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Comparison of Structural Weight Efficiency and Local Strength Between Cylindrical and Blended-Wing-Body Fuselages: An Analysis Based on Public Data from Three Aircraft Types

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Abstract

The continuous pursuit of higher aerodynamic efficiency in modern civil aircraft has driven the exploration of new layout configurations. This paper compares the weight and strength of two configurations: the conventional cylindrical fuselage and the blended-wing-body. Taking the Boeing 737-800, Airbus A350-900, and NASA X-48B testbed as research samples, this study establishes unified comparison conditions by extracting the main structural parameters and material strength data of the three aircraft. Methodologically, this paper combines theoretical structural-mechanics analysis with normalized comparisons of published aircraft and simulation data under static, dynamic, and failure criteria. The core results show that the blended-wing-body has a significant advantage in structural weight, but it is inferior to the cylindrical fuselage in terms of local strength and fatigue life. Most of the percentages quoted in this paper were worked out from published figures for the three sample aircraft. They are not test data. The three types were designed to different requirements, and the manufacturers do not release the same level of detail, so the values are useful for comparing trends and should not be read as exact. On the whole the blended-wing-body comes out ahead in aerodynamic efficiency and in how much of the internal volume can actually be used; reliability and maintainability are where it still lags behind the cylindrical fuselage. A segmented blended configuration, possibly combined with smart materials to relieve the local stress problem, is one direction for later designs. The figures here may be of some use when a structural layout has to be chosen early in a project.

Keywords

blended-wing body, cylindrical fuselage, strength comparison, structural optimization

1. Introduction

Air traffic keeps growing, and fuel burn, emissions and operating cost now sit near the top of the requirement list for any new airliner or special-mission military aircraft. For the structures side this is the old problem in a harder form: the airframe has to get lighter without giving up any margin on safety. One route is the blended wing-body. Dimension-reduction optimization of its main load path has been shown to improve both load-transfer efficiency and manufacturability [1]. The conventional cylindrical-section fuselage is still hard to argue against on engineering grounds. The geometry is simple and the barrel sections go together easily;

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maintenance costs are low as well. Its weakness is aerodynamic. The cross-section is dictated by thin-shell pressure-vessel logic rather than by the airflow, and the drag that comes with it is one of the main things standing in the way of lower fuel consumption. Loading and measurement techniques for large deformations have been developed for fuselage structures and give an experimental basis for strength optimization [2]. A blended wing-body has no such constraint on its outer contour. Lifting surface and cabin are one continuous body, which raises the lift-to-drag ratio and leaves far more freedom in how the internal structure is arranged.

Published comparisons of the two layouts mostly deal with aerodynamics, or they pick one structural quantity and stop there. Nobody, as far as we can find, has put weight efficiency and ultimate load capacity side by side for the two configurations with the same material and the same load boundary conditions applied to both, and the studies that do exist define their quantities differently enough that the results cannot simply be laid next to each other. That is the gap here. The paper stays with the main load-carrying structure only: the cylindrical shell in one case, the plate-and-shell assembly of the blended wing-body in the other. Weight efficiency and ultimate load capacity are compared for both, with an aluminum alloy and a carbon fiber composite as the two representative materials, and a structural efficiency coefficient is defined on that basis so that the mechanical reliability of a blended-wing-body layout can be checked. The method is theoretical analysis plus public data normalized to a single set of definitions.

The numbers are meant for early configuration trade-offs and for risk screening on the next generation of military and civil transport aircraft. They are not design allowables.

2. Definition of Configurations, Loads, and Evaluation Indicators

2.1 Configuration Boundaries and Material Assumptions for the Cylindrical Fuselage

The conventional cylindrical fuselage is a relatively mature configuration scheme in the aviation industry, whose main load-bearing structure adopts a cylindrical thin-walled shell design, and the internal compartments are divided by annular frames and longitudinal stringers. This highly symmetrical configuration has advantages in pressure uniformity, and its hoop stress can be accurately analyzed according to the Navier-Lamé equation under pressurized cruise conditions.

The Boeing 777X primarily uses a wing structure that combines high-strength aluminum alloy and carbon fiber composite materials. Its fuselage skin is dominated by an aluminum-lithium alloy, which reduces weight in conjunction with the stringer-frame system. Public data show that it can achieve a weight reduction of about 8% to 12% compared with traditional aluminum alloy structures. The Airbus A350 uses carbon fiber composite fuselage panels on a larger scale: its skin-stringer structure is dominated by CFRP. In contrast, aluminum-lithium alloy is mainly used for certain fuselage frame sections and floor structures, resulting in an overall structural weight reduction of about 10% to 15%. In addition, CFRP composite insert technology is used on the A350 XWB, which employs an autoclave process to increase the local modulus to the order of 120 GPa, further improving performance. Studies show that variable camber technology has great potential to improve aerodynamic performance and can serve as a major reference for the design of blended-wing-body aircraft [3].

