Preliminary design of a supersonic passenger aircraft

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Abstract:

This work will discuss the basic issues and problems related to the design of aircraft geometry to be as economical, durable and functional as possible during flights at speeds greater than the speed of sound.

The aim of the work is to create a design for a supersonic passenger plane capable of carrying at least 200 passengers and reaching at least twice the speed of sound. Analysis of the influence of geometrical parameters of airfoils, airfoils adapted to supersonic flights and aircraft fuselages will be carried out. The analysis will include such factors as relative thicknesses of aviation profiles, geometric elongation of airfoils and fuselages, and slants of airfoils constituting the supporting surfaces of aircraft. The result will be the presentation of the most optimal parameters for passenger aircraft performing supersonic flights. The final aspect of the work will be the determination of the analytical pole of the aircraft, including the phenomenon of air compressibility in its scope, thus enabling the reading of the aircraft's flight characteristics for Mach numbers greater than M = 0,4.

Market research conducted by Airbus [1] confirms data collected by the World Bank on the increase in the number of passengers transported, they also forecast an increase for 2018-2038. The projected increase in demand for new planes and air connections is particularly high for intra-US, People's Republic of China and European Union connections, but also for intercontinental connections. An exemplary wide-body aircraft flight from Frankfurt am Main in Germany to Orlando in the United States of America takes 7.5 hours. A supersonic plane could cover this route in less than 4 hours. The growing demand for intercontinental air connections is a market niche that could be filled by supersonic passenger planes, significantly reducing travel times between distant places.

In order to select the optimal parameters of the structure and components, and thus increase the performance and refine the design, design analyses will be carried out taking into account not only aerodynamic parameters, but also the geometry of the wing and the entire aircraft. Also available power units of a similar application will be analysed in order to select the most appropriate source of thrust for the airframe. An extremely important aspect is also the environment in which the airframe will move, and therefore the characteristics of changes in gas parameters and flow depending on the flight altitude and speed.

Due to the airplane's cruising altitude of 25 000 m, an estimate has to be made for many of the flight altitudes that the airplane will reach during its climb. The calculations were carried out for five different heights, assuming the air density prevailing there. A constant increase in the speed of the aircraft was also assumed, where for the two highest ceilings they reach supersonic values.

Analyses and design assumptions have been made, preliminary aerodynamic calculations should be carried out to select the dimensions of the airfoil, fuselage, and the entire structure. For instance, based on the information gathered during the analysis of existing supersonic passenger aircraft structures, the aerodynamic profiles of the maximum thickness in the shifted profile were collected. The maximum relative thickness of the selected profiles does not exceed, also 5%.

For the fuselage design, the Whitcomb area Rule was used. It is a design principle for supersonic airplanes to avoid the adverse effects of the connection of wings, especially triangular wings with the

fuselage. In line with this rule, the hull should be designed so that there is no overlap of local overpressure areas. According to this rule "... the combination of a wing with a fuselage will have the least drag if the position of the wing along the plane sections, normal to the stream, has the same character as the rotation body with the least drag"

The analytical polar of an aircraft is the basis for calculating its performance. The supersonic analytical polar was carried out for the preliminary design of an aircraft as shown in the figure 1. The flow around an aircraft is complex and the mathematical models that describe the phenomena vary depending on how accurate the data the engineer has. Aerodynamic tests, both in tunnels and in free flight, are very expensive and time-consuming. Therefore, at the design stage, it is necessary to calculate the aerodynamic characteristics of the aircraft using the design data. The computational methods used to determine the characteristics are methods based on theoretical and experimental studies of flows. These methods allow calculating the analytical polar of an aircraft with geometry similar to that used today in flying machines in the range of Mach numbers from zero to four.

The method described in article was used to calculate the supersonic analytical polar of the designed aircraft. When starting polar calculations, it is necessary to have data such as geometric characteristics of the aircraft and to have analytical polar characteristics that ignore the phenomenon of air compressibility. Such parameters were assumed during the preliminary design.

The paper presents a complete analysis of the issues associated with supersonic flights. The topics of passenger aircraft construction were discussed. Recognition of the existing structures of supersonic passenger aircraft as well as plans for future constructions of such an application was carried out. A specific number of passengers, range, and economy were assumed to be combined by the designed aircraft and on this basis, calculations were made. The key element of the work was the determination of estimated and then exact aerodynamic characteristics, ending with the determination of the analytical supersonic polar of the aircraft.

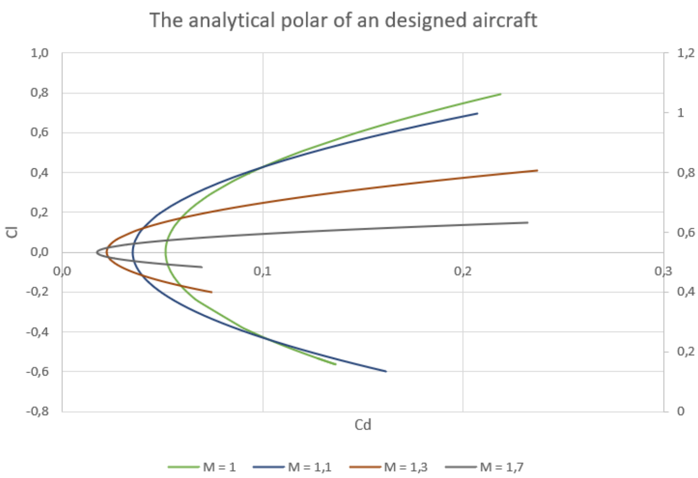

Figure 1 - The supersonic analytical polar of a designed aircraft

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