin rolled sheets. This requires detail design with great care and very effective corrosion protection. From the angle of the aircraft operator the use of very large integral components is not very attractive. In case of damage, either as a result of operational mishaps or corrosion, repair is difficult and sometimes replacement of such entire panels at high costs for long down-time and labour are unavoidable. The "old-fashioned" method of approach is the built-up of the components out of thin rolled sheets, stringers and doubler plates. Initially such structures were mainly assembled by means of riveting. The availability of adhesive bonding processes has offered an effective compromise between the mechanically fastened built-up structure and the integrally machined structure. Initially the adhesive bonded structure was attractive for application in rather thin sheet-stringer panels, where the stability of the bonded joints offered interesting weight saving possibilities over the riveted counter parts. Also the fatigue properties of the bonded structures were much better than the riveted ones, due to the absence of the fastener holes. (15) At a later date it has been discovered that the fracture mechanical properties of bonded multilayer metal laminates are superior over those of solid materials, due to the fact that the good fracture toughness properties of the thin sheets are maintained also in the thick built-up sections (16). Fig. 16.

It is unfortunate that in the eyes of many operators adhesive bonding has become synonymous for low durability. That has been caused by the fact that the applied adhesive bonding process, in particular the surface treatment prior to bonding, had been insufficient.
Aircraft, where this weak point had been foreseen and in the surface treatment process anodizing had been incorporated have shown excellent durability (17). There is no doubt that the manufacturing cost advantages of integral machinining can not be attained by the adhesive bonded skin-stringer construction. The "parts-count" of the bonded structure is unfavourable as compared with the solid one. It could be that in the future a compromise between the favourable properties of

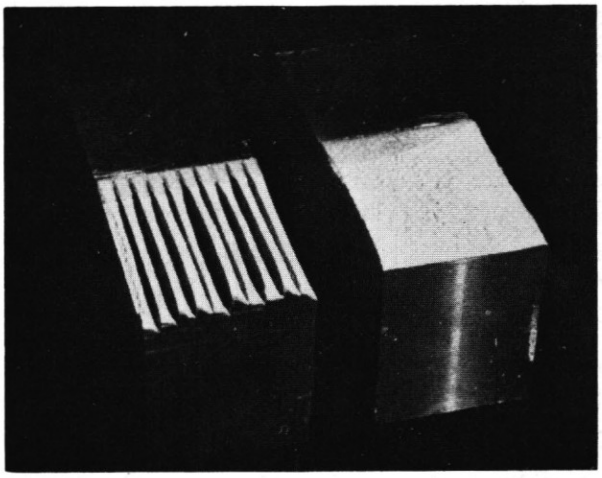

Fig. 6 Residual statical failures after fatigue cracking in solid and laminated metal (2024-T3). The right-hand specimen shows a brittle failure after the initial fatigue crack has penetrated from the topside. The laminated metal specimen the same alloy shows residual failure of a ductile nature in the individual bonded metal sheets.

bonded structures and those of integral machined structures could be found. The machining of prebonded laminated metals in combination with locally bonded stringers could give a fulfilment of as well cost as durability requirements.

Last mentioned solution is typically suitable for the heavier wing skins. Integral machining of the thinner fuselage structures is generally less attractive from standpoints of production economy as well as fulfilment of damage tolerance requirements, that demand for slow crack propagation in case of cracks in the pressure cabins. The attachment of longitudinal stringers and circumferential crack stopper doublers by bonding offer there very attractive solutions both from weight as well as fatigue resistance and damage tolerance points of view. The U.S.A.F. Primary Adhesive Bonded Structure Technology Program (PABST) has shown that including in the bonding operation of the circumferential frame flanges of the fuselage is feasable and leads to remarkably favourable results (18). The use of proven adhesive bonding systems, in particular those where phenolic adhesive resin and anodizing treatments are combined, lead to a durability that cannot be met by classical riveted structures. In this respect the IATA Guidelines for corrosion prevention in which bonding is excluded from lower lobe fuselage skin structures, is in error. That directive must have been based on out-of-date bonding technology and the use of closed top-hat stringers, that anyway offer insufficient guarantee for condensate drainage from fuselage structures, form a danger for corrosion and prevent suitable corrosion inspection. The continuous bonded joints are moreover superior to the riveted joints of which each rivet hole is a potential source of corrosion and fatigue problems. In areas of the lower fuselage where drainage of condensate and other fluids will not be completely possible, suitable sealing must anyway be applied. A well-protected adhesive bonded lower fuselage structure will be lighter and more durable than an equivalent riveted one.

