

## Adequate Protection Systems for Reduction of Wear on Tornado Aircraft

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### ABSTRACT

*The use in service life of the Tornado aircraft showed several areas subjected to wear. Due to its design some of them include, for example, the attachment for the variable wings, the related components and the flap tracks; some concern the taileron and the air intake ducts. According to this, the affected interfaces of different materials and the structural components have been protected with appropriate coatings to maintain the operability of the aircraft. Depending on the function of the moveable joints on the structure coatings with adequate hardness and wear resistance have been adopted. The range of applied anti wear coatings comprises both organic and inorganic compounds, such as polymers, composites, oxides, carbides, etc.. Sometimes the adopted protection methods showed good results; in other cases, alternative systems to improve the wear protection have been investigated.*

*This paper describes protection systems proposed and introduced on components in the Tornado aircraft structure subjected to adhesive and erosive wear. Particular attention will be addressed to the flap tracks and to the leading edges of both taileron and air intake ducts.*

### 1.0 INTRODUCTION

The Tornado is a multirole fighter – bomber aircraft with a variable sweep wings. In relation to its characteristic, several structural groups, in addition to the engines, are subjected to different kind of wear that include, for example, the wing attachment, the nib and the fairing. In particular, the related components of the wing attachment, such as the pivot pin, the bearing and the shear bearing device, are affected by sliding and fretting, as well as the roller and the bearing pin of the nib are exposed to friction. Other structural parts, such as the leading edge, are exposed to damage caused by the impingement of raindrops of high speed or owing to the missile firing. In an effort to find a solution, IAF, GAF, RAF and the related Industries have been concerned to introduce adequate protection systems to maintain the operability of the aircraft. Therefore, investigations with several materials were performed by tests simulating the realistic service conditions, in terms of loads, speed, temperature and environmental exposition. The wear resistant coatings comprise composite materials [1, 2], ceramics [3], and both organic [4] and inorganic [5] compounds. The minimum cost and the best performance in terms of wear resistance, high temperature strength and chemical stability made in the last years more attractive the use of ceramics and composites. Most of the adopted systems showed good results in terms of FH, so that they have been introduced on Tornado aircraft structure. Table 1 shows some structural parts subjected to wear and the specific materials applied. Nevertheless, in some cases, the achieved results were not satisfactory and further investigations are still ongoing.

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**Table 1: Structural parts and coatings applied**

Structural part	Protection system
Wing pivot pin	Silver plating
Wing bearing	Silver plating, Teflon liner
Shear bearing device	Teflon liner
Bearing pin	Titanium alloy strip, Karon V

## 2.0 IDENTIFICATION OF STRUCTURAL GROUPS SUBJECTED TO ADHESIVE AND EROSIVE WEAR

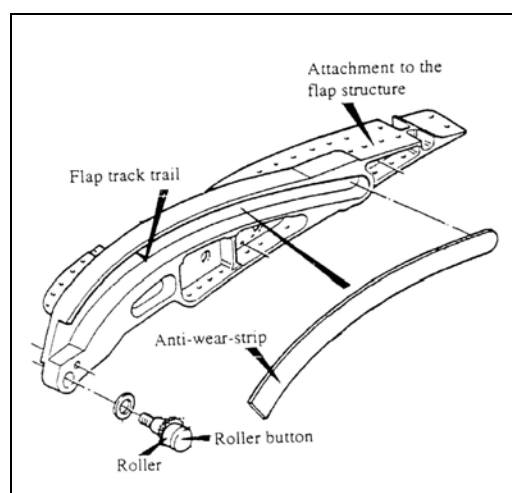
The structural groups subjected to adhesive and erosive wear on Tornado structure are:

- Attachment of the wings;
- Wing fairing;
- Wing nib;
- Flap track;
- Taileron;
- Air intake ducts.

In this paper will be describe the protection systems proposed and in case introduced on the flap tracks and on the leading edges of both taileron and air intake ducts.

### 2.1 Flap track

The flap track elements consisting of the flaps and rollers are bolted to the wing structure. The rollers allow continuous movement of the flaps during flight operation. The wear affected part of this assembly includes the flap track in titanium alloy, the roller in steel and the Teflon liner as anti wear strip attached to the face wall of the flap, Figure 1.



