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Design and Analysis of Aircraft Wing Rib

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***Abstract*—In wing most of the weight is contributed by the ribs which gives the basic shape to the wing. The weight of the aircraft is reduced by the optimization techniques using the optistruct software and again the rib model is redesigned and analyzed. Initial design of wing is created and analysis is done for that base with the necessary boundary condition, after the base model is optimized. The base model is redesigned based on optimization result and analyzed with same boundary condition. Then both the result is compared. In this paper the structural optimization of the rib is performed and explained that wing rib optimization of weight does not affect the lift and drag theoretically. By this optimization the weight of the wing gets reduced even with the better performance.**

Index Terms—Drag, Lift, Material reduction, Topology optimization

I. Introduction

Aggressive weight targets and shortened development time-scales in the business aircraft industry naturally calls for an integration of advanced computer aided optimisation methods into the overall component design process.

Optimization is a process of selecting or converging onto a final solution amongst a number of possible options, such that a certain requirement or a set of requirements is best satisfied i.e. you want a design in which some quantifiable property is minimized or maximized (e.g., strength, weight, strength-to-weight ratio).

The application of optimization technology is becoming widespread throughout the aviation industry, exploiting the potential to design lighter aircraft. This paper deals with the Cessna citation, a business aircraft.

A. Topology Optimization

The objective of topology optimization is to determine holes and connectivity's of the structure by adding and removing material in the extended domain which is a large fixed domain that must contain the whole structure to be determined. Thus, a material model must be defined to allow the material to assume intermediate property values by defining a function of a continuous parameter.

II. Lift and Drag

A. Lift and Drag

Lift is the force that directly opposes the weight of an airplane and it holds the airplane in the air. Lift is generated by entire part of the airplane, but most of the lift is generated by the wings. Lift is a mechanical aerodynamic force produced by the motion of the airplane through the air.

B. Factors affecting Lift and Drag

- Object: At the top of the object, aircraft wing geometry has a large effect on the amount of lift generated. The shape of the aerofoil and wing size will both affect the amount of lift.
- Motion: To generate lift, we have to move the object through the air.
- Air: Lift depends on the mass of the air flow over the aero foil.
- Weight of the aircraft.

III. Load Calculation

The total weight of the aircraft is calculated by the following for Cessna citation aircraft.

A) Weight and lift before optimization

The TOW is broken into four elements

1) Payload weight (WPL) = (12*120) + (1000) = 2440kg.
2) Crew weight (WC) = 2* 120 = 240 kg.
3) Fuel weight (Wf) = 5560 kg
4) Empty weight (WE) =9798 kg

WTO = WPL + WC + WF + WE
= 2440+240+5560+9798
= 18038 Kg / 176.952 KN

Lift calculation:

Lift formula, $L = (1/2)\, dv^2\, S\, CL$

Wkt, L=W

D = 0.362 (from I.C.A.O standard atmosphere table)
S = 48.96 m^2
V=270 m/s
$C_L = 2W*9.81/ D*S* V^2$
=0.27

For angle of attack by Velocity Relationship Curve Graph

α =3 degree, C_L =0.4
α =5 degree, C_L =0.52
α =8 degree, C_L =0.8
α=16 degree , C_L =1.4

Corresponding lift forces are,

L=258408.92 N for C_L =0.4
L=335931.49 N for C_L =0.52
L=518617.84 N for C_L =0.8
L=904431.22 N for C_L =1.4

