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ASSESSMENT OF AIRCRAFT COATING RESISTANCE TO LIGHTING STRIKES

ANALÝZA VPLYVU ZÁSAHU BLESKU NA RÔZNE TYPY LETECKÝCH NÁTERO

Matúš Sudin
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
matus.sudin@gmail.com

Pavol Pecho
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
pavol.pecho@fpedas.uniza.sk

Abstract

The paper evaluates the damage caused by lightning strikes on various types of aircraft coatings, the extent of the damage and the evaluation of technical and economic factors. The aim of the work is to evaluate and compare the damage after lightning strikes on metallic and non-metallic coatings of aircraft and to find out which coatings are more advantageous from a technical and economic point of view for use in practice. In the introductory part, the work describes the current state, the coating of aircraft, their function and application and the phenomenon when the aircraft is struck by lightning. Subsequently, the work deals with selected coatings and briefly describes them. The main part describes all parts of the performed experiment, samples and technical equipment used for the experiment and compares the damage on selected types of coatings. The last part of the work deals with the evaluation of results, based on which it evaluates the technical and economic advantages and disadvantages.

Keywords

Aircraft coatings. Lightning strikes. Lightning damage. Metallic coatings. Non-metallic coatings.

1. Introduction

The meteorological incident known as the lightning strike is one of the common meteorological hazards which can damage the airplane. After a lightning strike the airplane can possibly be damaged in many ways. Damage taken by a lightning strike can impair the coating to electronical systems of an airplane.

2. The current state analysis

As we mentioned in introduction the main idea came from Job Air Technic a.s. in Ostrava. They came with thought, that different types of aircraft coatings, especially metallic ones which are used mostly in eastern Europe are much more reactive with lightning strikes. Lightning strikes are generally known in aviation and they are commonly accompanying weather phenomenon. So, based on this knowledge we can ask a few questions as where and with what probability we can be hit by lightning strike.

2.1. Lightning strikes

Lightning strikes are not something unusual in aviation, but it can also affect airline operations and cause delays and interruptions of flights. It is something common in aviation to be hit by lightning strike, but it rarely has a significant impact to the safe operation of the airplane. Aircraft maintenance personnel must be familiar with repair procedures to be quick, cautious, and effective to avoid delays or shorten the time during these procedures. [1][2]

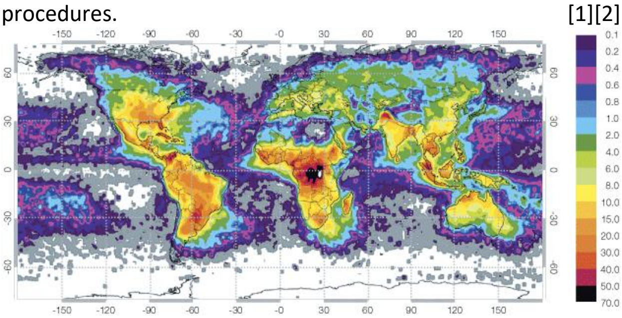

Figure 1: Lightning Observations for April 1995 through February 2003. Source: [1].

2.2. Coatings

The paint manufactures are using different structure of paint which depends on altitude, pollution, and environment. It´s important to use the best possible structure of paint in aviation.

There are a few conditions to choose aviation paint. It must have chemical resistance formula that resist hydraulic fluid, oil, and jet fuel. It´s important to use the same brand of painting when you do your etching, primer, reducers, and topcoat. Mixing brands is so risky and you have to be prudent and don´t use cheap paints. Also, you need to follow manufacture guidelines and read the material sheet before u use aircraft paint. [2][3]

The most common paint is single stage polyurethane paint which is like liquid plastic. We know three types of polyurethane paint:

- Water-based

- Oil-based
- Oil modified water based

For better and longer lasting paint, you should use the brand new and non-expired paint cans. You can notice a skin or film formed on the primer or paint in an opened container/can. In this case you are supposed to completely remove the film from top before you going to mix it and use it. The old or expired paint is dangerous to use because it becomes too thick or jelled. In this case, the paint is applied unevenly and will not have the right effect, which may also emphasize the aerodynamics of the aircraft. [2][3]

Air paint manufacturers are trying the best to create air paint which will fulfil these following points:

- Increased paint life
- Increase surface smoothness
- Corrosion protection
- Decrease adherence of dirt and other contaminants
- Decrease drag and reduce fuel consumption

2.3. Why are airplanes painted with aerospace coatings?

Aerospace coating has many pseudonyms in aviation, for example it is also known as aircraft coating, aviation coating or aircraft paint. Specific aviation paints are used by the aircraft's manufacturing, repair, and maintenance personnel to prolong the life of the plane's surfaces. Advanced aircraft coatings can be applied to jets, planes, helicopters, and many other planes to improve their appearance and prevent them against corrosion.

