

The Fuselage Model of Non Circular Section

Mohd Ridhwan Bin Abu Bakar, and Bambang Basuno

Abstract— Fuselage plays important role as part of the aircraft. Fuselage acts as structural supporting part of other aircraft component, it has also to accommodate space for passenger and other payload. As result the fuselage cross section may not be in the form as a circular cross section. The present work investigates the influence of four type of fuselage cross sections to the aerodynamics characteristics on it. Here the aerodynamics prediction method used a semi empirical aerodynamics method and their result compared to the result provided by the DATCOM software. The result indicates that the shape of fuselage cross section has significant effects to the aerodynamics characteristics especially for the fuselage having a rectangular cross section.

Keywords— Non Circular Cross Section Fuselage, Semi Empirical Aerodynamic Method, DATCOM Software.

I. INTRODUCTION

THERE are several factors need to be taken account in designing the fuselage shapes. Such as the fuselage has to be designed in order to fulfill a comfort and attractiveness in terms of seat design, placement, and storage space or it may be to satisfy the structural support for wing and tail forces acting in flight etc. As result the fuselage cross section may not be in the form as a circular cross section. Figure 1 shows side view of the actual airplane Lockheed Three Stars L-1011 [1]



Fig. 1 Side view of the actual airplane Lockheed Three Stars L-1011 [1]

This airplane has its first flight in 1971 and around 250 airplanes had been built with the last production in 1983. The fuselage cross section along its longitudinal x – axis varying as depicted in the Figure 2a.

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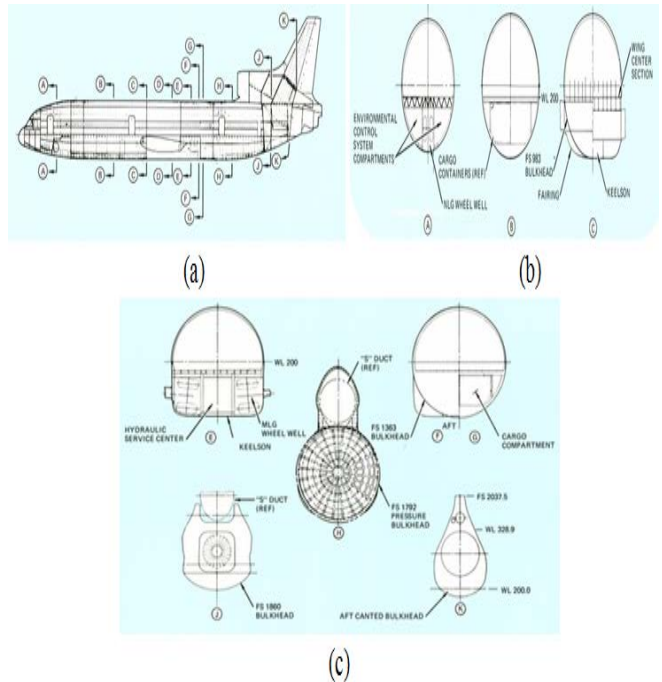


Fig. 2 The variation fuselage cross section of the Airplane Lockheed Three Stars L-1011 [2]

Another example of non circular fuselage cross section may be found to the small airplane had been used by NASA called as Airplane – A. The side view of this airplane and their shape fuselage cross section as depicted in the Figure 3

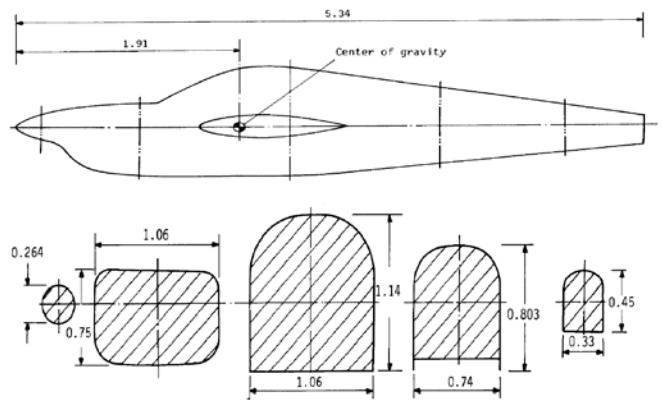


Fig. 3 The variation fuselage cross section of the NASA Airplane - A [3]

