EFFECT OF ASPECT RATIO WITH ROLL MOMENT DERIVATIVE OF A DELTA WING IN SUPERSONIC FLOW

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ABSTRACT

In this paper attention is focussed on study of effect of Aspect ratio of the wing on roll moment derivatives at various angle of attack and Mach number for a Supersonic flow. It is been observed that there is a linear increment in rolling moment derivative with aspect ratio as well as with Angle of attack. The reason behind this being rolling moment derivative is a linear function of aspect ratio and angle of attack. The requirement for the validity of the present theory is the attachment of the shock at the leading edge of the wing. Whereas, in the case of detached shock wave, this theory is not valid.

Keywords: Aspect ratio, inertia, rolling moment derivative, supersonic, wing

INTRODUCTION

With a growing interest of invading the space the design of hypersonic/supersonic vehicle is becoming a topic of most importance in the field of research. The knowledge of load and stability derivatives facilitating the design process is of utmost importance. In the present scenario the design of the wing, its stability becomes the topic of interest. Ghosh in his theory has presented two similitudinal parameters for oscillating delta wing with shock wave attached for high angle of incidence[1,2] .This theory is been extended by Crasta and Khan to hypersonic[3,4,5,6,8] /supersonic flows with wedges of planar and non planar surfaces and to delta wings[7,9]. Presently, the paper focuses on the variation of rolling moment derivative with aspect ratio for flow past supersonic delta wing.

ANALYSIS:

At the outset we assume the rate of roll be $\overline{p}$ and L be the rolling moment, which is defined as per the right hand rule.

$$\therefore L = 2\int_0^c \left(\int_0^{Z=f(x)} p.zdz \right) dx$$

(1)

The roll damping derivative is non-dimensionalzed by multi-plying by the inverse of the product of dynamic pressure, wing plan form area, and span of the wing and characteristic time factor $\frac{C}{U_\infty}$

$$\therefore -C_{l_p} = \frac{1}{\rho_\infty U_\infty C^3 b \cot\varepsilon}\left(\frac{-\partial L}{\partial p}\right)_{\substack{\alpha=\alpha_0 \\ \bar{p}=0}} \quad (2)$$

Solving we get

$$\therefore -C_{l_p} = \frac{\sin\alpha_o f(S_1)}{(\cos^2\phi)}\left[\frac{\cot\ \varepsilon}{12}\right] \quad (3)$$

Where $f(S_1) = \frac{(r+1}{2S_1}[2S_1 + (B+2S_1^2/(B+2S_1^2)^{\frac{1}{2}}]$

$$\therefore -C_{l_p} = \frac{\sin\alpha_o f(S_1)}{(\cos^2\phi)}\left[\frac{AR}{48}\right]$$

Various results on rolling moment derivative with aspect ratio have been computed, plotted and discussed below.