The aircraft paint must withstand harsh operating conditions and can be applied to both the outer and internal surfaces of the airplane. To protect an airplane's surface from severe weather, improve dirt resistance, and reduce drag, it needs an effective and high-quality coating. Coatings are in high demand in the aerospace industry these days, owing to the rapid changes in the climate. According to a report published by Research Dive, the global aerospace coatings market is expected to expand at a CAGR of 5.5 percent in the coming years.

2.4. Covid-19 and aircraft corrosion prevention

Although several planes are grounded due to the COVID-19 pandemic's lockdown, aerospace coating manufacturers are assisting aircraft repair departments by providing temporary and protective airplane coatings. Environmentally friendly materials like Z6160 and Z6148 peelable temporary protective paints aid in aircraft protection. When the airline services are ready to resume operation following the COVID-19 pandemic, these items can be easily withdrawn. These coatings have a low VOC content and are waterborne, so they can be applied without the use of a paint hangar. The peelable paint is applied directly to the skin of the inlet lip or over the fuselage livery. I fit is stored indoors or outdoors, this paint is waterproof, as well as light and heat resistant, and can protect the plane for up to a year. When it is time to put the plane back into service, the paint can be stripped away, leaving the original paint and exteriors intact.

3. Properties analysys of selected aircraft coatings

Experiment was done with 24 samples on aircraft material plates. First 15 samples are combination of 3 lower paints and 5 upper paints, next 9 are combination of that 3 lower coatings and 3 upper coatings, which we simulated metallic paint not used in aviation.

3.1. Non-metallic coating

In cooperation with ATB Bratislava, we were able to get 15 samples of aircraft samples from aircraft material with original lower paint and upper paint. Lower paints are real basic paint for three types of planes as Dash, Fokker and Embraer. For Dash is used Aerowave 2001-Primer, for Fokker it is PR143-KBHU and the last is Embraer with 10P20-44MNF. On each one we have five upper paints starts with CA8000-BO7067 Kahm-white, AVIOX 77702 041537 white FSB17875, ARC-Abrasion resistant 23+3-105, CA8800-P064C-Kaho-blue and last one Eclipse 080775 red Bac 1023.

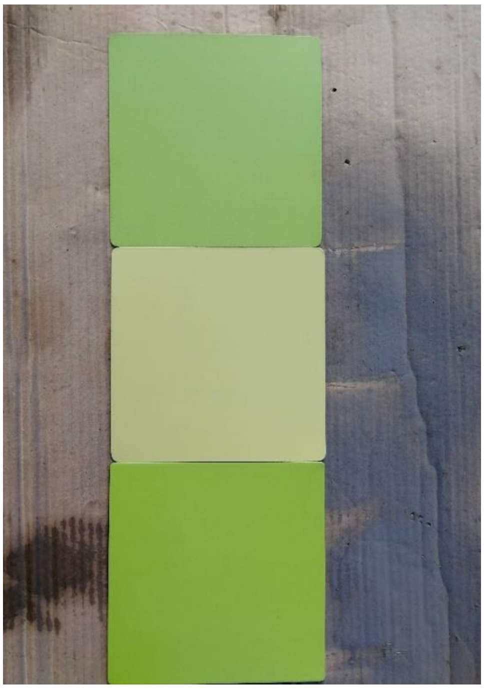

Figure 2: Three bottom primers from ATB. Source: Authors.

3.2. Metallic coating

As was mentioned, for experiment was used non-aviation paint for this type of coating, but we tried to simulate it on paints which are free to buy in stores. On Figure 3 are the samples of metallic spray colors. They are usually used in homes or they are used for covering damaged parts on cars or motorcycles. For experiment was choosen two Primalex samples, but one is glossy and the second one is matte. Last one is Decocolor which is glossier than color from Primalex.

Figure 3: Upper metallic coatings sprays. Source: Authors.