Selection of Materials and Processes

When selecting the primary structural materials attention must be paid to avoid aluminium alloys which have a strong directional sensitivity both for stress perpendicular to and stress corrosion parallel with the main rolling direction of the materials. Also materials that are typically known for their low corrosion resistance, like magnesium alloys, should be eliminated from primary structure.
All individual aluminium alloy components must be provided with a complete set of corrosion preventive measures before they are assembled into the main structure. Such corrosion preventive measures are subject of many controversies. Several approaches are possible. One way is to provide the metal surface with an impermeable coating that will keep water away from the aluminium alloy surface. The adhesion of that coating to the surface must be such that even in case of local mechanical damage of the coating this joint between coating and surface will not be broken. Another approach is that this coating allows some moisture to penetrate through the coating but that in the coating chromate pigments are available, that dissolve in the water and provide an anti-corrosion solution that prevents any corrosive action when the water will reach the surface. That pigment will slowly disappear during the so-called "leaching" process. This pigmentation has a certain distance effect that prevents corrosion to occur also in gaps and at edges of the coating. During a long time chromated paint primers have been successfully protecting aircraft along this principle. However, since the introduction of phosphate-ester hydraulic oils these materials were not suitable anymore. The chemical composition of these oils is such that the resinous bases of the old primers were dissolved by the oil. Only higher polymerized resins have sufficient resistance against these oils. These more chemical resistant resins are also more water resistant and subsequently pigment leaching effects became negligable. Their corrosion protection effects therefore developed towards the direction of the first-mentioned principle. When no additional provisions are made, penetration of the coating, regardless the cause, can easily lead to corrosion between the coating and the metal surface. This phenomenon is known as "filiform" corrosion. The problem must be seen as similar to that of providing insufficient corrosion resistance to adhesive bonded joints. An aluminium alloy substrate, that offers good adhesion to either cured adhesive layers or highly chemical resistant paints, must be provided with an extra interface protection in order that penetrating moisture from damaged areas, sheet edges or rivet holes cannot cause hydration and subsequent corrosion of that interface as well as delamination. The best solution of this problem for civil transport aircraft, for which a long operational life is specified, is the use of anodizing prior to both painting as well as adhesive bonding. In this way an excellent durable bond is achieved. For detail parts of the structure this generally is little problem. Skins of fuselages, wings and tailplanes often form problems of different nature.
Airline companies for various reasons desire to change or refresh the paint scheme of their aircraft. The outside paint coat then must be removed. It is painful for the aircraft manufacturer, who did all his best to provide the aircraft with a durable protection scheme, to see how operators with help of highly agressive chemicals try to remove the well adhering and chemically resistant coating, they put on with so much effort. In this way, areas that are not so well coated, are seriously

endangered to obtain corrosion. The only solution to this problem, is to provide the outside of the aircraft with a phosphate-ester oil resistant paint primer system, that is covered with an easily removable, less chemical resistant topcoat system. For large aircraft, p.e. "Wide Body" aircraft, this may be a solution as the hydraulic oil contamination covers only a small part of the immense outside area of the skins. For small, to medium-size aircraft, including those of the short-haul class, hydraulic oil contamination will occur easily over the greater part of the outside skin. A non-strippable outside paint scheme is then the only realistic solution. A renewal of the outside paint scheme then can take place only by light abrasion of the exterior paint coat and application of a new coat on top of this, taking the weight penalty as unavoidable. A more ideal solution would be when the operating companies would be satisfied to have their company decoration limited to self-adhesive plastic coatings on a highly resistant base coating, that never will be stripped. Asking for a very durable but strippable phosphate-ester paint scheme is asking for an impossibility.