Generally, the cross-sections along the fuselage mid-section are the same and mostly, shaped like cylinders. However, there are many fuselage bodies of the actual aircraft especially for small aircraft having an asymmetric shape with their fuselage cross sections are not round. To define the non circular fuselage cross section one may use a super-ellipse equation. This equation can be used to generate the fuselage cross section from circular cross section up to a chine-shaped cross sections. Thus it can be used to define a variety of different cross sectional fuselage shapes. The super-ellipse equation for a cross section defined as [4] :

$$\left(\frac{z}{b}\right)^{2+n} + \left(\frac{y}{a}\right)^{2+m} = 1 \quad (1)$$

Where

- n, m - adjustable coefficients that control the surface slopes at the top and bottom plane of symmetry and chine leading edge.
- a, b - the maximum width of the body and the upper or lower centerlines respectively.

The super-ellipse equation of Eq.1 can produce various cross sectional shapes depending on the given value of n and m as shown in Figure 4.

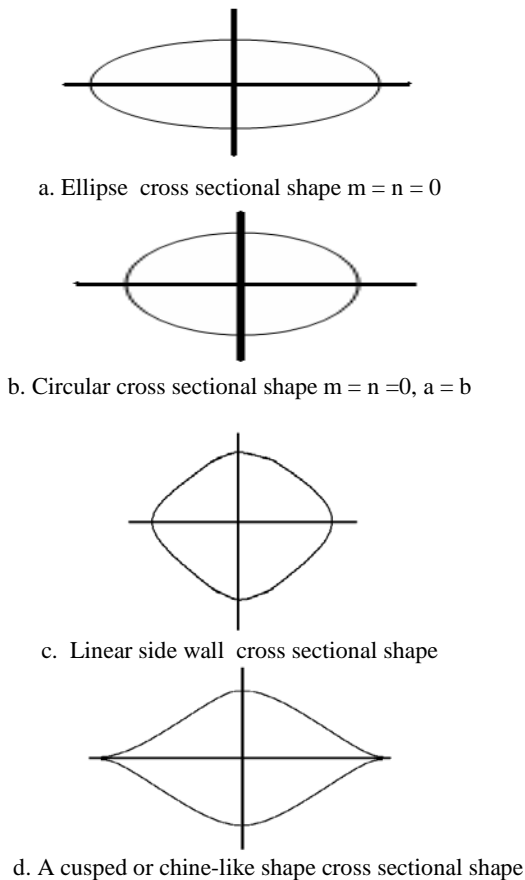


Fig. 4 Various shape cross section derived from Super Elliptic equation

II. RESULT AND DISCUSSION

A. Non Circular Fuselage's Cross section NACA Report TN 4176 [5]

Polhamus [5] introduced various shape of fuselage cross sections as reported in his NACA Report TN 4176. Unfortunately his aerodynamics experiments were not focusing to obtain the overall aerodynamics characteristics for the fuselage as three dimensional flow problem but focused to gain the aerodynamic characteristics from two dimensional point of view of its cross section. Figure 6 shows a side view of the fuselage shape. The fuselage cross section may in the form as circular cross section, Figure 7a, or in the form of rectangular cross section as depicted by Figure 7b.

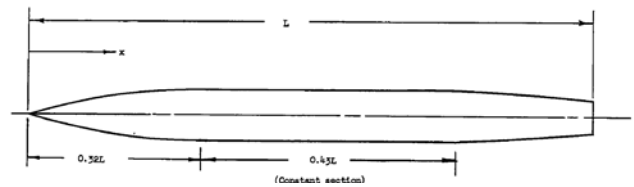


Fig. 6 Side view of fuselage model NACA TN 4176 [5]

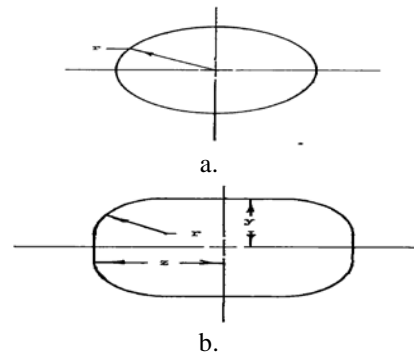


Fig. 5 The shape of Fuselage cross section of NACA TN 4176 [5]

The present work use of fuselage cross section introduce by Letko W and William J.L [6] - [8]

At any station x , for the non circular cross section, defined by the following expression

$$4w^2 - 4\left(\frac{R}{3}\right)^2 - \pi\left(\frac{R}{3}\right)^2 = \pi R^2 \quad (2a)$$

While another one is given by :

$$4wd - 4\left(\frac{R}{3}\right)^2 - \pi\left(\frac{R}{3}\right)^2 = \pi R^2 \quad \text{and} \quad w = \frac{2}{3}R \quad (2b)$$

The implementation of Equation 2a and Equation 2.b, in view of shape of the cross section, produce the result as depicted in Figure 6 while Figure 7 in view of their three dimensional shape.

