Computational Analysis and Prototype Experiment of anomaterial for Aircraft Wing Inboard Flap in Aerospace Industry

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ABSTRACT

The aircrafts fly at both high altitude and fast airspeed in the air but needs slow airspeed in order to land safely. To increase aircraft fly efficiency, the material and design of wing inboard flap should be carefully engineered to provide aircraft with high speed flight in the air but keep strong lift with lower airspeed in order to safely land to the ground. The wing inboard flap is a critical part for the aircrafts and the previous researches showed that the damaged inboard flap can lead aircraft function failure and even cause fatal accidents in the flight and landing processes. Since the defects in wing inboard flap can cause potential safety hazards, the strong inboard flap materials and good inboard flap design to keep safe flight is very important. This paper studies and analyzes the nanocoated material applied in the design and development of aircraft wing inboard flap by using computer-aided 3D modeling, numerical simulation, and prototype experiment to improve current and future wing inboard flap design and development

INTRODUCTION

The technical and industrial innovations to the wing inboard flap can help to keep aircraft safe flight. The aircraft needs to fly at higher altitude and fast airspeed to efficiently travel more distance with less time. It also needs lower airspeed but strong lifting capability in the landing process. Because of the above conflicting situation that high airspeed required in the fly but slow airspeed needed with higher lifting capacity in the landing, the study and analysis of aircraft wing inboard flap are very critical to the aircraft performance. The controlled inboard flap with its hinges at the top surface of aircraft wing can generated more lifting forces for the fly and landing. The wing flaps can increase both lifting capability of the aircraft wing and drag force. The aircraft inboard flaps can also play an important role in decreasing airspeed and adjusting parasite drag force for safe landing. The nanocoating technology is a renovation introduced to improve inboard flap material properties due to its enhanced material properties and better corrosion-resistant performance. Because the nanomaterial shows significantly reduced grain size and enlarged grain boundary ratio, it can improve both material physical and mechanical capabilities. Nanocoating technology can make nanomaterial strongly adhered into the coated material substrate to improve material functions in anti-scratch, wear-resistant, and rust-protective. This research paper introduces the applications of nanotechnology in aircraft wing inboard flap development by applying nanocoating technology to improve inboard flap function based on computational simulation, prototyping, and sampled experiment. The performed computational simulation and prototype testing in this research show closed results which verifies the feasibility of analytic methodology introduced in this research. The technical outcome from this research can assist scientists and professionals in their future design and development of aircraft inboard flap products.

COMPUTER AIDED 3D MODELING AND NUMERICAL SIMULATION

Inboard flaps are located in the wing trailing edge at the inboard section and flaps can be adjusted downwards to enlarge the wing curved surface. With this control, inboard flaps can help to increase the lift coefficient of aircraft and decrease the aircraft stalling speed. The inboard flaps helps aircraft in slow airspeed with large attack angle fly and safe landing. The aircraft lift coefficient is a dimensionless parameter integrating the lift force produced by a lifting aircraft, air pressure of airflow surround the aircraft, and involved area related to the aircraft body. The nanocoating technology can help to improve material property and control the lift coefficient for optimal aircraft flight function. The mathematic equation for lift coefficient (L_{coef}) of inboard flap is as follows:

$$L_{coef} = \delta * [\frac{\partial(N_{coef})}{\partial \delta}] + \beta * [\frac{\partial(N_{coef})}{\partial \beta}] \qquad (1)$$

Here, δ - airflow deflection angle; β - airflow incident angle;

The stress induced in the inboard flap is primary local stress when it is produced from unrelenting loads. Fig. 1 shows the 3D model of aircraft wing inboard flap.