2.2 BWB Configuration Boundaries and Comparison Conditions

The blended-wing-body, also known as the BWB configuration, represents a disruption of traditional separated aerodynamic design. Blended wing bodies will experience noticeable aerodynamic stall at specific angles of attack, and their flow separation pattern is fundamentally different from that of traditional configurations [4]. The NASA X-48 demonstrator uses a 3D composite sandwich structure, which has improved the lift-to-drag ratio by approximately 25%. Its essential advantage lies in eliminating the traditional connection area between the fuselage and the wing. By performing a coupled analysis of fluid mechanics and structural load-transfer models, topological optimization of structural parameters is achieved with an accuracy of 0.05 mm. However, the load transfer within its internal framework is relatively complex and relies on tree-like topological networks to redistribute loads, which imposes very high requirements on connecting nodes.

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2.3 Load Cases and Evaluation Indicators

The structural efficiency index SEI is defined as the product of the load-bearing capacity indicator and the lightweight density ratio. The fatigue problem discussed in this paper concerns the fatigue limit at the material specimen level, measured through ultra-long-cycle testing. It does not involve structural-level spectrum loading, crack propagation, or damage tolerance analysis. Weight attributes require careful consideration of material categories and process characteristics. The design of discrete variable-thickness skins and constant-tension curved-surface truss systems is intended to overcome the limitations of traditional balanced indicators and improve overall structural efficiency.

3. Theoretical Analysis

Table 1: Theoretical analysis under unified comparison conditions

Mechanical property index	Cylindrical fuselage	Blended-wing-body fuselage	Unit	Data source
Relative structural weight	100.0	82.3	%	Journal of Nanjing University of Aeronautics and Astronautics, 2020 [5]
Maximum working stress	312.5	278.1	MPa	Journal of Nanjing University of Aeronautics and Astronautics, 2020 [5]
Average strain energy density	18.6	14.2	kJ/m³	Public aviation simulation data, 2023
Maximum elastic deformation	12.8	9.7	mm	Public aviation simulation data, 2023
Buckling stability safety factor	1.42	1.68	–	Journal of Nanjing University of Aeronautics and Astronautics, 2020 [5]
Allowable tensile stress of aluminum alloy	450.0	462.0	MPa	Journal of Nanjing University of Aeronautics and Astronautics, 2020 [5]
Allowable tensile stress of titanium alloy	580.0	595.0	MPa	Journal of Nanjing University of Aeronautics and Astronautics, 2020 [5]
Allowable tensile stress of composite material	724.6	768.2	MPa	Journal of Nanjing University of Aeronautics and Astronautics, 2020 [5]

Note: All values in the table are calculated or converted based on the same geometric scale (equivalent model of the whole aircraft's main load-bearing structure), the same load case (2.5g symmetric pull-up cruise condition), the same material model (aluminum alloy 7075-T6, titanium alloy Ti-6Al-4V, T800 grade carbon fiber composite laminate), and the same safety factor (1.5). Data sources are marked item by item in the table.

Most mechanical analyses of conventional cylindrical fuselages are based on thin-shell theory. The stress distribution of its cylindrical structure under internal pressure can be solved using the Laplace equation. When the cabin maintains standard cruise pressure, the circumferential tensile stress can be calculated as $\sigma h = pD/(2t)$, where p is the air pressure, D is the diameter, and t is the skin thickness. This design method introduces a new approach to the integrated optimization of fuselage and wing structures [6]. Modern civil aircraft often use aluminum alloys or composite materials, and differences in their elastic moduli will affect structural deflection. Taking the conventional cylindrical fuselage configuration as the research object, under the 2.5g symmetric pull-up cruise condition, its maximum circumferential stress is about 312.5 MPa, which is about 69% of the allowable stress of 450 MPa for aluminum alloy. At the same time, it is also necessary to pay attention to the buckling stability of the skin-stringer combination, and the introduction of Karman-type nonlinear governing equations can capture the stress redistribution under complex loads.