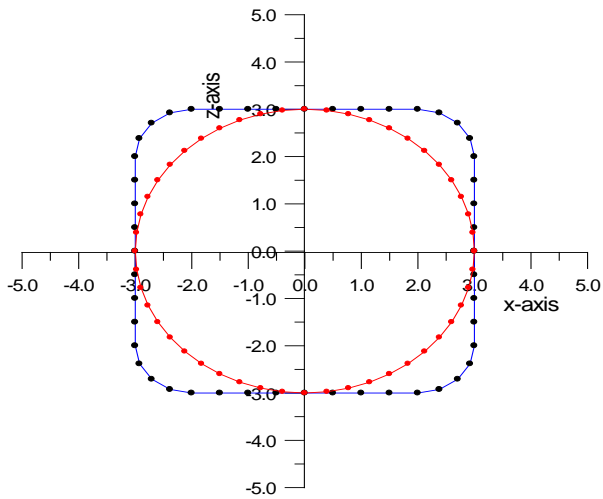


Fig. 6a Rectangular Cross section fuselage width > fuselage height

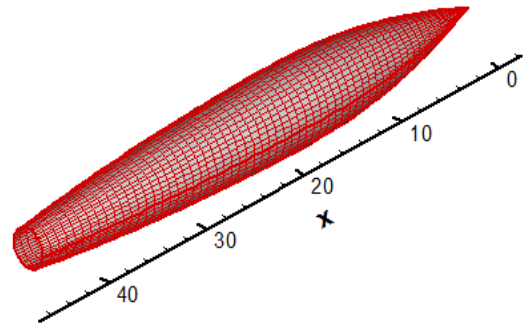


Fig. 7a Fuselage geometry with circular cross section

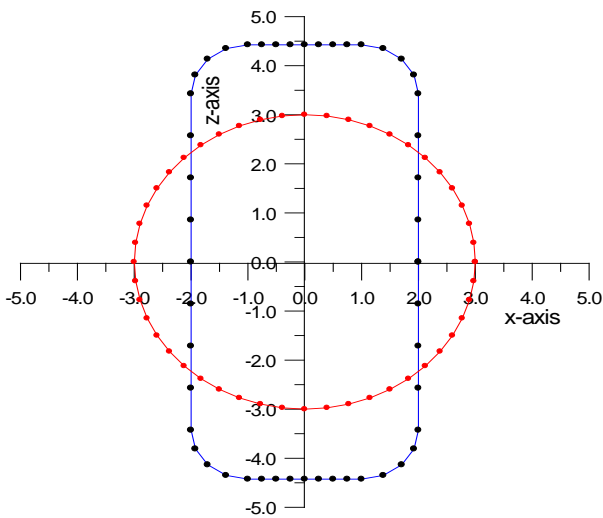


Fig. 6b Rectangular Cross section fuselage width > fuselage height

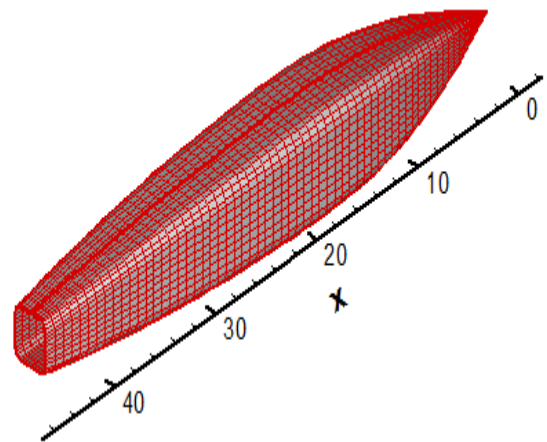


Fig. 7b Fuselage geometry with square cross section

