Evaluate the potential of applying a nano paint on SLAF Y-12(II) aircraft as a nanotechnology modification

ND Hiripitiya#, HVH De Soysa, SKK Dilshan, WMSKB Wijayathunga, KADD Kuruppu and DJK Lokupathirage

Department of Aeronautical Engineering, Faculty of Engineering, General Sir John Kotelawala Defence University, Sri Lanka.

#dhanuddhara7@gmail.com

Abstract— *This study is mainly focused on enhancing the durability of the existing external paint coated on Y-12(II) aircraft by using a "Flight Shield" nanopaint. According to the literature, this nanopaint is a crystal clear and it has the capability of bonding to the existing aircraft paint. This new layer protects the existing paint and provides a smooth, gloss by chemically and also it gives self-cleaning property. In the methodology, the 25/26 Ardox cleaning solvent has to be used in order to clean outer skin of the Y-12(II) aircraft. Cracks of the skin have to be identified and required remedies have to be performed. The pre-treatment primer and epoxy primer hardener have to be mixed in 1:1 ratio according to the manual. The mixture has to be applied on the surface. Let the primer to dry about 18 hours. Gallon kit (white, black, blue paints, thinner for poly paint and epoxy thinner) has to be applied next and painting has to be done in a colour chamber under 25 ^oC – 30 ^oC temperature. Flight Shield nano coating has to be applied as a final coating followed by drying for about 24 hours. The additional cost incurred for the nanopaint is $ 930. Even though the initial cost is high, the nanopaint protects the existing paint by 5 years. In addition to that, from 1 l volume of nanopaint, it can cover 900 ft^2 and approximately 6.5 l need to cover the whole Y-12(II) aircraft which has 5658 ft^2. Due to the nanopaint smoothness will increase which leads to reduce the drag hence this leads to increase the performance of the Y-12(II) aircraft. The dynamic contact angles were 161^o and 162^o for the surface which was coated by nanopaint. This proves the super hydrophobicity of the surface, which leads for water droplets to easily slide off.*

Also, as this nanopaint is durable for 5 years, it reduces the cost for painting the aircraft every year, which leads for a financial benefit ultimately to SLAF.

Keywords— Nanopaint, Y12 aircraft, Nanotechnology

I. INTRODUCTION

Nanotechnology is the science and technology of small things that are less than 100nm less than in size. One nano-meter is 10^{-9} meters or about 3 atoms long (Rathbun, 2005). When considering the development of aviation industry, nanotechnology has been influenced a lot. It is prominent in the fields of nano electric devices, engine components and airframe systems in aircraft. The Y-12 has been designed to take-off and land over short distances. The aircraft has been designed to execute passenger or cargo transportation, parachute jumping, geological exploration, aerial photography and ocean surveillance operations. It can also perform a wide range of other missions, including medical rescue and touring. The aircraft is equipped with a single vertical stabilizer, upper wing and front fixed tri cycle type landing gear as shown in Fig. 01 below.

Figure 01: The exterior of the Y-12 (II) aircraft

The flight deck of the Y-12 aircraft can accommodate two crew members such as pilot and co-pilot. The Y-12 also features a spacious and comfortable cabin fitted with 19 seats for passenger transportation. When we consider the engine of the Y-12 it is powered by two Pratt & Whitney Canada PT6A-27 turboprop engines. Each engine can produce 462 kW of output power. The aircraft is fitted with a Hartzell three blade propeller made of aluminum. The

propeller can rotate at a constant speed of 2,200 rpm. The Table 01 below illustrates the performances of Y-12(II) aircraft.

Table 01: Details of the Y-12 (II) aircraft (www.airlines-inform.com, 2012).

Weight	
Maximum take-off weight (kg)	5 300
Operating empty weight (kg)	2 840
Performance	
Range with max payload (km)	1 300
Cruise speed (km/h)	250
Maximum speed (km/h)	330
Maximum operating altitude (m)	7 000
Engines	P&WC PT6A-27, 1 x 620 shp

When we consider any aircraft there are several reasons which effect for the removal of paint such as bad weather conditions, bird strikes and fading naturally with the time. Therefore, partial painting may also take place at least once in every 2 months.