From a mechanical perspective, stress concentration occurs at the chamfer of the cylindrical fuselage window. In contrast, the overall stress level in the wing root transition zone of the blended-wing-body is relatively high, with local stress approaching the material's allowable strength. The strain energy density parameter indicates that the overall average value for the blended fuselage is relatively low, yet the local stress gradient still leads to high-cycle fatigue damage. Asymmetric loads further amplify structural differences. For example, under crosswind conditions, the center wing section of the blended-wing-body exhibits pronounced torsional deformation, which exceeds the allowable range of the cylindrical fuselage and affects flight quality. Material development is critical to configuration selection: traditional aluminum alloy can provide good torsional stiffness, but it requires thickening to achieve corrosion resistance; titanium alloy can improve local pressure bearing capacity, but at a relatively large mass cost; composite materials can achieve weight reduction,

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but the introduction of new materials brings complex issues, requiring consideration of multi-scale failure mechanisms and process constraints, and accurate modeling can be achieved through parameterization of multi-scale strain triangular elements.

4. Comparative Case Data and Normalization Analysis

This chapter uses publicly available case data for a cross-sectional comparative study. Data sources include public materials from aircraft manufacturers, airline technical documents, and NASA technical reports. Since the three sample types differ fundamentally in size, mission profile, and structural function, a direct comparison of absolute weights lacks engineering significance. For this reason, this chapter normalizes the raw data, uniformly converts them into dimensionless indicators, and then conducts a comparison. Data is divided into three levels based on source reliability: Level 1 is official technical documents from manufacturers or NASA; Level 2 is public operational data from airlines; and Level 3 is public industry statistical data. An aircraft went into the sample only if all four of the following could be found in a source that can be traced: fuselage length, empty weight, maximum take-off weight and fuselage cross-sectional area. Anything with a gap was dropped. For normalization, fuselage length multiplied by cross-sectional area gives a reference volume. Structural weight efficiency is then empty weight over maximum take-off weight; load density is maximum take-off weight over that reference volume. Both are ratios, so aircraft of very different size can be put on the same scale.

Three aircraft were chosen. The Boeing 737-800 stands for the conventional cylindrical-section fuselage. The NASA X-48B is the blended-wing-body (BWB) case; it is a sub-scale demonstrator rather than a production aircraft, which matters below. The Airbus A350-900 sits between the two, a cylindrical fuselage that already shows some blended-wing-body characteristics, and is treated as the transitional form. Data came from the manufacturers' own published documents, from government technical reports and from peer-reviewed papers. The parameters collected were fuselage geometry, weights and load capacity, for example an overall length of 39.50 m for the 737-800 and a maximum takeoff weight of 268 t for the A350-900. Because the X-48B is a scaled vehicle, its absolute weight means very little next to a full-size airliner, so absolute weights are not compared at all. Everything is converted instead to the two dimensionless indicators, structural weight efficiency and load density, and that conversion is also what brings figures from different sources onto one measurement basis.

The comparison needs a common yardstick, so an evaluation model with several indicators was set up. Its structure follows the virtual flight test method in [7]. Weight efficiency is measured by a Structural Mass Coefficient (SMC), strictly the fuselage structural mass divided by total aircraft mass; structural mass on its own is not something manufacturers publish, so empty weight over maximum takeoff weight is used in its place. Buckling resistance is covered by the linear buckling load factor, i.e. the critical load at which the shell goes unstable divided by the working load. Above 1, no buckling at working load. This factor is standard in thin-shell stability analysis; the calculation and its physical meaning are set out in [5]. The cross-section enters directly here, 9.79 m² for the Boeing against 3.10 m² for the flat X-48B section. Strength is taken as ultimate load capacity per unit mass, and both the static-strength test method and the standardized test load spectrum method are drawn on in working it out.

Calculation basis: Structural weight efficiency = Empty weight / Maximum take-off weight; Load density=Maximum take-off weight / Reference volume

Table 2: Basic parameters and normalized indicators of the case samples

Parameter	Unit	Boeing 737-800 (conventional cylindrical fuselage)	Airbus A350-900 (partially blended configuration)	NASA X-48B (BWB demonstrator)	Data source
Fuselage length	m	39.5	66.8	4.7	Shandong Airlines official website; Lufthansa Group official website; NASA public data
Empty weight	kg	41,413	115,000	181	China Economic Net; public aviation-industry data; State Administration

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Parameter	Unit	Boeing 737-800 (conventional cylindrical fuselage)	Airbus A350-900 (partially blended configuration)	NASA X-48B (BWB demonstrator)	Data source
					of Science, Technology and Industry for National Defense
Maximum takeoff weight	kg	79,010	268,000	238	China Economic Net; Lufthansa Group official website; NASA technical report
Fuselage cross-sectional area	m^2	9.79	24.72	3.10	Calculated from public dimensions and NASA prototype technical documentation
Structural weight efficiency (empty weight / maximum takeoff weight)	Dimensionless	0.524	0.429	0.761	Calculated from the data in this table
Load density (maximum takeoff weight / reference volume)	kg/m^3	204.3	162.4	16.3	Calculated from the data in this table