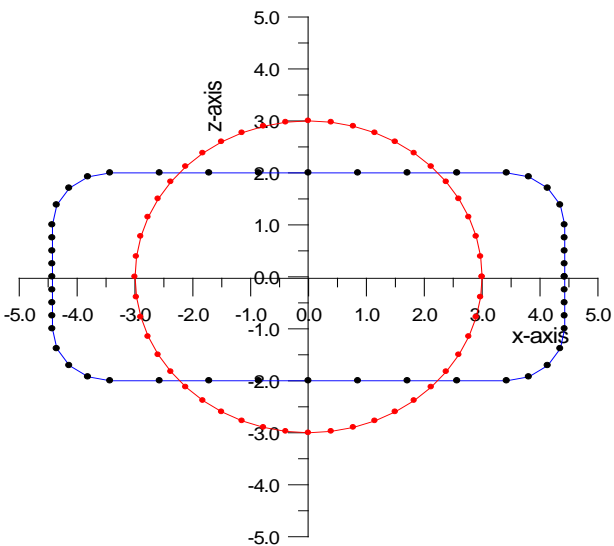


Fig. 6c Rectangular Cross section fuselage width > fuselage height

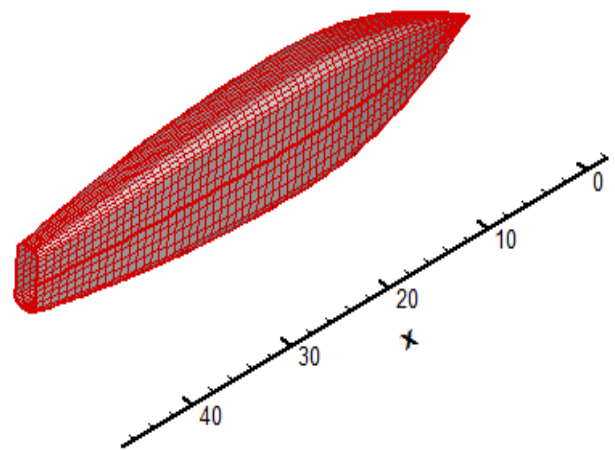


Fig. 7c Fuselage geometry with rectangular cross section, Fuselage width less than fuselage height

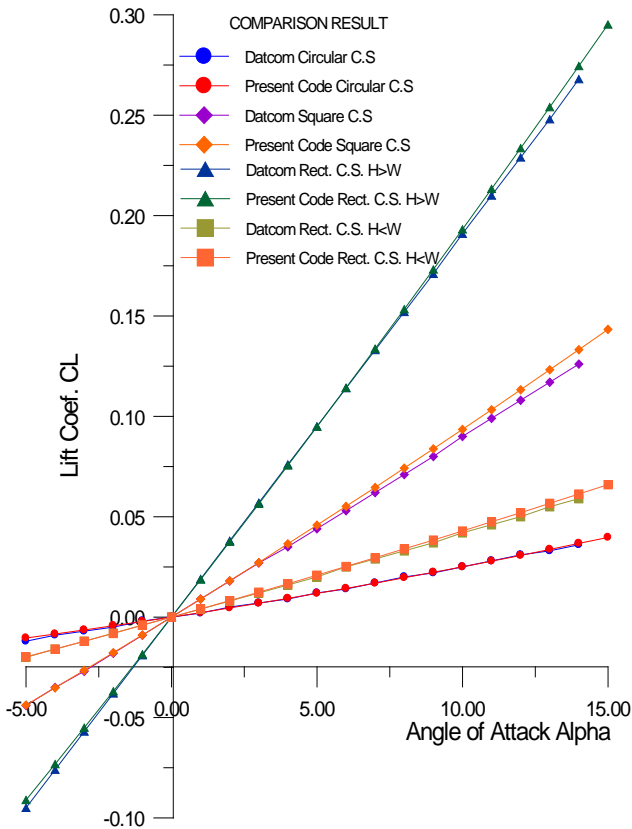


Fig. 8a A comparison result of lift coefficient C_L between DATCOM Software and the Present Code for different fuselage cross sections