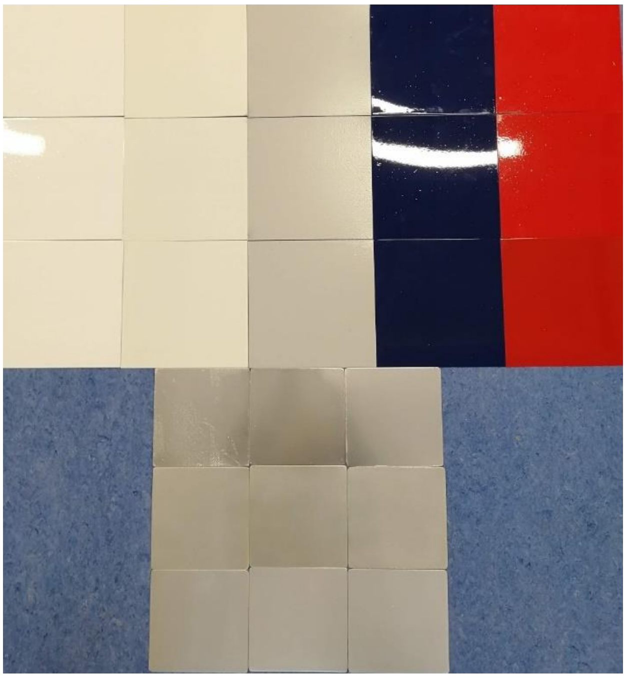

Figure 4: Metallic and non-metallic coating samples. Source: Authors.

4. Experimental verification analysis of lightning strikes on selected aircraft coatings

Experimental part of the work took place in Slovak technical university in Bratislava. The measurements were provided in setup shown in Figure 4, the electrode configuration is shown in Figure 5 while Figure 6captures electrodes in detail with dimensions. The air gap above tested sample was set to 50 mm. The small gap shown between the steel gauge (serial no. C0298) and the tip electrode in Figure 5 is the thickness of tested sample.

As the source of lightning impulse, a symmetrical 10-stage impulse generator with the maximum output voltage of 2500 kV_{max} was used with total energy of 100 kJ from TuR Dresden (serial no: 0-1656). During the experiment only two stages of impulse generator were connected. For measuring purposes an impulse voltage divider from Haefely-Trench RCR 400 (serial no. 554381-2), digital measuring instrument DMI 551 (serial no. 081 393-03), digital oscilloscope Tektronix TDS3052C (serial no. TDS3052C C011754) and a notebook computer with Tektronix SignalExpert software installed were used.

To every sample a set of 10 negative lightning impulses with shape of 1,2 / 50 µs at maximum voltage level of 100 kV_{max} were applied.

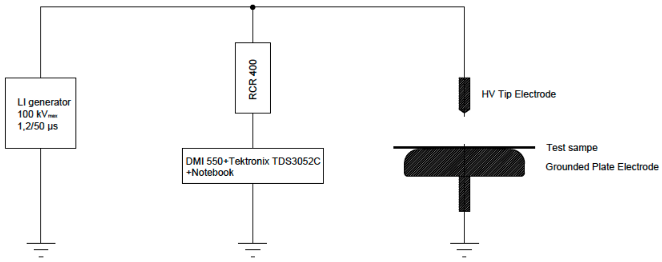

Figure 5: Wiring diagram. Source: Authors.

Figure 6: Workplace view. Source: Authors.

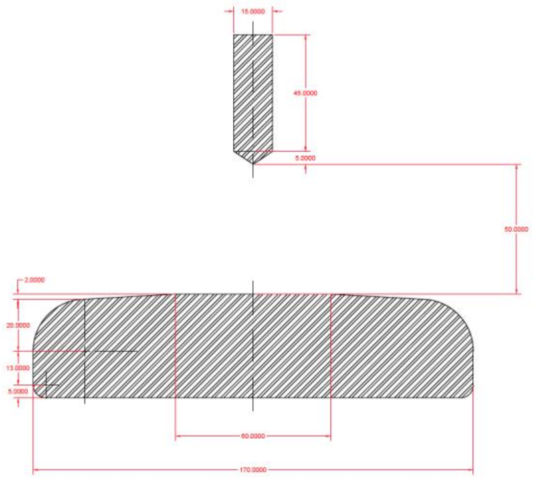

Figure 7: Electrodes in detail. Source: Authors.