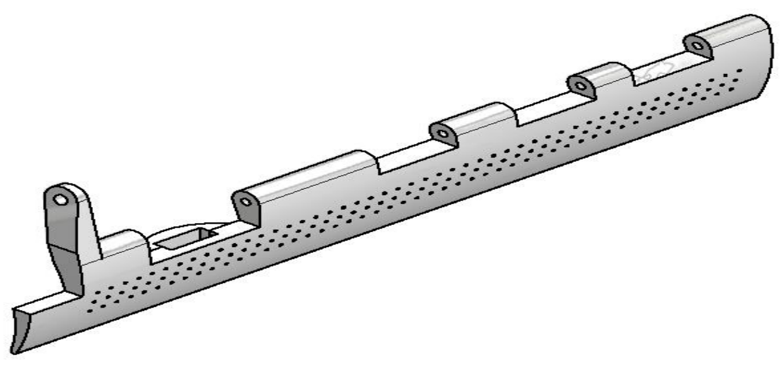

Fig. 1 Aircraft wing inboard flap

Gradually produced permanent flap collapse is caused by cyclic strain accumulation that leads component damage and flap function instability through material permanent deformation. It will reduce flap material life cycle by gradually decaying material surface and spreading damaged cracks. The cyclic life model for aircraft inboard flap can be analyzed by applying the following equation:

$$\frac{1}{S_{unit}^{W}} = \sum_{n=1}^{n=M} \frac{1}{S_n^{W_n}} = [\frac{1}{S_1^{W_1}} + \frac{1}{S_2^{W_2}} + \ldots\ldots + \frac{1}{S_M^{W_M}}] \qquad (2)$$

Here, S - cyclic life time of inboard flap, W - slop coefficient

The computer aided 3D model and numerical simulation methodology developed in this research can help inboard flap design, study mechanism of anti-corrosion, and decrease inboard flap corrosion by applying nanocoating technology. The thin films consisting of nanocoated material can function as a rust-resistant barrier making it hard for dispersive molecules permeating nanocoated material surfaces. The computer aided simulation results are displayed in Figs. 2 and 3. Fig. 2 presents the diagram of simulated dispersive ratio of molecules C_0 / C vs. internal gap Z of nanocoated element in different nanocoated volume ratio.

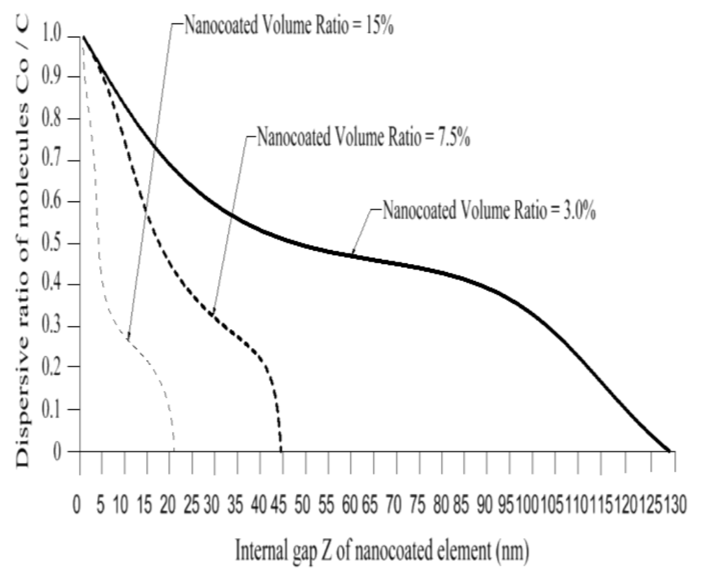

Fig. 2 Dispersive molecular ratio C_0 / C vs. internal gap Z of nano-coated element