The nano-technology has been used on U.S. military aircraft, but this is the first time a U.K. airline has applied it to commercial planes. The coating, which is 100 times thinner than a human hair, smooths out microscopic bumps and nicks on a plane's surface, letting it glide more easily when in flight, ultimately cutting fuel consumption and cost. It adds only 4 oz of weight to the aircraft, and reduces the build up of debris on the aircraft's surface, thus reducing drag (Dailey, 2011). This nanopaint has an ability of self-cleaning which means it repels water droplets, dirt, oil and other contaminants from the surface of the nanopainted aircraft. Furthermore, this paint provides many benefits such as paint protection where obstruction to harmful things like UV rays, de-icing fluids, dirt and bugs. As this paint repels harmful contaminants which leads to depreciate the paint life of the existing aircraft paint which will be protected and hence life of the paint is high. The nanopaint remove oxidation and contaminants of years and therefore, repainting is not required for five years which saves repainting costs. And also as this coating repels contaminants such as dirt, oil, exhaust stains, de-icing fluids and bugs, frequent cleaning is not necessary. Hence this reduces cleaning costs. Furthermore the nanopaint is colourless due to this property it doen't add extra colour to the existing colour. FlightShield is a crystal clear nano coating that chemically bonds to aircraft paint to become a new surface and protective layer offering an ultra smooth, high gloss and resistant coating. This coating stands between harmful contaminants and the paint, providing exceptional protection and gloss retention. FlightShield also offers the finest paint revitalization system in the industry. Our revolutionary process restores oxidized and faded paint to look like new, for a fraction of the cost of repainting the aircraft. Flight Shield extends paint life, reduces cleaning expense, optimizes performance and keeps the aircraft looking its best. After applying this coating, the surface becomes smooth and high gloss. Therefore, it improves a laminar flow and reduces the coefficient of friction which leads to reduce the fuel consumption as well. This nanopaint also has ability to act as a shielding coat which provides paint protection for the existing paint and several other advantages such as paint life extension, paint revitalization, cleaning expense reduction, performance optimization and environmentally friendly. During the washing process of the aircraft by using cleaning solvents, water get pollute. But, if we apply this coating on the aircraft, the dirt particles do not remain on the aircraft and hence no need to wash the aircraft frequently. This leads to save water and reduces the amount of pollutants that could enter the water passages from washing. Therefore, this nanopaint act as an environmentally friendly coating (Shield, 2015). The objective of this research is to analyse the potential of applying a nanopaint on SLAF Y12(II) aircraft as a modification done using nanotechnology in order to achieve minimum number of paintings which leads for a better saving in both materials and man hours.

II. METHODOLOGY

A. Selecting of Y-12 (II) aircraft

Y-12(II) aircraft was selected due to easy accessibility of it to obtain information from Ratmalana Air Force Base and also it is one of the aging aircraft in Sri Lanka Air Force.

B. Identify the issues related to existing paint

Analysis was done regarding the existing paint and the issues it encountered. Several senior technicians at the no. 8 squadron, Ratmalana SLAF base were interviewed via telephone conversations to identify the issues relating to the existing paint. There were several reasons which affect for the removal of paint such as bad weather conditions, bird strikes and fading naturally with the time.

C. Selecting a nanopaint

Out of several nanopaints "Flight Shield nanopaint was selected based on the properties of it such as we analysed that there is a potential of applying nanopaint on top of the existing paint. Test trial had to be done in a model aircraft before it apply to the Y12(II) aircraft.