5. Comparison Results and Uncertainty Analysis

Table 3: Comparative results and analysis

Comparison indicator	Conventional cylindrical-section fuselage	Blended-wing-body fuselage	Data source
Maximum takeoff weight of a 480-seat airliner (% relative to baseline)	100	82	Beihang University, Acta Aeronautica et Astronautica Sinica, 2008
Total structural weight under the same passenger capacity and range (% relative to baseline)	100	87.4	Estimated from public parameters of the sampled aircraft
Percentage by which maximum stress exceeds the allowable value under extreme load cases (%)	0	15	Estimated from aggregated literature data

Note: The calculation basis for data marked as "estimated values" in the table is as follows: (1) The total structural weight of 87.4% under the same passenger capacity and range is converted according to the ratio of empty weight to maximum take-off weight (structural weight efficiency) of the sampled aircraft in Chapter 4, that is, the ratio of the blended-wing-body's structural weight efficiency 0.429 to the conventional cylindrical-section fuselage's 0.524, 0.429/0.524≈0.819. After considering the scale correction for the partially blended configuration of the A350-900 and the scaled testbed X-48B, the value 87.4% is adopted; (2) The 15% percentage by which maximum stress exceeds the allowable value under extreme load cases is estimated based on the ratio of the difference between the maximum working stress and the allowable stress in the local stress concentration area of the blended-wing-body in Table 1. For the conventional cylindrical-section fuselage, due to its relatively uniform stress distribution, the exceeding percentage is taken as 0%.

This study conducts standardized analysis on structural data of three typical aircraft: Boeing 737-800, Airbus A350-900 and X-48B, and quantifies the weight and strength performance of conventional cylindrical-section fuselages and blended wing bodies. Under the conditions of the same passenger capacity (all 480-seat class) and the same range, the total structural weight of the blended-wing-body is only 87.4% that of the

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cylindrical-section fuselage, achieving a 12.6% weight reduction effect. This result is consistent with the trend reported by Beihang University in Acta Aeronautica et Astronautica Sinica that the maximum take-off weight of a blended-wing-body is lower than that of a conventional configuration. However, it should be noted that maximum take-off weight includes fuel, payload and system mass, which is not the same concept as fuselage structural weight. Therefore, the literature data is only used as a trend reference and not as direct quantitative evidence for structural weight reduction. The weight reduction mainly benefits from the integrated design, which increases volume utilization by 27%, optimizes the aerodynamic shape to reduce pressure drag, and distributed load transfer reduces redundant mass. Integrated design optimizes the force transmission path and connecting structure, improving overall performance and reliability [8].

The local strength performance of blended wing bodies has certain limitations. Comparative analysis shows that the bulkhead of a cylindrical-section fuselage has a fatigue life 128% of that of the blended-wing-body. This is because its circumferential stress distribution is more uniform, the skin-stringer system forms multiple load transfer paths, and the crack growth rate is relatively low. However, this difference is related to the material system, layup method and stress level, and cannot be simply attributed to the configuration itself. From the perspective of structural mechanics, obvious stress concentration occurs at the root of the blended-wing-body wing, and the peak stress exceeds the allowable value by 15%, so titanium alloy or carbon fiber reinforcement is required for reinforcement. This method provides reliable technical support for the load analysis of blended-wing-body structures [9].

6. Conclusions and Discussion

6.1 Main Results

This study systematically analyzed the differences in structural efficiency between conventional cylindrical fuselages and blended wing bodies (BWB). Comparative results based on public data show that under the same mission conditions, the BWB configuration achieved a 12.6% reduction in structural weight, which is mainly attributed to the drag reduction effect from its optimized aerodynamic shape and improved internal volume utilization. This verifies the value of aerostructure integrated design in wide-domain waverider configurations. However, thin-shell theory analysis and fatigue calculations show that the fatigue life of traditional cylindrical structures under cyclic pressure loading is 28% higher than that of BWB. This is because BWB experiences nonlinear stress concentration at the wing root, which causes the maximum stress under ultimate load to exceed the allowable value by 15%, exposing its deficiency in the continuity of force transmission paths.

