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Statistical Analysis and Conceptual Design of Business Aircraft

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Abstract:

The objective of the project is to design and construct a business jet that can cater to a range of customers, including corporate conglomerates, private groups, and individual individuals. A business jet, private jet, or simply bizjet is a jet aircraft, usually of a smaller size, designed for the transportation of wealthy individuals or groups of business colleagues. This project involves building a heavy business aircraft that can accommodate about 12 passengers when all seats are occupied. It also aims to deliver the facilities and comfort level expected of a business jet while satisfying the standards of a long-haul commercial airliner. The airplane uses less fuel and improves the efficiency of long-distance travel.

***Keywords* —**Business Aircraft, Conceptual Design, Aerodynamics, Aircraft Structures

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I. INTRODUCTION

Modern airplanes combine aerodynamic performance, lightweight design, robust construction, and state-of-the-art systems engineering. Passengers demand environmentally friendly and more comfortable aircraft. Therefore, a lot of technological barriers need to be balanced in order for an airplane to cheaply satisfy its design specification. In order to achieve the greatest potential outcome, the complex and time-consuming process of designing an aircraft necessitates careful consideration of several variables and features. The design process involves many calculations, logistical planning, design and practical considerations, and keeping composure to confront any challenges head-on. These tasks begin at the very beginning.

An airplane goes through multiple design iterations before it is ever constructed in a factory. The sequence of events that transpire between an airplane's first conceptualization and its actual flight is known as the design process. Along the journey, engineers take into account the four main areas of aeronautics: propulsion, structures and materials, stability and control, and aerodynamics.

II. DESCRIPTION

A. Weight Estimation

When estimating an aircraft's weight, a number of elements must be taken into account, including the design, materials, cargo, fuel, and other components. Empty weight, payload, fuel, operational items, and total weight are among the various forms of weight. Extensive computations based on particular aircraft specs, load distributions, and flight plans are required for precise weight estimation.

B. Wing Loading

The weight supported by a specific region of an aircraft's wing is measured as wing loading. Units like pounds per square foot or kilos per square meter are commonly used to convey it. When designing and assessing an airplane, wing loading is a crucial factor.

$$\text{Wing Loading}=\frac{\text{Total weight of Aircraft}}{\text{Total Wing Area}}$$

The performance of an aircraft is influenced by wing loading in a number of ways, such as maneuverability, stall speed, efficiency during takeoff and landing, and overall performance. Higher wing loading often leads to faster cruise velocities and more stable flight during turbulent situations; however, it can also result in longer takeoff and landing distances and decreased maneuverability.

C. Airfoil Selection

When choosing an airfoil for an aircraft, it is important to take into account a number of elements, such as the aircraft's intended use, performance specifications, aerodynamic qualities, and structural issues. This is a summary of the procedure: Iterative design process, aerodynamic considerations, structural considerations, mission requirements, and performance goals in general, choosing an airfoil for an aircraft is a complicated process that calls for in-depth research, careful evaluation of a variety of aspects, and occasionally making concessions in order to strike the right balance between performance, economy, and safety.

D. Powerplant Selection

A vital choice in aircraft design, the choice of powerplant (engine) has an impact on performance, efficiency, dependability, and total operating costs. The following is a general rundown of the process of choosing an engine: Mission Profile and Performance Requirements, Thrust or Power Requirements, Engine Types, Specific Engine Models, Integration and Compatibility, Final Selection and Validation.

E. Fuselage Design

An aircraft is a rigid (assumed) system comprising of many more components with all these components to be in the air medium. To have a stable aircraft system and easily controllable, its center of gravity Should be positioned in an appropriate manner. So, the weights in the aircraft should be distributed such that it has a defined CG position, which is critical. Also, the weight distribution should be such that on certain situations where some components may be consumed or even removed, its CG movement should be in a controllable manner so that is not compromised. One important condition is that when fully loaded, the CG is at 30 % of mean aerodynamic chord and in different situations such as landing, with or without payload, the CG movement should be restricted within 25% of mean aerodynamic chord and 35% of mean aerodynamic chord.