D. Method of applying the nanopaint

Before applying the nano paint, the existing paint had to be removed using the 25/26 Ardox, which act as a solvent to remove the existing paint. A cleaning solvent had to be used in order to clean the outer skin of the Y-12(II) aircraft in order to carry NDT testing. Cracks of the skin had to be identified and required remedies had to be taken as the nanopaint last for 5 years. After the verifications of absence of cracks, pre-treatment primer and epoxy primer hardener had to be applied after mixing by 1:1 ratio according to the manual. The primer had to be on the surface of the aircraft and it had to keep 18 hours to dry. Gallon kit (white, black, blue paints, thinner for poly paint and epoxy thinner) had to be applied and the painting had to be done in a colour chamber under 25 ^{o}C – 30 ^{o}C temperature. The aircraft allowed to dry for 24 hours as per the procedure follow by SLAF. The nanopaint could be applied under the given conditions. The nanopaint had to be applied using sprayer to cover the existing paint. The aircraft had to be dried for 24 hours.

A. Dynamic contact angles for the nano paint

Wetting properties of a superhydrophobic surface were characterized as follows. The measured data on five different spots on the surface were considered. 1.00 µl droplet was applied on the surface, and the needle was lowered behind the drop so that the tip was about at the midway of the droplet height. The volume of the droplet was slowly increased to 2.00 µl. To measure the advancing contact angle, the volume of the droplet was increased from 2.00 µl to 10.00 µl. The droplet volume was increased to 15.00 µl and decreased back to 11 µl. The receding contact angles were measured by decreasing the volume until the drop lost contact with the surface.

III. RESULTS AND DISSCUSSION

A. Cost calculation for the existing paint

As shown in Table 02 below total cost for the existing paint was approximately $ 33215.

Table 02*:* Cost calculation for the existing paint

Item	**Price per liter ($)**	**Quantity (l)**	**Cost ($)**
25/26 Ardox paint removal	17	400	6800
Cleaning solvent	10.7	300	3210
Thinner for pretreatment Primer	14.53	19.987	290.40
Epoxy primer Hardner	98	100	9800
Gallon kit (white)	37	22.7	841.03
Gallon kit (Black)	37	22.7	841.03
Gallon kit (Blue)	37	22.7	841.03
Thinner for poly paint	35.3	200	7060
Epoxy Thinner	35.3	100	3530
Total cost			**33,213.49**

B. Area calculation for Y-12 (II)

As given in Table 03 below the total area of the Y-12 (II) aircraft was 5658 ft^2.

Table 03: Surface area calculation for the Y-12(II) aircraft (Corporation, 1988).

Location	Area (ft^2)
Rudder	50
Ailerons	96
Ventral Fin	10
Flaps	192
Fin	40
Fuselage on STBD and PORT	275
Fuselage on STBD	250
Fuselage on STBD	350
Fuselage on PORT	350
Fuselage on PORT	250
PORT and STBD wing top	480
PORT and STBD brasing members	40
PORT and STBD Engine bottom panels	65
PORT and STBD wing bottom	480
Bottom fuselage	400
Top fuselage	375
Fuselage on STBD and PORT	275
Fuselage on STBD	250
Fuselage on STBD	350
Fuselage on PORT	350
Fuselage on PORT	250
PORT and STBD wing top	480
Total area	**5658**

C. Cost calculation for painting Y-12(II) aircraft using existing paint

Total area of the outer skin of the Y12(2) aircraft = 5658 ft^2

Cost for the existing paint = **$ 33,213.49**

D. Cost for the nanopaint

Area coverage per liter = 900-940 ft^2 (According to the given data for the flight shield nanopaint)

Required volume of nanopaint = 1 l/900 ft^2 ×5658 ft^2

= 6.29 l

≈ 6.5 l

Cost for nanopaint = $ 150 per liter × 6.5 l

= **$ 930**

E. Cost comparison

Applying frequency of the existing paint = 2 year

Paint life expansion due to nano paint = 5 years

Saving cost due to nano paint = 2 X $ 33,213.49

=**$ 66246.98**

F. Calculation of weight increment due to nanopaint

Weight increment of the aircraft due to nano paint = ρV = 950Kgm^{-3} × (6.5 × .001 m^3) = **6.175 Kg**

G. Assumptions encountered for the calculation

1. Nano paint was applied in an efficient manner (no wastage occurred of paint)
2. Man hours were not considered in cost calculation
3. Equipment required to apply the paint was not considered.
4. Cost incurred for cleaning the aircraft was not considered.