RESULTS AND DISCUSSIONS

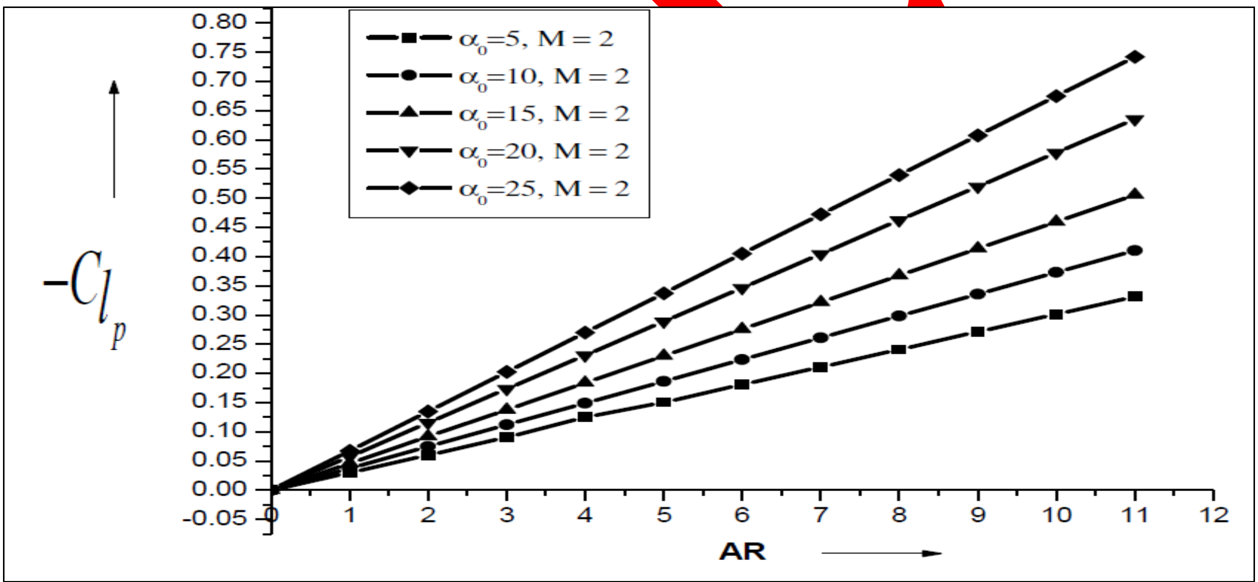

Fig. 1: variation of rolling moment derivative with aspect ratio for Mach number M =2

Figure1 indicates the results of the roll damping derivative with respect to the aspect ratio for a fixed Mach number of 2 for various angle of incidence from 5 to 25 degrees. From the results it is observed that there is a linear increment in rolling moment derivative with respect to aspect ratio for Mach number 2. The magnitude of rolling moment derivative is in the range from 0 to 0.75 for Aspect ratio in the range 0 to 11. It is also seen that further increment in Angle of attack gives a liner enhancement in rolling moment derivative. It is found that as Aspect ratio increases the wing span area will also increase, the reason being the direct proportionality of Aspect ratio with rolling moment derivative and hence the corresponding lift generated by the wing which in turn increase the lift of the wing. There is larger plan-form area is being shifted towards the trailing edge.