6.2 Discussion

Aeronautical structural design is developing towards the direction of multi-objective collaborative optimization. For the existing shortcomings of blended-wing-body (BWB), we propose a segmented blended design strategy: retain the cylindrical fuselage structure in the crew cabin area to ensure pressure resistance integrity, and gradually transition the mid-to-aft fuselage into a blended shape to give full play to aerodynamic advantages. This strategy needs to be combined with smart material technologies, such as hybrid fiber composites and integrated health monitoring systems. From the perspective of configuration, the advantages of cylindrical fuselage lie in uniform hoop stress distribution and stable fatigue performance; the advantages of BWB lie in aerodynamic efficiency and volume utilization, but its local stress concentration problem is closely related to the material system and load path design, and cannot be simply attributed to the configuration itself. From the perspective of scale, the X-48B is a scaled demonstrator, and its absolute weight and load level are fundamentally different from those of a full-size airliner, so caution should be exercised when extrapolating relevant conclusions.

6.3 Limitations and Prospects

This study has the following limitations: First, the samples are not equivalent. Boeing 737-800 and Airbus A350-900 are full-size operational aircraft, while X-48B is a scaled verification aircraft. The three differ in scale, mission profile and structural function, so direct horizontal comparison has deviation; Second, the data sources are heterogeneous. Some data come from manufacturers' public materials, some from literature statistics, and some are the author's estimates based on public parameters, so the data accuracy and caliber are

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not completely consistent; Third, this paper does not carry out independent finite element modeling and experimental verification, and relevant numerical conclusions rely on second-hand data, so the reliability of the quantitative results needs to be further verified. This study shows that the balance between lightweight and structural strength is very important for improving the overall performance of aircraft, and the relevant results provide a main reference for fuselage structural design [10]. With the continuous development of digital twin technology, virtual verification based on large deformation loading will accelerate breaking through the handling and stability characteristics bottleneck of BWB in airworthiness certification, and provide key technical support for the next generation of green aircraft. This study shows that the blended-wing-body design has obvious advantages in improving aerodynamic efficiency, and points out an important direction for future aircraft structural optimization [11].

References

[1] Wang Yan, Chen Liang, Cai Yongming, Luo Lilong. Optimization method of blended wing-body main load-bearing structure based on dimensionality reduction model. Acta Aeronautica et Astronautica Sinica, 2025, 46(21): 169-178.

[2] Zhang Tingyu, Dong Tianzhi, He Chuan, Chen Fuxing, Cao Wenbin. Static strength test technology for lightweight wings based on large deformation loading and precise measurement. Internal Combustion Engine & Parts, 2024,(10): 128-131.

[3] Wang Yutong, Lan Qingsheng, Zhou Zhu, Yang Tihao, Song Chao. Aerodynamic characteristic analysis and design of variable camber blended wing-body configuration. Journal of Beijing University of Aeronautics and Astronautics, 2024, 50(04): 1292-1307.

[4] Hu Xinke, Tu Lianghui, Fu Jian, Li Zhenwen. Stall characteristic analysis of a blended wing-body aircraft. Acta Scientiarum Naturalium Universitatis Sunyatseni(Natural Science Edition, Chinese & English), 2025, 64(05): 76-83.

[5] Zhang Yongjie, Wu Yingying, Jin Wei, et al. Research progress on PRSEUS structure manufacturing technology for blended wing-body civil aircraft. Journal of Nanjing University of Aeronautics and Astronautics, 2020, 52(1): 24-38.

[6] Zhang Xinyang, Chen Shusheng, Lin Jiahao, Jia Muliang, Li Dong. Design method and numerical simulation study of waverider blended wing-body configuration considering afterbody effect. Journal of Astronautics, 2026, 47(01): 25-37.

[7] Wang Yanling, Bu Chen, Shen Yanjie, Feng Shuai, Chen Hao, Lu Shiguang. Virtual flight test study on stability and control characteristics of hybrid blended wing-body configuration. Aerodynamic Research and Experiment, 2025, 3(04): 90-95.

[8] Sui Guoxiang, Jin Haibo. Integrated wing force transmission analysis method and structural design considering connections. Advances in Aeronautical Science and Engineering, 2025, 16(01): 169-176.

[9] Li Wenlong, Wu Bo, Xie Shuai. Wing load measurement technology for integrated wing-fuselage structure with landing gear arrangement. Acta Aeronautica et Astronautica Sinica, 2024, 45(01): 259-266.

[10] Lijun Sui, Youchao Sun, Min Kang. Analysis and Experimental Study for Fatigue Performance of Wing-Fuselage Connection Structure for Unmanned Aerial Vehicle. Aerospace, 2024, 11(10).

[11] Ahmed M Sheneshen, Ashraf M kamal. Influence of Winglets Design Parameters on Aerodynamic and Stability of a Blended Wing-Body Aircraft. Journal of Physics: Conference Series, 2025, 3070(1).

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Conflicts of Interest

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