F. Landing Gear Design

When designing landing gear, an aircraft's size, weight, intended use, operating environment, and legal requirements must all be carefully taken into account. Load factors, shock absorption and dampening, stability and control, retractable mechanism, structural integrity, and emergency extension are some of its needs.

G. Performance Characteristics

An aircraft's performance characteristics are a collection of elements that affect how well the aircraft performs under different flying situations. These features are crucial for determining an aircraft's capability and appropriateness for a given mission. Performance characteristics include things like speed, range, payload, endurance, altitude performance, maneuverability, stability and control, fuel efficiency, and environmental performance. These characteristics also interact with one another and are influenced by a number of different things, such as aerodynamics, propulsion system, and operational considerations.

H. Centre of Gravity Estimation

Determining an aircraft's center of gravity (CG) is essential to maintaining its controllability and stability while in flight. The center of gravity (CG) is the point at which the mass of the aircraft is effectively concentrated. To maintain stable flying characteristics, the CG must be situated within a specific range. Under varied operating conditions, aircraft designers and operators can guarantee stable and predictable flight characteristics by precisely estimating and preserving the center of gravity within the designated envelope.

III. METHODOLOGY

A set of 10 Business Aircrafts has been considered for comparative study in various Parameters such as Length, Height, Wing span, Wing Area, MTOW, Cruise Speed, Service Ceiling, Range, Payload, Powerplant, No of Engines, Aspect Ratio, Wing Loading, Max Thrust and Gross weight etc.,

The following Aircrafts are taken for the Comparative studies,

a) Cessna Citation x
b) Gulfstream G200
c) Cessna Citation Sovereign
d) Challenger 300
e) Embraer Legacy 450
f) Praetor 500
g) Embraer Legacy 500
h) Praetor 600
i) Raytheon Hawker 4000
j) Challenger 300

On Considering the Parameters from the comparative study, we have Carried out several Estimations to define the required Parameters for the Aircraft to be Designed.

Initially for Weight Estimation, we have carried out calculations of Total weight of the Aircraft which is the sum of Weight of Payload, Weight of Fuel and Weight of empty aircraft.

$$W_e = W_{payload} + W_{fuel} + W_e$$

After the Weight Estimation, Wing loading has been calculated based on the landing distance and with the V_{max}. Then the Airfoil Selection has been carried out based on the required parameters like Camber, lift required and the lift coefficient.

A dimensionless parameter known as the lift coefficient (CL) connects the lift produced by a lifting body to the fluid velocity, surrounding fluid density, and related reference area. A foil or an entire foil-bearing body, like a fixed-wing airplane, is referred to as a lifting body. The body's angle to the flow, its Reynolds number, and its Mach number all affect CL. The dynamic lift properties of a two-dimensional foil section are described by the section lift coefficient CL, where the foil chord serves as the reference area instead of the reference area.

Powerplant Selection is the main part of the process where the powerplant plays the major role and it creates a great thrust which is sufficient for the aircraft. Then in the Fuselage design it is developed based on the purpose and performance characteristics of the aircraft where it plays the major role of the aircraft.

Then it comes to the part of landing gear design where most of the business jet utilizes the Tricycle Landing gear system. There are two primary landing gears under the wings and one nose landing gear under the nose of the aircraft in this layout. During flight, the landing gear retracts inside the fuselage to lessen drag and increase fuel economy. The landing gear is extended for stability and support when the aircraft is on the ground or during takeoff and landing.

IV. RESULT AND DISCUSSION

Based on the Parameters of the comparative study the aircraft is designed with a mean value.

We have several Plots and table to study the parameters of the aircraft mentioned below,

Aircraft Model	Wing Span(M)	Length(M)	Height(M)	Wing Area(M^2)	Max Seating Capacity
Cessna Citation x	21.1	22.04	5.85	48.96	14
Gulfstream G200	17.7	18.97	6.53	34.3	18
Cessna Citation Sovereign	22.04	19.35	6.2	50.4	14
Challenger 300	18.4	20.92	6.2	48.5	11
Dassault Falcon 50	18.86	18.52	6.98	46.83	11
Embraer Legacy 450	19.25	19.69	6.43	44.85	11
Praetor 500	21.5	19.69	6.43	44.85	11
Embraer Legacy 500	19.25	20.74	6.44	44.85	14
Praetor 600	21.5	20.74	6.44	44.85	14
Raytheon Hawker 4000	18.82	21.08	5.97	53.4	10

Table-1.