**Figure 1: The flap track**

The flap track is subject to slight deformation in the contact area of the roller in completely extended position of the flap mainly caused trough taxiing and during landing. Problems are caused by the anti wear strip as protection against contact of the roller end button with the flap track material. In the past loss of

adhesive bonded anti wear strip or damages of this protection occurred within less than 300 FH causing fretting on the flap track. Introduction of a new adhesive system reduced the loss of the strip but significant improvement of the reliability could not be achieved. Further solutions to improve this situation were investigated. In particular, coating of the roller end buttons with Karon V polymeric coating containing PFTE applied by spray equipment (thickness about 300  $\mu\text{m}$ ) together replacement of the Teflon strip and the use of LW-5 tungsten/silicon carbide applied by D- gun (thickness about 300  $\mu\text{m}$ ) were proposed for testing [6]. The use of Karon V protection system experienced good results achieving more than 300 FH without severe sign of wear both on the flap track and the roller buttons.

## 2.2 Taileron leading edge

The taileron are attached to the rear fuselage by pivot pins and consist of twist panel, leading and trailing edge, Figure 2. As consequence of the AIM-9L Sidewinder firing missile the leading edge, consisting of aluminium alloy, is subjected to heavy damage due to thermal erosion. To overcome the problem investigations with different anti erosion coatings on behalf of nations using Tornado were performed during the years. One solution proposed from IAF concerned the use on the leading edge of silicone rubber against the thermal stress covered with polyurethane anti erosion adhesive. Nevertheless the results of this experience were not significant for damages caused for aerodynamic friction on the protection within less 40 FH and with only two firing missile.

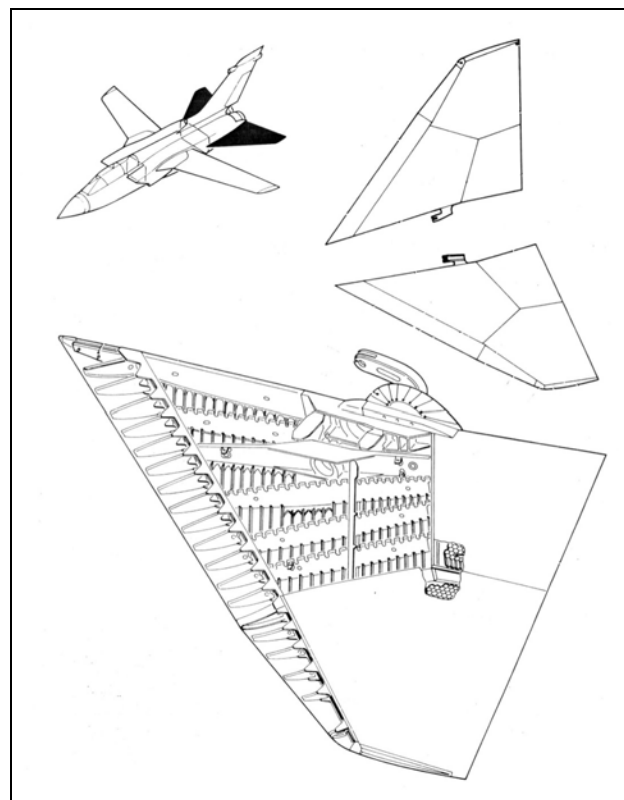


Figure 2: The taileron

The use of an acrylic primer [7] proposed from GAF improved the thermal resistance of the leading edge but caused problems by age hardening of the resin which could be cured by re-painting. Therefore, the RAF thought necessary to use new taileron with leading edge made in nickel alloy as Inconel 600, which showed good properties in terms of both thermal resistance and erosion. On this experience IAF and GAF replaced the taileron as well: in particular, in the case of the IAF, the introduction of new taileron has become executive from May 2002 and will be completed in 2012.