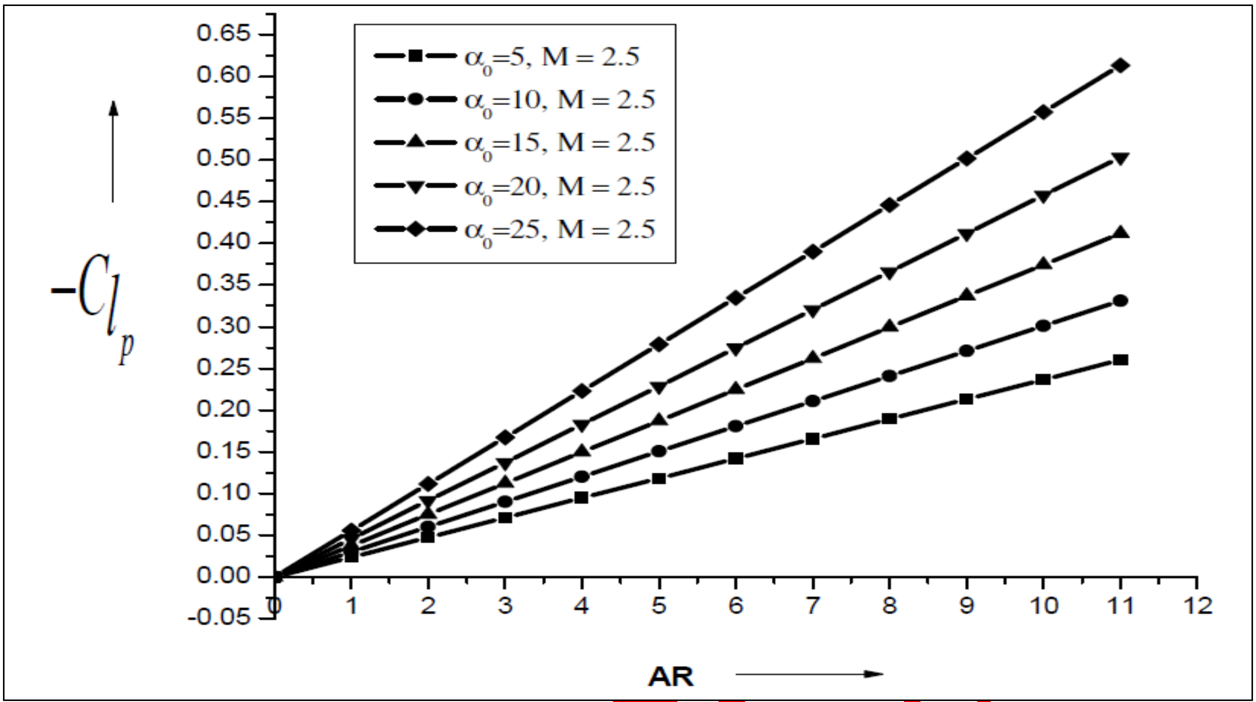

Fig. 2: variation of rolling moment derivative with aspect ratio for Mach number M =2.5

Figure 2 presents the results of rolling derivative with Aspect ratio for Mach number 2.5. This figure shows similar trend and results as discussed above, the only change being that the inertia level has been marginally increased as in case of previous figure. It is observed that the magnitude of rolling moment derivative is reduced as compared to Mach 2 as shown in Figure 1, the reason being the decrement of rolling moment derivative with an increment in Mach number.

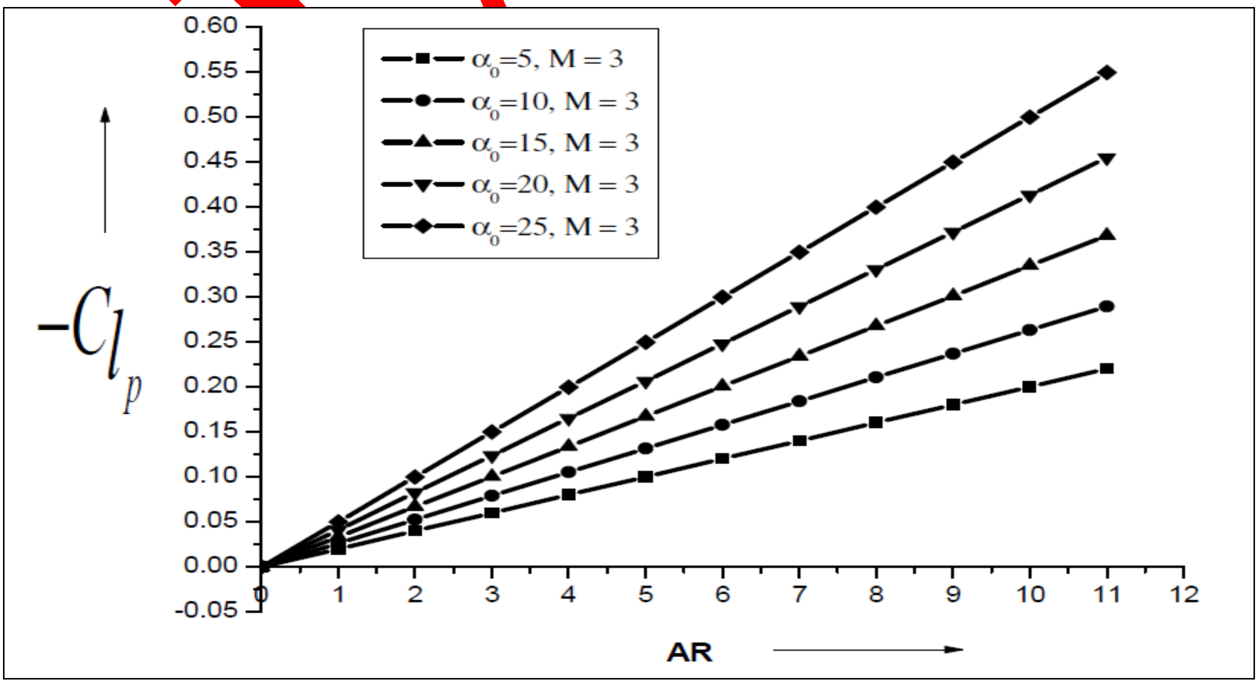

Fig. 3: variation of rolling moment derivative with aspect ratio for Mach number M = 3