Aircraft Model	Max TakeoffWeight(KG)	Fuel Capacity(L)	Max Speed (KM/HR)	Cruise Speed (KM/HR)	Service Ceiling(M)
Cessna Citation x	16,375	7,371	1,127	978	15,545
Gulfstream G200	16,080	6,492	900	850	13,700
Cessna Citation Sovereign	13,608	6,457	980	850	14,000
Challenger 300	17,622	8,022	882	850	13,716
Dassault Falcon 50	17,600	8,800	1,054	903	14,936
Embraer Legacy 450	16,220	6,202	1,017	856	13,716
Praetor 500	17,040	7,400	1,017	863	13,716
Embraer Legacy 500	17,400	7,400	1,017	863	13,716
Praetor 600	19,440	9,150	1,017	863	13,716
Raytheon Hawker 4000	17,917	8,278	889	870	13,716

Table-2.

Aircraft Model	Payload (KG)	Range (KM)	Powerplant	Number of Engines	Empty Weight(KG)
Cessna Citation x	440	6,410	Rolls-Royce AE 3007C	2	10,038
Gulfstream G200	1,837	6,300	Pratt & Whitney Canada PW306D	2	9,049
Cessna Citation Sovereign	549	5,900	Pratt & Whitney Canada PW306D	2	7,893
Challenger 300	545	5,741	Honeywell HTF7000	2	10,659
Dassault Falcon 50	1,397	5,695	Honeywell TFE 731-40	3	9,163
Embraer Legacy 450	833	5,400	Honeywell HTF7500E	2	10,425
Praetor 500	729	6,186	Honeywell HTF7500E	2	10,391
Embraer Legacy 500	730	5,788	Honeywell HTF7500E	2	10,750

Praetor 600	617	7,441	Honeywell HTF7500E	2	11,503
Raytheon Hawker 4000	1,190	6,188	Pratt & Whitney Canada PW308A	2	10,104

Table-3.

Aircraft Model	Aspect Ratio	Chord Length (M)	Max Thrust (N)	Wing Loading (KG/M^2)	Gross Weight
Cessna Citation x	7.8	1.65	30,090	483	16,375
Gulfstream G200	7.7	1.88	26,900	495	16,080
Cessna Citation Sovereign	8.3	2.48	25,700	291	13,959
Challenger 300	8.92	2.53	30,400	363	17,622
Dassault Falcon 50	8.56	3.51	49,500	296	18,008
Embraer Legacy 450	8.55	1.98	29,090	481	16,220
Praetor 500	9.49	2.24	29,090	444	17,040
Embraer Legacy 500	8.71	2.12	31,300	500	17,400
Praetor 600	8.64	2.13	33,490	495	19,440
Raytheon Hawker 4000	8.43	2.52	30,700	318	17,917

Table-4.

WEIGHT ESTIMATION	Max TakeoffWeight(KG)	Fuel Capacity(L)	Fuel wieght(kg)	Empty Weight(KG)	Payload (KG)
Cessna Citation x	16,375	7,371	5,897	10,038	440
Gulfstream G200	16,080	6,492	5,194	9,049	1,837
Cessna Citation Sovereign	13,608	6,457	5,166	7,893	549
Challenger 300	17,622	8,022	6,418	10,659	545
Dassault Falcon 50	17,600	8,800	7,040	9,163	1,397
Embraer Legacy 450	16,220	6,202	4,962	10,425	833
Praetor 500	17,040	7,400	5,920	10,391	729
Embraer Legacy 500	17,400	7,400	5,920	10,750	730
Praetor 600	19,440	9,150	7,320	11,503	617
Raytheon Hawker 4000	17,917	8,278	6,623	10,104	1,190