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### 2.3 Air intake duct

On both top and bottom lips of the air intake ducts is placed the anti ice coating, Figure 3, which consists of seven glass fiber layers and heating elements applied by spray among the layers selves. Stranded wire in copper give the continuity. The coating, attached to the structure by polymerization of spraymat resin in autoclave at high temperature, is covered by erocoat top coat layer (thickness about 300  $\mu\text{m}$ ) for protection against both the rain and impact of materials.

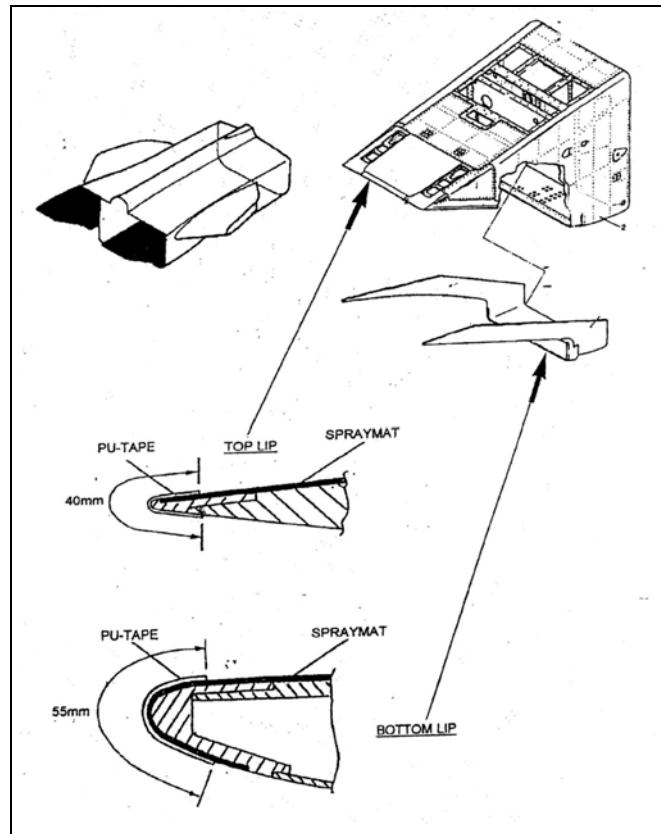


Figure 3: The air intake ducts

The erosion of the top coat permits the water permeation between the resin and the surface of the air intake which causes superficial corrosion detectable only after the coating raising or with the short circuit of the heating elements. Methods of protecting the coating were proposed during the years. RAF intended to spray tungsten carbide [8] to retard erosion, whereas GAF used a polyurethane tape and a Thermovision trial as method of inspection for corrosion with good results, suggesting the regularization from Panavia. Nevertheless further tests are still ongoing to solve problems due to overheating of the heating elements for insulating effect and aerodynamic erosion of the tape.

### 3.0 CONCLUSIONS

This paper showed the structural parts of Tornado aircraft more affected to wear and the investigations carried out to limit the phenomenon. Some, such as in the case of the taileron leading edge, were adequate, so that were adopted from the Nations using Tornado aircraft; some, for example in the case of air intake ducts, require further improved wear systems.

#### 4.0 REFERENCES

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**AVT-109****Specialist Meeting on the Control and Reduction of Wear in Military Platforms****Summary of Discussion Sessions**

The following presents a summary of the discussion of papers presented in the various sessions of the workshop. Only questions where the authors provided transcripts of their answers are reported.

**Session 1 – Service Experience and Repair**

Chair: Dr. Georg Gunther, EADSM, Germany

**Paper MP-AVT-109-7**

Dr. Ali Lafci, ASELSAN A.S., Turkey

Q. What are the corrosion and erosion problems on the service parts of the F16 aircraft?

Dr. Franco Bagnoli, Italian Air Force, Italy.

A. The F16 aircraft were in service in the Italian Air Force (IAF) only for the last year, and cases of erosion or corrosion problems so far have not been seen.

Dr. Ali Lafci, ASELSAN A.S., Turkey

Q. Are the problems faced on Tornados arising from materials selection or other sources?

Dr. Franco Bagnoli, Italian Air Force, Italy

A. The main problems are due to aerodynamic and thermal effects.