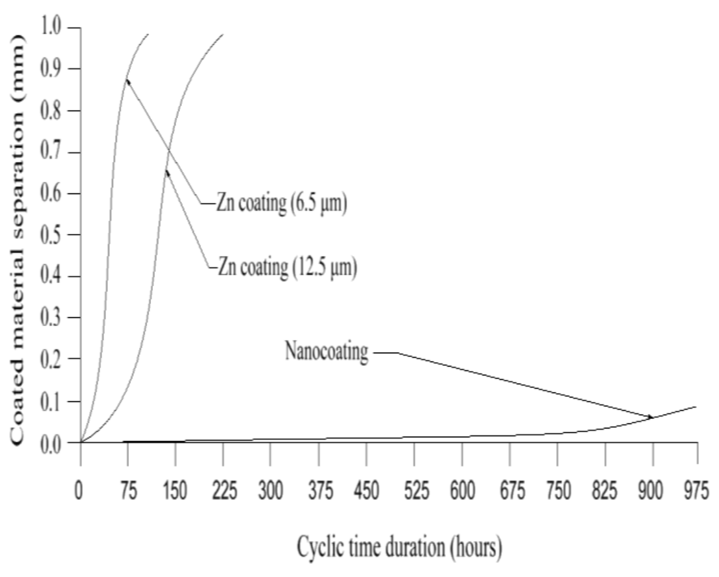

Fig. 3 Coated material separation vs. time duration

Figs. 2 displays that dispersive ratio of molecules C_0 / C is reduced as nanocoated volume ratio is increased since more nano elements appeared in the materials can help reducing the material loss due to the strong material bond. Fig. 3 shows the coated material separation in three different coatings vs. cyclic time duration.

Fig. 3 shows that the corrosion-resistant performance in nanocoated material is significantly improved compared with regularly coated materials due to the decreased grain size and increased grain boundary ratio that prevents the external moisture from penetration. Figs. 4-5 demonstrate the structural analysis on this nanocoated aircraft inboard flap during landing processes.

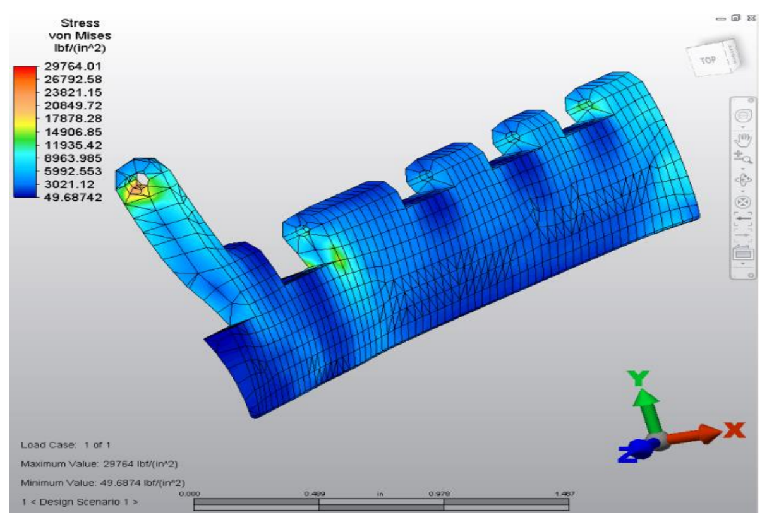

Fig. 4 Stress profile in nanocoated aircraft inboard flap

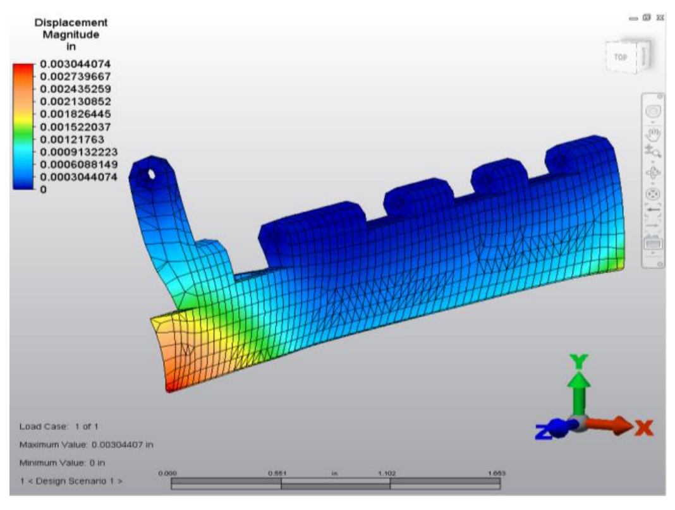

Fig. 5 Deflection profile in nanocoated aircraft inboard flap

Figs. 4 and 5 confirm that the maximum stress and deflection generated in the nanocoated aircraft inboard flap are below the material strength and within allowable deflection. The analytic results demonstrate that this nanocoated inboard flap keeps strong mechanical properties while shows its improved anti-corrosion performance.