Table-5. Weight Estimation

Powerplant	Length (m)	Diameter (m)	Thrust (kN)	Weight (kg)
Rolls-Royce AE 3007C	2.54	1.07	40	900
Pratt & Whitney Canada PW306D	2.26	0.61	26.9	574
Honeywell HTF7000	2.79	1.17	35.6	1,134
Honeywell TFE 731-40	2	1.04	17.8	816
Honeywell HTF7500E	2.74	1.12	33.4	1,134
Pratt & Whitney Canada PW308A	2.7	1.07	31.1	862

Table-6. Powerplant Selection

Powerplant	T/W	Bypass Ratio	Pressure Ratio	SFC (1/hr)
Rolls-Royce AE 3007C	3.9	5:1	25:1	0.25
Pratt & Whitney Canada PW306D	2.9	5:1	25:1	0.23
Honeywell HTF7000	3.43	5:1	30:1	0.23
Honeywell TFE 731-40	1.72	2.27:1	14:1	0.23
Honeywell HTF7500E	3.19	5:1	30:1	0.23
Pratt & Whitney Canada PW308A	2.95	5:1	30:1	0.23

Table-7. Powerplant Selection

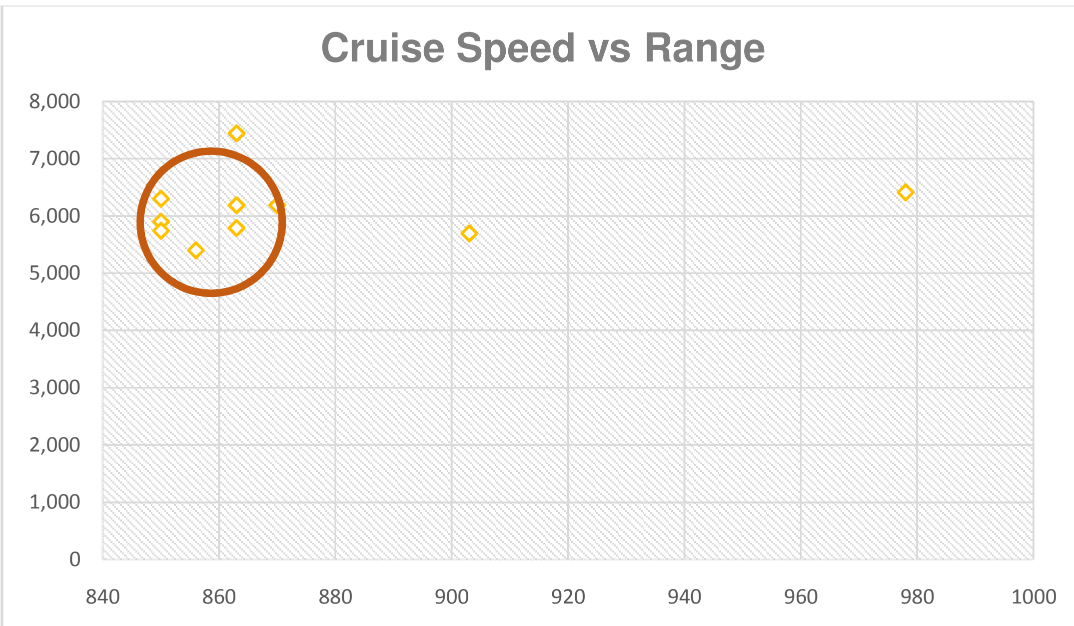

Chart-1.