H. Overview of the coating of Y-12(II)

After applying the nano paint, cross section of the paint layers could be visualized as below.

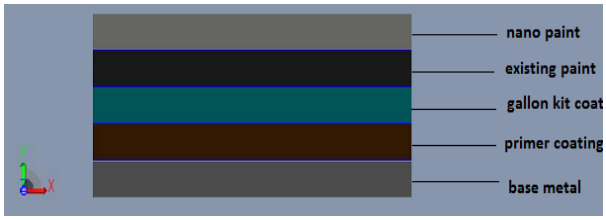

Figure 02: Solid works diagram for cross section of all coatings

As according to the Fig 02, there were several coating layers such as primer, gallon kit, existing paint and the proposed nanopaint coating.

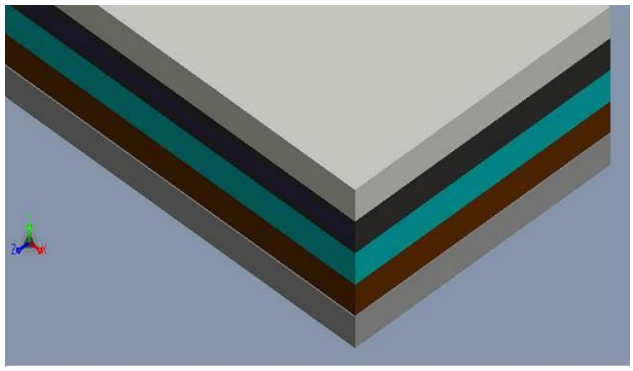

Figure 03: Solid works schematic diagram of front view of the coatings after apply nanopaint

The overviews of the coatings are shown in Fig 03.

I. Less adhesion due to nanopaint

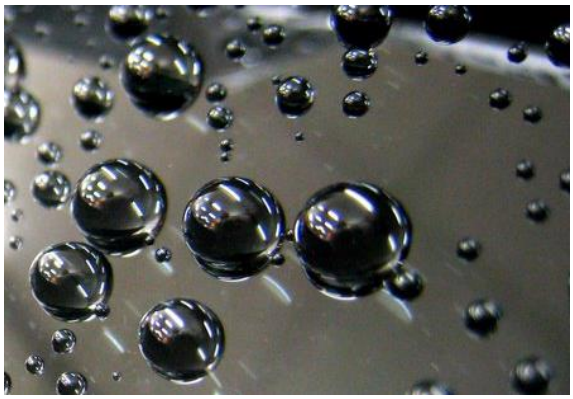

Figure 04: self cleaning (lesser adhesion) property on a surface after coated using nanopaint

As Fig 04 illustrate the surface of the nano coating act as a dirt repellent surface with low adhesion which leads to have self cleaning property and also to lower the drag. This leads to save huge amount of Jet A1 aircraft fuel.

J. Measuring contact angles using dynamic contact angles on superhydrophobicity surface

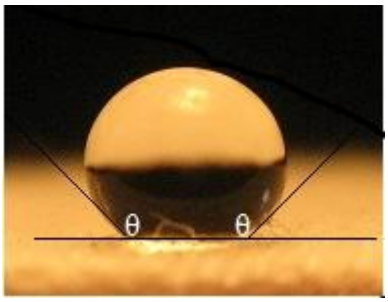

Figure 05: Dynamic contact angles for the nanopaint

As shown in Fig 05 the Dynamic contact angles were measures and the obtained data were as according to Table 04 below.

Table 04: Dynamic contact angles

Material	Average advancing contact angle (degree)	Average receding contact angle (degree)
Reference	-	-
With nanopaint	161±1	162±1

As according to the given data after applied nano paint on the surface the contact angle measurement were 161^{o} and 162 ^{o}. According to the literature, it's super hydrophobic as the contact angle is above 150 ^{o}.

