EFFECT OF ASPECT RATIO WITH ANGLE OF ATTACK OF AN OSCILLATING HYPERSONIC DELTA WING WITH STRAIGHT LEADING EDGES

ASHA CRASTA, S. A. KHAN

Abstract: The present study focuses attention on effect of the Aspect ratio of the wing on roll damping moment derivatives at various angles of attack and Mach number has been studied. It is found that the rolling moment derivative increases with aspect ratio as well as with the angle of attack as the roll damping derivative is linear function of aspect ratio as well as the angle of attack. It is also seen that with the increase in the aspect ratio, roll damping derivative decreases with the increase in the Mach number initially and then attains steady state and confirms the Mach number independence principle for higher values of the Mach numbers in the hypersonic flow regime. The Present theory is valid only when the shock wave attached with the wing leading edge, for detached shock case this theory is no more valid and also the flow will be subsonic locally leading to flow separation and finally tremendous deceleration in the flow. Also, the effects of wave reflections and viscosity have not been considered in the present study. Results have been obtained for hypersonic flow of perfect gases over a wide range of angle of attack, the Mach number, and the aspect ratio.

Keywords: Angle of attack, Aspect Ratio, Mach number, hypersonic, roll damping derivative

Introduction: With the advent of space shuttle the thrust and importance of research has been shifted to the field of hypersonic flows. The analysis of hypersonic flow past a delta wing at large angle of incidence as well as high aspect ratio has attained importance with the evolution of space crafts and high performance military aircrafts. The knowledge of aerodynamic load and stability derivatives facilitating the design process of a delta wings and the high performance military aircrafts has become important at the preliminary design stage. This will facilitate the designer to have fair idea about the design parameters and the performance of the wing plan form for high performance military aircraft and the launch vehicles. With this aim the present study has been taken up. Ghosh [4] has developed a large incidence 2-D hypersonic similitude and piston theory; it includes Light hill's [1] and Miles [3] piston theories. This theory has been applied for oscillating plane ogives. Ghosh [5] has extended the large deflection similitude to non-slender cones, quasi cones and also for shock attached delta wings. Crasta & Khan have extended this similitude to oscillating delta wings with straight leading edges past a Hypersonic [15] and supersonic flow [16] and in this paper the effect of Aspect ratio with rolling moment derivative at high angle of incidence and Mach number have been studied. The pressure on the lee surface is assumed to be zero as it is well known that at hypersonic speed the pressure on the Lee surface will be negligible and can be neglected.

Analysis:

ROLLING MOMENT DERIVATIVE DUE TO RATE OF ROLL:

Let the roll be p and rolling moment be L, defined according to the right hand system of reference

$$\therefore \quad L = 2\int_0^c \left(\int_0^{Z=f(x)} pz\,dz \right) dx \tag{1}$$

The local piston Mach number normal to the wing surface is given by

$$\left(M_P\right) = \left(M_\infty\right)\sin\alpha_o \frac{z}{a_\infty}\bar{p} \tag{2}$$

The roll-damping derivative is non-dimensionalised by dividing with the product of dynamic pressure, wing area, and span and characteristic time factor

$$\therefore \quad -C_{lp} = \frac{1}{\int_\infty U_\infty C^3 b\cot\in} C^3 \tag{3}$$

Rolling moment due to rate of roll of roll calculations has been carried out

$$-C_{lp} = \sin\alpha_0 f(S_1)\left[\frac{\cot\in}{12}\right] \tag{4}$$

Where $S_1 = M_\infty \sin\alpha_0$

$$f(S_1) = \frac{(\gamma+1)}{2S_1}\left[\ 2S_1 + \frac{(B+2S_1^{\ 2})}{(B+S_1^{\ 2})^{\frac{1}{2}}}\ \right]$$

Rolling moment derivative can be expressed in terms of aspect ratio as follows.

$$-C_{l_p} = \sin\alpha_0 f(S_1)\left[\frac{AR}{48}\right] \qquad (5)$$

Where $AR = 4\cot\varepsilon$

Results and discussions:

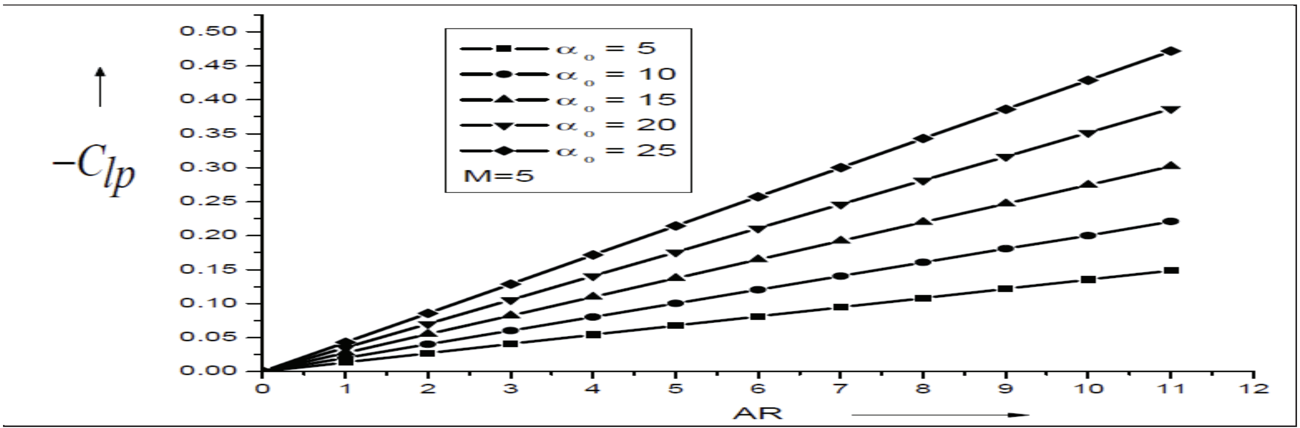

Fig1: Variation rolling moment derivative with wing aspect ratio for Mach number = 5

Fig. 1 presents the results of the roll damping derivative as a function of aspect ratio for a fixed Mach number of 5 various angle of incidence in the range from 5 degrees to 25 degrees. From the figure it is seen that the rolling moment derivative increases as Aspect ratio increases for a Mach number 5. The range of rolling moment derivative is (0 - 0.50) for Aspect ratio range (0 – 11). It is also seen that when angle of attack increases rolling moment derivative increases. It is also seen that as aspect ratio increases the wing span area will increase as the aspect ratio is directly proportional to rolling moment derivative and hence the corresponding lift generated by the wing which in turn increases the lift of the wing/aerofoil.