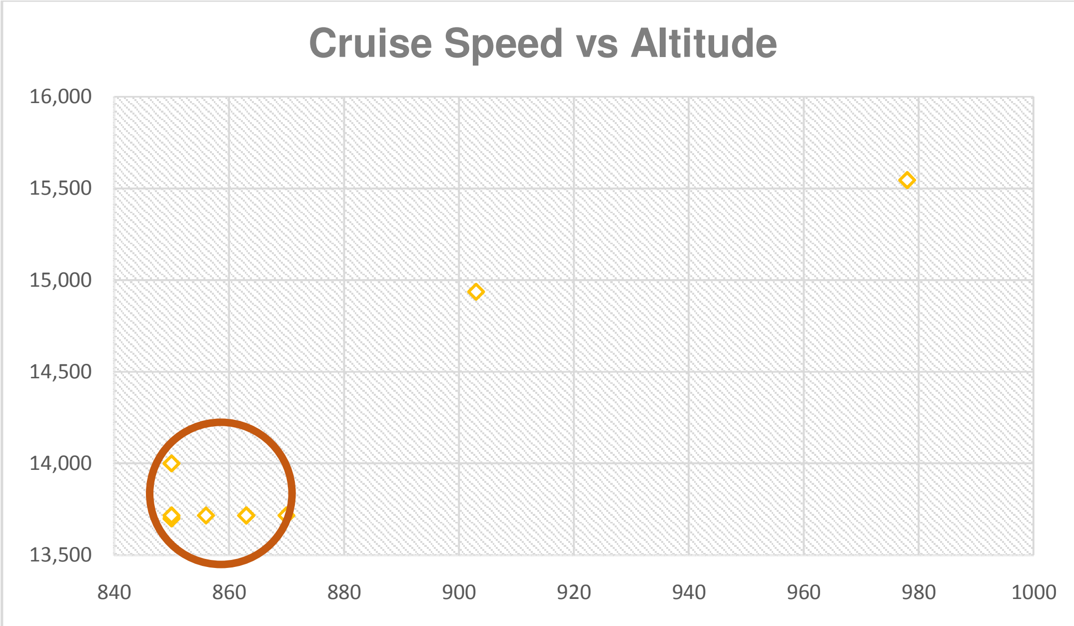

Chart-2.

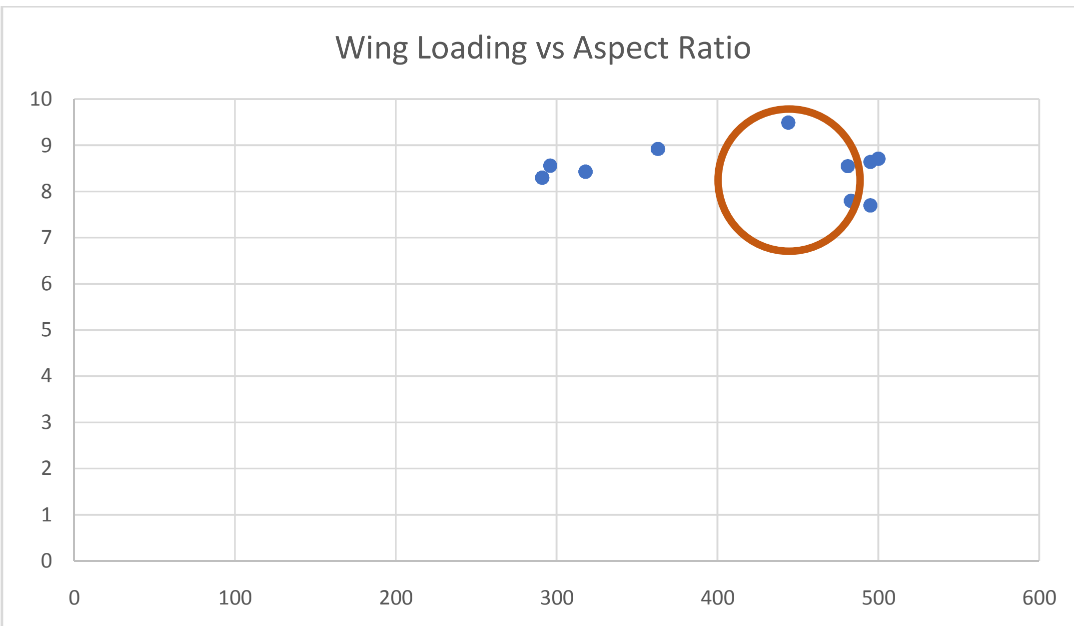

Chart-3.