4.1. Experiment

Each sample was hit 10 times. In a few samples it was necessary to repeat the discharge, because some of them did not hit the sample. On fifteen non-metallic samples we have made 154 discharges with four times when the discharge did not break through the sample. On the metallic coating samples were made 97 discharges but seven of them did not breakthrough. These seven shots which didn't make a breakthrough. There are at least three reasons why it is like this. First one is, that the metallic samples what we got are smaller, so the square area is smaller too. Second, the metallic base is not attracting electrical discharge at high intensity. And the last one is just mechanical error, like fatigue of generator, longer charging between discharges.

4.2. Non-metallic samples

Experimental part of non-metallic samples was as predicted. There was not too much damage on the samples, just a little hole after discharge shots. Damage taken was observable by an eye, but we could not see some big range of it. On every sample was shoot ten discharges with small area range. Obviously, it was because of conductive tip which aim discharges to the center of sample. After few shots on first ten samples, we could see just around eight shots landed.

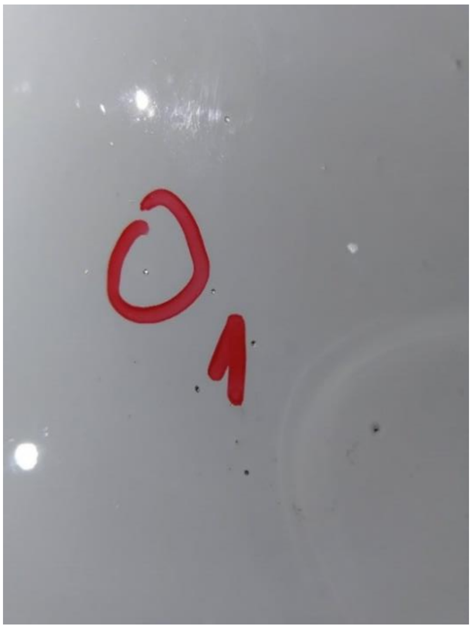

Figure 8: First sample after beeing hit by discharge. Source: Authors.

4.3. Metallic samples

The metallic parts were a lot of different. Discharge strength was still same as on non-metallic about 100kV. On the first sign we can observe a different between metallic and non-metallic samples.

Figure 9 Metallic Primalex gloss coating on PR143-KBHU before and after hit by discharge. Source: Authors.

4.4. Microscope observation

Second part of experiment was made in the place of University of Žilina in science park, where was used an electronic microscope to observe how large impact the discharges had made.

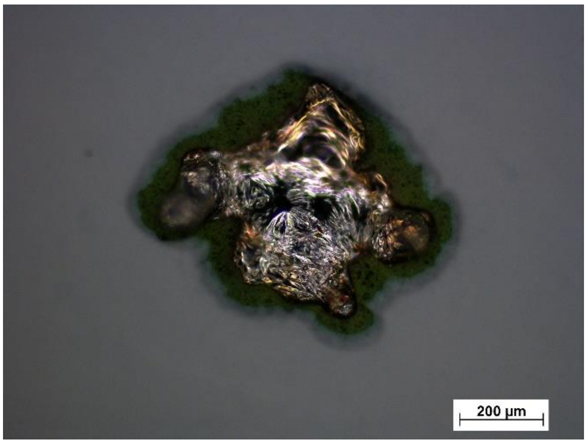

Figure 10: Microscopic view of crater in CA8000 Abrasion, non-metallic coating. Source: Authors.

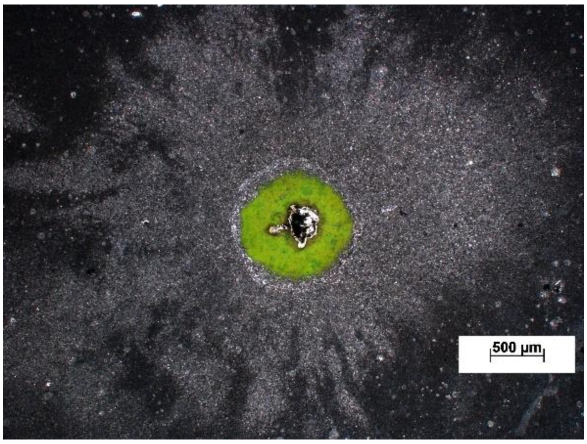

Figure 11: Microscopic view of craters on metallic coating Primalex gloss on Aerowave2001. Source: Authors.