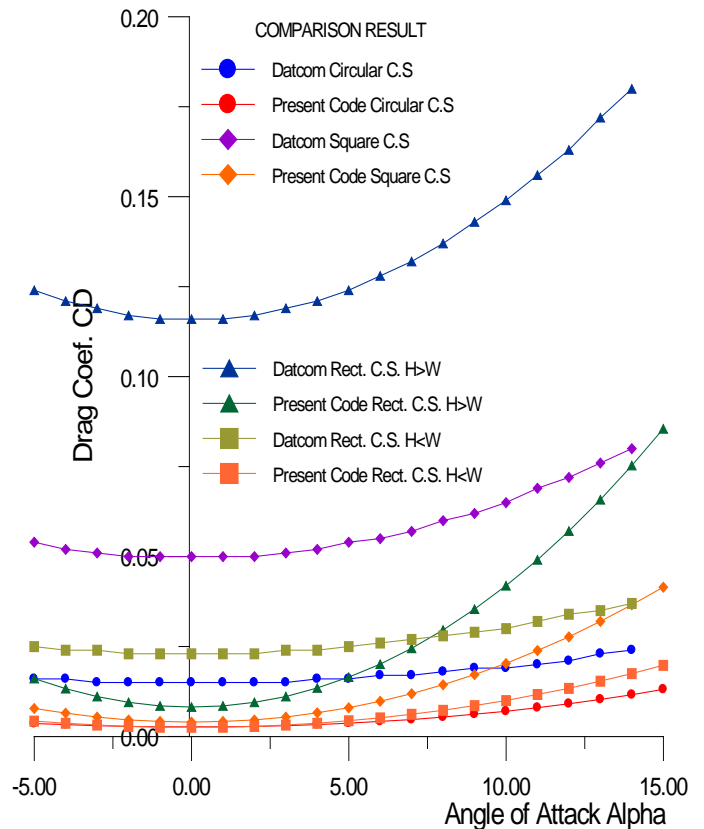


Fig. 8c A comparison result of Drag coefficient C_D between DATCOM Software and the Present Code for different fuselage cross sections

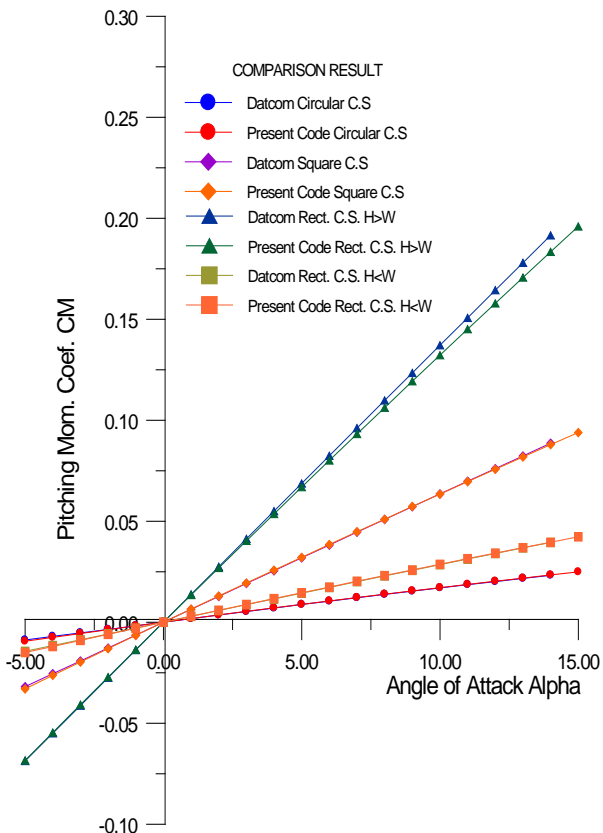


Fig. 8b A comparison result of pitching moment coefficient C_M between

The comparison result in term of lift coefficient C_L between DATCOM software and the present code for different type fuselage cross section at the Mach number $M = 0.13$ as shown in the Figure 8a. While Figure 8b shows their comparison in term of pitching moment coefficients C_M . Considering above two figures are clearly indicating that there are a good agreement between DATCOM software or the developed computer code. However when it come to the drag coefficient, a significant difference result appears between them. Their comparison results as shown in the Figure 8c.

III. CONCLUSION

The cause of difference is due to the contribution of the zero lift drag coefficient C_{D0} . DATCOM software predicts a higher C_{D0} compared to the present computer code. The experimental result indicated that the drag differences due to cross section effects are not as big as obtaining by DATCOM software. The experiment shows that a rectangular cross section with fuselage height greater than fuselage width tends to provide a higher drag compared to others.

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