V. AVERAGE DESIGN PARAMETERS

S. No	Parameters	12-SEATER BUSINESS AIRCRAFT
1	Wing Span(M)	19.842
2	Length(M)	20.174
3	Height(M)	6.347
4	Wing Area(M^2)	46.179

5	Max Seating Capacity	12
6	Max Take-off Weight (KG)	16,930
7	Fuel Capacity(L)	7,557
8	Max Speed (KM/HR)	990
9	Cruise Speed (KM/HR)	863
10	Service Ceiling(M)	14,048
11	Payload (KG)	887
12	Range (KM)	6,105
13	Powerplant	2XRolls-Royce AE 3007C
14	Number of Engines	2
15	Empty Weight (KG)	9,998
16	Aspect Ratio	8.51
17	Chord Length(M)	2.304
18	Max Thrust(N)	31,626
19	Wing Loading (KG/M^2)	416.6
20	Gross Weight	17,006

Table-8. Average Values

VI. CONCLUSION

The fundamental design of a commercial aircraft is finished, and the many design parameters and performance standards are calculated and established. Although the basic framework of development has been completed, the resulting design values might not fully capture the true and intended design of the airplane. The final design meets the desired requirements for a long-range aircraft that has high fuel efficiency. There is no such thing as an ideal design; rather, designs are always being created, improved upon, and modified in an effort to achieve optimal performance. We have learned a lot while working on this project, which has needed a lot of work.

REFERENCES

[1] Anonymous,(2012) Business Aircraft Market Forecast 2012-2031, Bombardier.

[2] Anonymous (2005), The VELA Project, DLR, Martin Hepperle, downloaded at www.dlr.de/as/en/desktopdefault.aspx/tabid-370/.

[3] Carter, M. B., Dan, D., Vicroy, D. D., Patel, D., (2009) Transonic Aerodynamics: Summary of Ground Tests and Sample Results (Invited), Proceeding of 47th AIAA Aerospace Sciences Meeting and Exhibit, USA.

[4] Djojodihardjo, H., Wei, A. K. L., (2012) Conceptual Design and Aerodynamic Study of Blended Wing Body Business Jet, Proceeding of 28th International Congress of the Aeronautical Sciences, Brisbane.

[5] Ikeda, T., (2006) Aerodynamic Analysis of a Blended-Wing-Body Aircraft Configuration, Master Thesis, RMIT.

[6] Liebeck, R. H., (2004) Design of the Blended Wing Body Subsonic Transport, Journal of Aircraft, Vol. 41, No. 1.

[7] Meheut, M., Grenon, G., Carrier, G., Defos, M., Duffau, M., (2009)Aerodynamic Design of Transonic Flying Wing Configurations, Proceeding of CEAS/KATnet II Conference on Key Aerodynamic Technologies, Bremen, Germany.

[8] Sivasankar G A, (2023) Study of hybrid fuel injectors for aircraft engines, 10.58414/SCIENTIFICTEMPER.2023.14.3.62

[9] Mukhopadhyay, V., Sobieszczanski-Sobieski, J., Kosaka, I., Quinn, G., Charpentier, C., (2002) Analysis Design and Optimization of Non-cylindrical Fuselage for Blended-Wing-Body (BWB) Vehicle, AIAA 2002-5664 paper.

[10] Okun, D. T., Williamson, I. A., Pearson, D. R., Aranoff, S. L., Pinkert, D. A., Johanson, D. S., (2012) Business Jet Aircraft Industry: Structure and Factors Affecting Competitiveness, United States International Trade Commission Report, April.

[11] Qin, N., Vavalle, A., Le Moigne, A., Laban, M., Hackett, K., Weinerfelt, P., (2002) Aerodynamic Studies for Blended Wing Body Aircraft, Proceeding of 9th AIAA/ISSMO Symposium on Multidisciplinary Analysis and Optimization, Atlanta, Georgia.

[12] Staelens, Y. D., (2007) Study of Belly-Flaps to Enhance Lift and Pitching Moment Coefficient of a Blended Wing Body Airplane in Landing and Takeoff Configuration, PhD Thesis, University of Southern California, USA.

[13] Velicki, A., Jegley, D., (2011) PRSEUS Development for the Hybrid Wing Body Aircraft, Proceeding of 11th AIAA Aviation Technology, Integration, and Operation, USA.