PROTOTYPE EXPERIMENT

The inboard flap has been prototyped and tested to verify coated material performances. The prototype experiment has been performed based on the testing regulation of ASTM B117 and ASTM D1654. Material particles sizing from 6 nm to 20 nm were used with 5.5% sodium chloride solution in the prototype testing. The experimental results show much improved rust-resistant performance in nanocoated materials because of its increased breakdown potential of corrosion and better blockade to the anodic dissipation. The prototyped materials have been coated with zinc or nanomaterial to verify the rust-resistant performance in different coated materials. The testing results of dispersive ratio of molecules C_O / C vs. internal gap Z of nanocoated element is displayed in Table 1.

Table 1 Dispersive ratio of molecules C_0 / C vs. internal gap Z of nanocoated element

Nanocoated element Internal gap Z (nm)	Dispersive ratio of C_0 /C		
	Volume ratio 3.0 %	Volume ratio 7.5 %	Volume ratio 15 %
0	1.00	1.00	1.00
5	0.91	0.88	0.45
10	0.85	0.70	0.41
20	0.73	0.57	0.24
30	0.59	0.32	0.00
40	0.55	0.24	0.00
50	0.52	0.00	0.00
60	0.50	0.00	0.00
70	0.48	0.00	0.00
80	0.43	0.00	0.00
90	0.38	0.00	0.00
100	0.35	0.00	0.00

Table 2 Coated Material separation vs. cyclic time duration in three different coatings

Cyclic time duration (hours)	Separation length in different coatings (mm)		
	Nanocoated material	Zn coated material (6.5 µm)	Zn coated material (12.5 µm)
0	0.00	0.00	0.00
25	0.00	0.15	0.07
50	0.00	0.78	0.12
75	0.00	0.98	0.18
150	0.00	5.36	0.65
225	0.00	>18.00	0.88
300	0.00	>18.00	3.88
375	0.00	>18.00	8.38
450	0.00	>18.00	>18.00
525	0.00	>18.00	>18.00
600	0.01	>18.00	>18.00
675	0.02	>18.00	>18.00
750	0.04	>18.00	>18.00
825	0.07	>18.00	>18.00
900	0.10	>18.00	>18.00

The prototype testing results in Table 1 show that the dispersive ratio of molecules C_0 / C can be reduced when nanocoated material volume ratio is increased. Table 2 displays the much better corrosion-resistant performance in nanocoated material than in traditionally coated materials including Zn coating.

Comparing computational simulation shown in Figs. 2-3 with prototype testing displayed in Tables 1-2, both computational simulation and prototype testing demonstrate close results which validates the analytic and prototyping methodologies introduced in this nanomaterial research.

CONCLUSION

This research paper studies and analyzes the material corrosion-resistant performance through computer aided 3D modeling and numerical simulation to verify the fundamental corrosion-resistant functionality in some coated materials. The introduced analytic model in this research paper can be potentially applied to the future research to investigate different coating properties to improve anti-corrosion performances. The prototyping and testing have been performed in this study to compare with computational simulation and verify the coating performance. Both computer aided simulation and prototype experiment showing close results present much lower corrosive rates in nanocoated materials than in regularly coated materials. In addition, both numerical analytic model and prototyping experimental method applied in this research, showing the increase of dispersive ratio of molecules C_0 / C with decrease of nanocoated material volume ratio, can be used to assist future study to improve nanocoating manufacturing and process to further improve material anti-corrosion performances.