Figure 3 presents the results of variation of rolling moment derivative with aspect ratio for Mach number 3. The results for this Mach number are on the similar lines as in case of Mach numbers M = 2 and 2.5 as discussed above in figures 1 and 2, however, the magnitude of rolling moment derivative has reduced considerably due to increase in Mach number and hence the increased inertia values of the flow and its value is 0.55 for angle of incidence 25 degrees, at a fixed value Aspect ratio = 11, and Mach number M = 3.

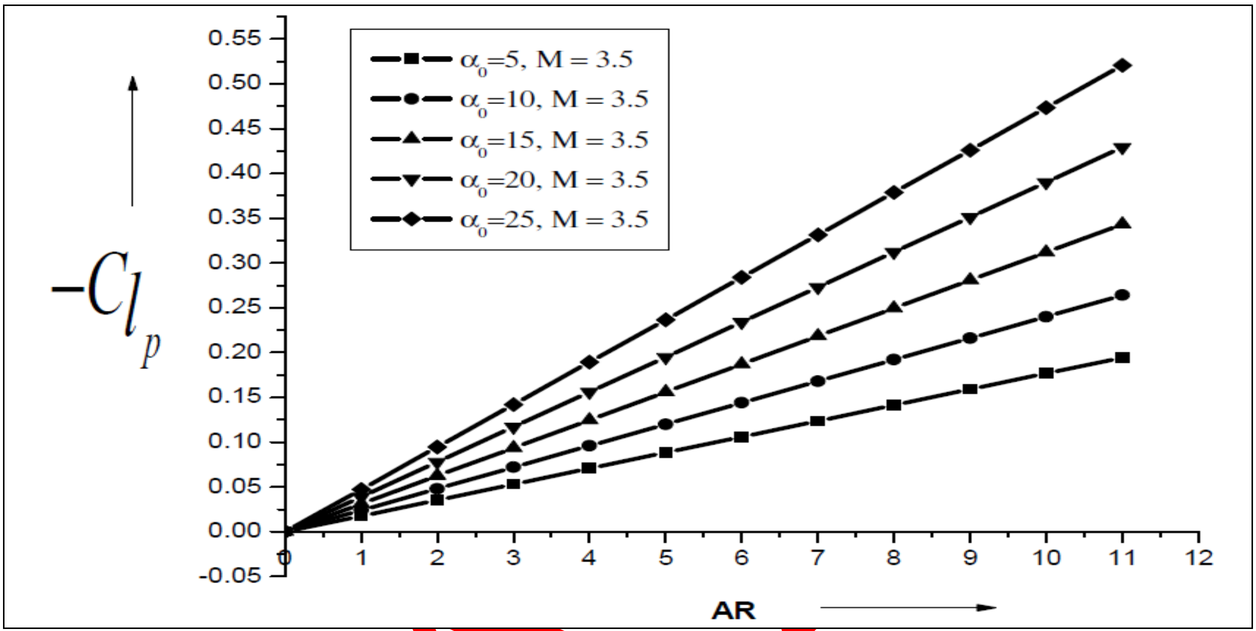

Fig. 4: variation of rolling moment derivative with aspect ratio for Mach number M = 3.5

Figure 4 shows the variation of rolling moment derivative with aspect ratio for Mach number 3.5. There is a considerable reduction of magnitude of rolling derivative with aspect ratio with progressive enhancement in the inertia level and the results show the similar trends as discussed above for lower Mach numbers.