Joining Methods

In one of the foregoing paragraphs the merits of mechanical fasteners were compared with those of adhesive bonded joints. It was concluded that the latter had excellent durability when provided with suitable surface treatment on the substrate to be bonded. The bonding processes discussed were meant to be those that cure under conditions of elevated temperature and pressure. It is the intention to discuss in this paragraph the joining methods that have to be used for assembly of premanufactured components such as panels, frames and bulkheads. It was mentioned earlier that the highly chemical resistant paint schemes are sensitive for penetration by damage by the drilling of holes prior to the joining by means of rivets or bolts, when no further protection measures will be taken. This has led to the requirement to provide each fastening hole or even the whole faying surface of the joined components with a chromated sealing compound. Reflecting that for a good adhesion the component surfaces prior to painting were provided with an anodizing coating this very complex set of measures is excessive when no air- or liquid-tightness is required. The large-scale use of sealing compounds between the faying surfaces of mechanically fastened joints has also an important disadvantage. These rubbery compounds have a low stiffness and they prevent the originally present friction between the joint surfaces. This creates higher stress concentrations at the locations of the fasteners and subsequent reduction of the fatigue life of the joints. When the joints concerned are critically loaded ones, like longitudinal joints in fuselages, it is highly desirable to avoid any influence that can lead to reduction of the fatigue life of the joint. Therefore it is effective to replace the flexible and viscous sealing compound by a more rigid resinous compound. These can be room temperature curing resins, that also are used as adhesives (19). When such material would be used on poorly treated surfaces again there would be a risk of corrosion. However, as we have discussed in the foregoing the proper treatment for both durable painting as well as adhesive bonding is at least anodizing, the room temperature curing stiff compounds are no danger at all. They give a very remarkable contribution to the fatigue life and durability of mechanically fastened joints and the whole airframe. Fig. 7/8. In this respect it is regrettable that on the basis of poor operating experience with low quality room temperature bonded joints in conjunction with riveting the IATA organization decided to exclude such joints from future aircraft. In this way a very effective method to increase the durability of their future aircraft has been eliminated. Room temperature bonded and riveted joints that have been manufactured on the basis of anodized surfaces provided with precured phenolic primer have shown excellent operating results on more than 100 airplanes flying in all climatological circumenstances of the

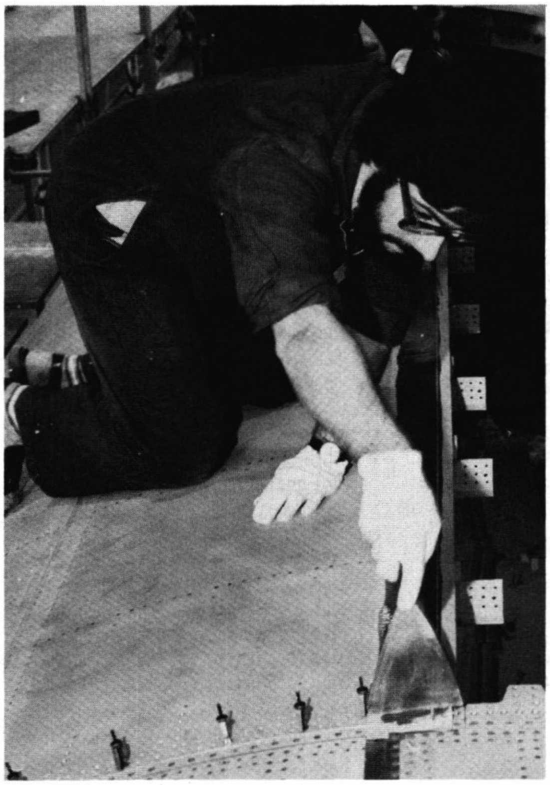

Fig. 7 A cold-curing adhesive mixture being applied on the well-prepared faying surface of a longitudonal fuselage joint prior to assembly (Fokker).