TABLE I
I.C.A.O STANDARD ATMOSPHERE TABLE

ALTITUDE (Feet)	TEMP. (°C)	PRESSURE			PRESSURE RATIO δ = P/Po	DENSITY σ = ρ/ρo	Speed of sound (kt)	ALTITUDE (meters)
		hPa	PSI	In.Hg				
40 000	- 56.5	188	2.72	5.54	0.1851	0.2462	573	12 192
39 000	- 56.5	197	2.58	5.81	0.1942	0.2583	573	11 887
38 000	- 56.5	206	2.99	6.10	0.2038	0.2710	573	11 582
37 000	- 56.5	217	3.14	6.40	0.2138	0.2844	573	11 278
36 000	- 56.3	227	3.30	6.71	0.2243	0.2981	573	10 973
35 000	- 54.3	238	3.46	7.04	0.2353	0.3099	576	10 668
34 000	- 52.4	250	3.63	7.38	0.2467	0.3220	579	10 363
33 000	- 50.4	262	3.80	7.74	0.2586	0.3345	581	10 058
32 000	- 48.4	274	3.98	8.11	0.2709	0.3473	584	9 754
31 000	- 46.4	287	4.17	8.49	0.2837	0.3605	586	9 449
30 000	- 44.4	301	4.36	8.89	0.2970	0.3741	589	9 144
29 000	- 42.5	315	4.57	9.30	0.3107	0.3881	591	8 839
28 000	- 40.5	329	4.78	9.73	0.3250	0.4025	594	8 534
27 000	- 38.5	344	4.99	10.17	0.3398	0.4173	597	8 230
26 000	- 36.5	360	5.22	10.63	0.3552	0.4325	599	7 925
25 000	- 34.5	376	5.45	11.10	0.3711	0.4481	602	7 620
24 000	- 32.5	393	5.70	11.60	0.3876	0.4642	604	7 315
23 000	- 30.6	410	5.95	12.11	0.4046	0.4806	607	7 010
22 000	- 28.6	428	6.21	12.64	0.4223	0.4976	609	6 706
21 000	- 26.6	446	6.47	13.18	0.4406	0.5150	611	6 401
20 000	- 24.6	466	6.75	13.75	0.4595	0.5328	614	6 096
19 000	- 22.6	485	7.04	14.34	0.4791	0.5511	616	5 791
18 000	- 20.7	506	7.34	14.94	0.4994	0.5699	619	5 406
17 000	- 18.7	527	7.65	15.57	0.5203	0.5892	621	5 182
16 000	- 16.7	549	7.97	16.22	0.5420	0.6090	624	4 877
15 000	- 14.7	572	8.29	16.89	0.5643	0.6292	626	4 572
14 000	- 12.7	595	8.63	17.58	0.5875	0.6500	628	4 267
13 000	- 10.8	619	8.99	18.29	0.6113	0.6713	631	3 962
12 000	- 8.8	644	9.35	19.03	0.6360	0.6932	633	3 658
11 000	- 6.8	670	9.72	19.79	0.6614	0.7156	636	3 353
10 000	- 4.8	697	10.10	20.58	0.6877	0.7385	638	3 048
9 000	- 2.8	724	10.51	21.39	0.7148	0.7620	640	2 743
8 000	- 0.8	753	10.92	22.22	0.7428	0.7860	643	2 438
7 000	+ 1.1	782	11.34	23.09	0.7716	0.8106	645	2 134
6 000	+ 3.1	812	11.78	23.98	0.8014	0.8359	647	1 829
5 000	+ 5.1	843	12.23	24.90	0.8320	0.8617	650	1 524
4 000	+ 7.1	875	12.69	25.84	0.8637	0.8881	652	1 219
3 000	+ 9.1	908	13.17	26.82	0.8962	0.9151	654	914
2 000	+ 11.0	942	13.67	27.82	0.9298	0.9428	656	610
1 000	+ 13.0	977	14.17	28.86	0.9644	0.9711	659	305
0	+ 15.0	1013	14.70	29.92	1.0000	1.0000	661	0
- 1 000	+ 17.0	1050	15.23	31.02	1.0366	1.0295	664	- 305

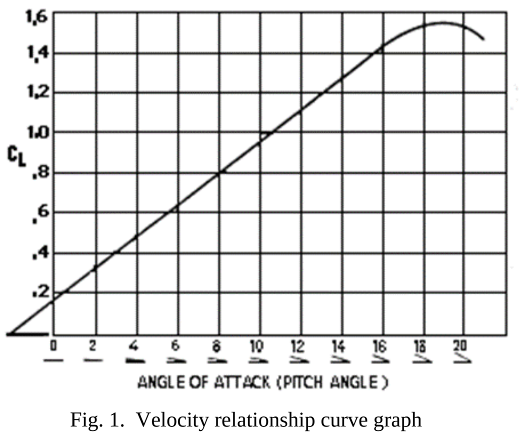

Fig. 1. Velocity relationship curve graph

B) *Weight and lift after optimization*

The MTOW is broken into four elements

1) Payload weight (WPL) = (12*120) + (1000) = 2440kg.
2) Crew weight (WC) = 2* 120 = 240 kg.
3) Fuel weight (Wf) = 5560 kg
4) Empty weight (WE) =9600 kg

$W_{TO} = W_{PL} + W_C + W_F + W_E.$
=2440+240+5560+9600
=17840 Kg / 175.010 KN

Lift calculation:

Lift formula, L = (1/2) dv^2 s CL

Wkt , **L=W**

D=0.362 (from I.C.A.O standard atmosphere table)
S=48.96 m^2
V=270 m/s
$C_L = 2W*9.81/ D*S* V^2$
=0.27 for C_L =0.3

L = (1/2) d v^2 s CL
= (1/2) *0.362*270*48.96*0.27
= 193.806 KN

Basic physics tells us that the lift and weight should be equal to each other for any aircraft in steady, level flight. If the two forces were not equal, the plane would not remain in level flight. Since the optimized weight of the model does not affect the lift and drag the software model can be done.

TABLE II
COMPARISON OF WEIGHT WITH LIFT

Actual Weight	Optimized Weight	Lift Force
176.952 N	175.101 N	193.806 N

IV. RESULTS AND DISCUSSION

The theoretical calculations show that the lift force does not varies by optimizing the wing model. Then the model is designed and optimized and redesigned and the weight is compared. The weight of the optimized model is low compared to the original model. Thus by using this method 1 to 5 % of weight of the aircraft is reduced.

TABLE III
COMPARISON OF TWO MODELS

Contents	Model	Optimized Model
Weight	21.8 Kg	15 Kg

The Table-III shows the comparison of and mass of two models, the weight of optimizes model is less the base model.

V. CONCLUSION

This paper is about the studies before the optimization. The lift force is calculated since the lift is equal to weight, by reducing the weight it will not affect the lift force and stability. And the drag force also doesn't affect by optimization. Thus weight can be reduced from 4-5% of the actual component weight by using topology optimization technique.

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