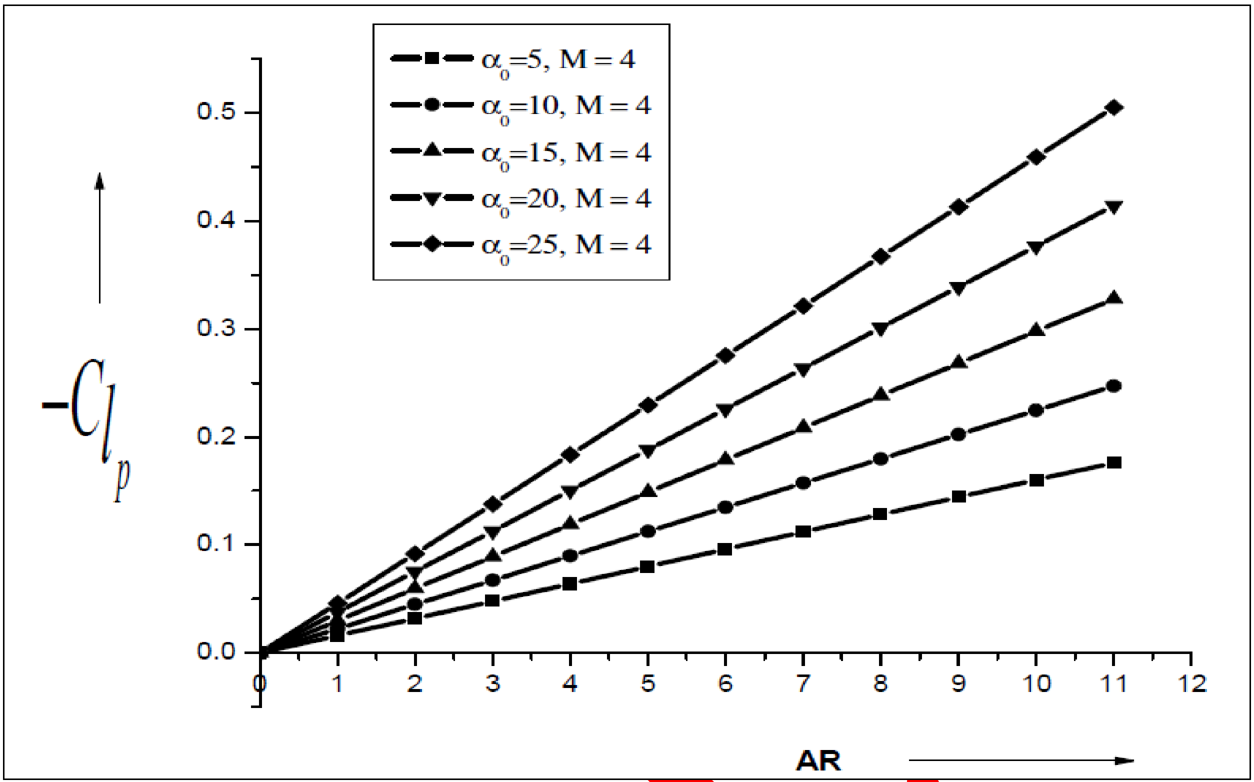

Fig. 5: variation of rolling moment derivative with aspect ratio for Mach number M = 4

Figure 5 shows the variation of rolling moment derivative with aspect ratio for Mach number 4. This Mach number is very close to hypersonic flow where we need to consider the other issues related to hypersonic flow are to be considered; however, as we have used the same expression without any change accounting for hypersonic flow it shows similar trends as discussed above.

CONCLUSIONS:

Based on the above discussions we can draw the following conclusions:

- The roll damping derivatives increases linearly with aspect ratio and angle of attack.
- With the further enhancement in the Mach number resulting in higher inertia values leads to decrement in roll damping derivative.
- From the results it is observed that the increment in aspect ratio increases the wing span area, thus as angle of attack increases the value of lift will increase.

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