4.5. Summary of comparation

Measured were the parameters of three different types of damage. These parameters are maximal inner crater diameter, maximal diameter of area range damage and maximal diameter of burned damage near crater

Table 1 Dimensions of damage parts.Source: Authors.

	Inner crater Diameter (µm max)	**Area range damage (µm max)**	**Burned damage near crater (µm max)**
Aviox 77702/10P20-44MNF	347,8	0	86,95
Primalex gloss/AW2001	416,6	2222,2	711
ARC-Abrasion/AW2001	652,7	388,8	41,7
Deco-color/AW2001	555,5	1250	416,6
CA8800-P064C/AW2001	458,3	486,1	69,4
Primalex gloss/PR143-KBHU	277,7	2222,2	638,8
Eclipse red/AW2001	416,6	208,33	111,1
Primalex matte/PR143-KBHU	375	2500	347,2

[Source: Authors]

In this table are the measurements of three parameters. There were chosen the aircraft coatings from comparation we made in chapter before. In the Table 1 the inner crater diameter has not big differences after lightning strike. Biggest differences are in area range damage and burned damage near crater. Aircraft coatings with metallic based structure have the area range damage from 1250 µm to 2500 µm. this area damage is much bigger than area damage on non-metallic based coatings. Burned damage near crater means the closer area to crater where was the upper aircraft coating burned up to the base primer. The best results have the non-metallic base coatings where was the diameter in range from 41 µm to 111,1 µm. Maximal diameter in metallic base coatings was in range from 347,2 µm to 638,8 µm, what is three and more times bigger damage.

5. Technical and economic evaluation

From a technical point of view, we now know that metallic kind of coating is much more reactive to lightning strike as metallic ones. There are many times larger damages taken by lightning. As we say in the beginning, we were just simulated the lightning strike with 100kV strong discharges. The strength of the lightning strike is about 300 million volts what is impossible to create just for experiment. By knowing this fact, we can make a statement that real damage after lightning strike will make more than 3 000 times bigger damage at all. On the Figure 4 we could see the real damage after lightning strike. Based on these facts, we can say that repairing the damage after lightning is really hard. Figure 4 is damage taken on the non-metallic base. If we compare the damage taken by ourselves on metallic and non-metallic samples the damage to metallic ones is going to be a much greater extend. The short, light maintenance is able to fix this damage, but from the technical point of view is going to be much harder and it is going to take much more time. Therefore, from this point of view is better to cover the planes with coating that do not contain overmuch metallic material in it. As we can see on the non-metallic coatings, there is for sure damage taken by lightning strike, but it is not going to take that much time as in maintenance on metallic coatings. The non-metallic coatings are going to safe a time, material, and manpower to fix the damage after lightning strike.

From economic point of view there are just few evaluations. In economic way we are looking mostly on a price. The results shown in our experiment tell us that damage taken by lightning strike on metallic samples is huge. That means the cost of repair is going to be much higher because of too many costs. One of the important factors is time. According to a well-known aviation statement, an airplane standing on the ground does not make money. Just planes in the sky make money, so it means that the longer the aircraft spends time with repairs in the hangar it is lossy. Repair time in this type of damage can be longer because of higher range of damage. There are also extreme cases where it is necessary to replace the entire damaged part of the aircraft. This type of repair can be the most valuable because the significant damaged part needs to be ordered, delivered, prepared for applying the coating and this process take a long time and as we said before, the time which airplane spends on the ground is the most valued factor of all.

6. Conclusion

The idea of this paper came from practice work in Jobair a.s. Ostrava. During the maintenance, they noticed a difference in damage taken by a lightning strike on different kinds of coatings. The main aim of this paper was to find out whether it is true that different types of coatings could suffer different types of damage.

The result and evaluation from this paper are that metallic-based coatings are damaged more than non-metallic-based coatings. We proved that damage taken on metallic-based coatings have a bigger impact than on non-metallic ones. This means that damage taken on metallic-based coatings needs more time and material to be fixed. Maintenance on this type of damage is more expensive which is not good from an economical point of view. Therefore, we propose using less metallic-based coatings to prevent aviation organizations from higher charges on maintenance. Based on the results from our paper it is much better to use non-metallic-based coatings to prevent the high risk of damage taken by a lightning strike. By using the non-metallic-based coatings, we could save more time and finances that have to be used for repairs and also prevent catastrophic consequences.

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