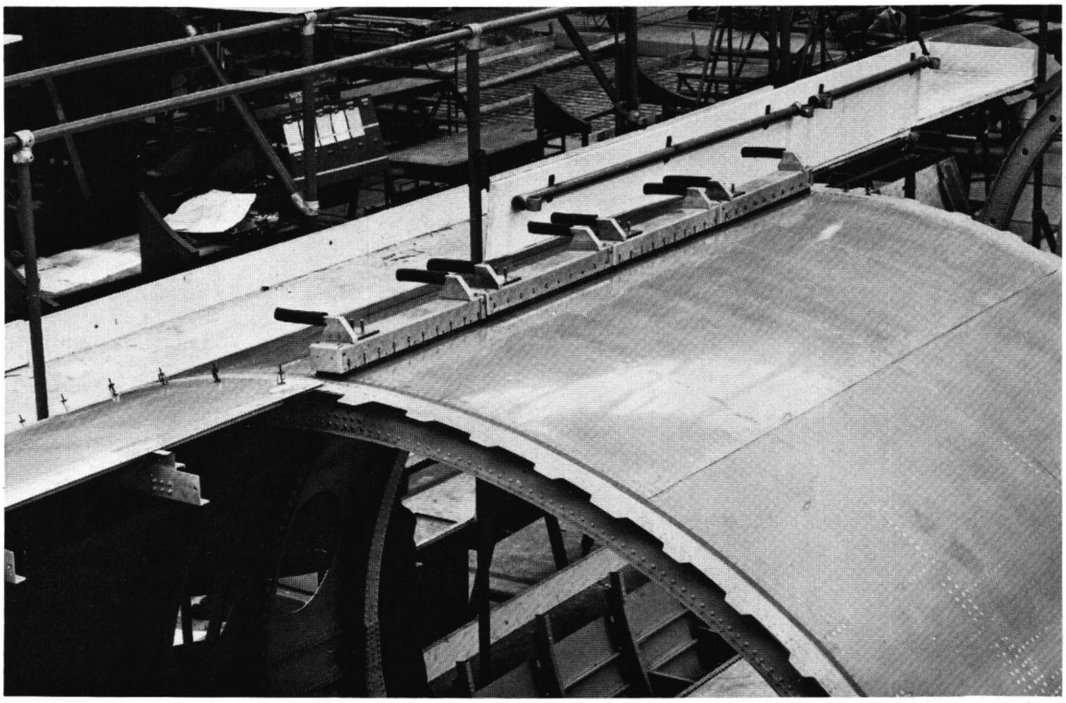

Fig. 8 Curing of a longitudonal bonded fuselage joint under magnetic pressure prior to emplacement of the rivets. (Fokker)

world and with lives uptill 11 years. This is unfortunately again an example how requirements for the future were based on bad experience caused by low quality instead of on new developments that have great promises for the future.

So far only metallic structures have been discussed. There will be no doubt that in the future generation of transport aircraft non-metallic advanced fibre reinforced plastic structures will be used on an increasing scale. As such fibre reinforced laminates are very sensitive for damage due to drilling of holes the use of adhesive bonding either hot cured or room temperature cured will be unavoidable. It is the best way to create effective joints between these non-metallic components, among themselves as well as with metallic components. In the latter case special attention must be paid to the avoidance of galvanic corrosion between the metal parts and carbon fibre based plastic materials. Operating experience with many advanced composite components have shown that the durability of such advanced composites structures is very acceptable. Also in that case quality control of a high standard is a firm requirement.

Integration

In the former paragraph only a rather limited scope of durability aspects has been reviewed. Many other ones, such as those concerning the use of steel and titanium as well in conjunction with fasteners as other joining processes such as bonding, are each worth a thorough discussion, but could not be included in this limited presentation.

It is hoped that from the foregoing it has become clear that a durability improvement of an aircraft cannot be obtained by initially neglecting that topic during design and manufacture, but subject the aircraft a few hours before delivery to some special treatment that will cover up all the durability deficiencies that have been built-in before. Durability is an aspect that during the design of each major component as well as the smallest detail part has to be considered just as well as strength and stiffness. The choice of methods to be applied for ensurance of durability must be made by the designer based on an effective durability plan, that has been composed prior to the start of the design work on a particular aircraft model. The various design features, materials and process selections must be based on one integral durability philosophy. In this respect the understandable desire of customers to have their new aircraft treated before delivery in many areas with water-repellant fluids to prevent corrosion is not as effective as expected. That will easily serve as an initial mask for weak durability points that should not be there but have been left as oversights in the aircraft. The durability plan must guide the designer through a proper choice of structural concepts and materials with their proper treatments to the most effective means to obtain a long-term durable structure. In this respect it should be recognized that not only metals are structural materials, but also synthetic resins in the form of paints, adhesives as well as matrix materials in composite structures.

The assortment must show a logical composition in order to avoid a multitude of different treatments and processes that will have to be applied in various structural configurations. There is little reason for keeping in operation parallel treatments for creation of adhesion between metal surfaces and resp. sealants, paints and cold- as well as hot-curing-adhesives. All aluminium alloy components of an aircraft should undergo one universal set of chemical treatments resp. for cleaning the surface, removal of residual oxydes and creation of a new strong and resistant oxyde that can serve as a base for paints, sealants as well as adhesives. At first sight it would seem whether negligence on the treatment for one of these materials is less serious than for another.
From a durability point of view, it is for the operator of the aircraft all equal. It will reduce the economical or military value of his aircraft.

Note

The opinions as expressed in this presentation are those of the author and will not necessarily represent those of the Fokker Company.

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