IV. CONCLUSION

In this research we considered the potential of applying nanopaint on Y-12 (II) aircraft. According to the data analysis we found that this paint add an additional cost of $ 930 same time it extends the life span of the existing paint by 5 years additionally. This led to minimize the servicing and maintenance of the existing paint. This coating added additional 6.175 Kg weight for the aircraft. This weight is very low compare with the weight of the aircraft. Even though this additional weight burn additional amount of the fuel, there are several advantages due to this nanopaint. Due to this nanopaint drag force will be reduced hence it leads to save fuel. As this nanopaint is smooth it leads for better aerodynamics stability. According to literature, this coating has been applied to various types of aircraft such as Gulfstream, G450, G550, Bombardier Challenger 604, Global Express and Beechcraft aircraft which fly at higher altitudes when compared with Y-12(II) aircraft (Painting and finishing, 2012). Hence, this is a proof that Y-12 aircraft is aerodynamically fit to fly after application of this coating. Also as the nanopaint is less in adhesion frequent cleaning is not essential, this leads to save man hours and cost for cleaning chemicals and water. Additionally touch-up paints also not required as this nanopaint can withstand for weathering conditions. As this nanopaint was based on Silicon it showed inert qualities which prevent the lightning strike damages, act as resistance to corrosion and act as colour protective layer. In addition to that, existing paint can have scratches due to misuse of tools inside the maintenance hangar during maintenance. Therefore this coating added additional protection to the existing coating. The dynamic contact angles were 161^{o} and 162^{o} for the surface which was coated by nanopaint. This proves

the super hydrophobicity of the surface, which leads for water droplets to easily slide off.
To succeed this process it requires well trained servicing personnel as well as the sophisticated equipment. Although the initial cost is high it is highly encourage to investment on this nanopaint.

V. FUTURE WORK

As future work we are going to incorporate the cost for the paint equipments such as spary guns and also man hours to the calculation. As the next step of this research we are going to analyse the applicability of this nanopaint on Y-12(IV) aircraft which is newly purchased by the SLAF.

ACKNOWLEDGMENT

The authors gratefully acknowledge all the academic staff members of the Department of Aeronautical Engineering, General Sir John Kotelawala Defence University for the support given in this mini research project and senior technicians at no 8 Squadron, SLAF base Rathmalana, Sri Lanka.

REFERENCES

Dailey J, (2011). EasyJet Coats Airplanes with Ultra Thin Paint To Reduce Fuel Consumption. *Inhabitat innovation*
Available at: http://inhabitat.com/easyjet-coats-airplanes-with-ultra-thin-paint-to-reduce-fuel-consumption/ [Accessed 12 May 2016]

Painting and finishing of Aircrafts. Federal Aviation Administration (2012)
Available at: https://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/amt_airframe_handbook/media/ama_Ch08.pdf [Accessed 15 May 2016]
Corporation, H. A. M., 1988. *Y12 (II) Aircraft Structural Repair Manual,* s.l.: Harbin Aircraft Manufacturing Corporation.
Rathbun, L., 2005. *National Nanotechnology Infrastruture Network.* [Online]
Available at: http://www.nnin.org/news-events/spotlights/what-nanotechnology
Shield, F., 2015. *Flight Shield.* [Online]
Available at: http://www.flightshield.com/
www.airlines-inform.com, 2012. *Harbin Y12.* [Online]
Available at: http://www.airlines-inform.com/commercial-aircraft/Harbin-Y-12.html

Biography of authors

ND Hiripitiya is a 4th year officer cadet undergraduate following the BSc Engineering degree in Aeronautical Engineering at General Sir John Kotelawala Defence University.

HVH De Soysa is a 4th year officer cadet undergraduate following the BSc Engineering degree in Aeronautical Engineering at General Sir John Kotelawala Defence University.

SKK Dilshan is a 4th year officer cadet undergraduate following the BSc Engineering degree in Aeronautical Engineering at General Sir John Kotelawala Defence University.

WMSKB Wijayathunga is a 4th year officer cadet undergraduate following the BSc Engineering degree in Aeronautical Engineering at General Sir John Kotelawala Defence University.