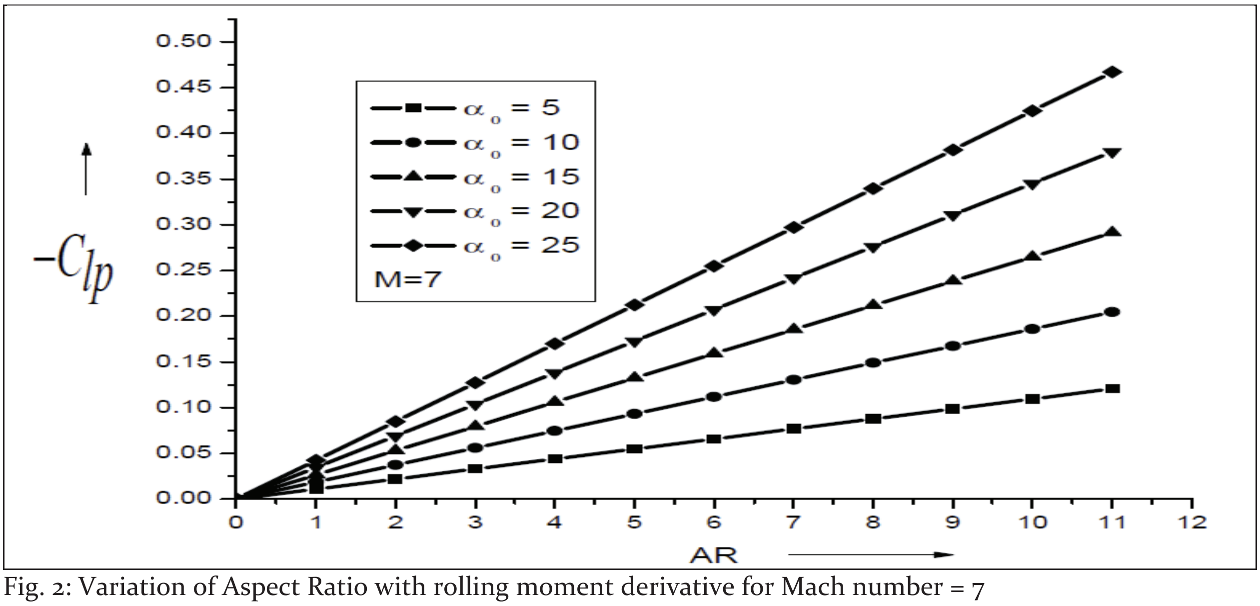

Fig. 2: Variation of Aspect Ratio with rolling moment derivative for Mach number = 7

Figure 2 shows the variation of rolling moment derivative with Aspect ratio for Mach number 7. This figure shows similar results with the same trends as discussed above, here the only difference is that the level of inertia has increased as compared to the previous case. It is seen that the magnitude of rolling moment derivative is less when compared to that in Figure 1. This is because the rolling moment derivative decreases with increase in the Mach number.

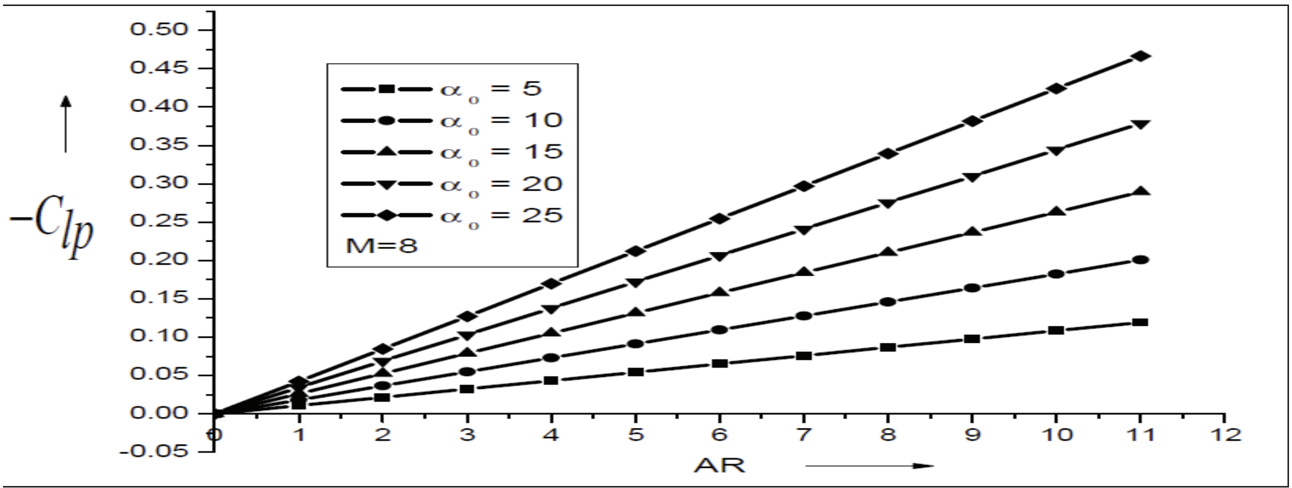

Fig. 3: Variation of Aspect Ratio with rolling moment derivative for Mach number = 8

Figure 3 shows the variation of rolling moment derivative with Aspect ratio for Mach number 8. The same trend is seen as in case of above figures 1 and 2 but the magnitude of rolling moment derivative has reduced considerable due to increase in the Mach number and hence the inertia values of the flow and its value is 0.46629 for angle of attack 25 degrees, Aspect ratio 11, and Mach number = 8.

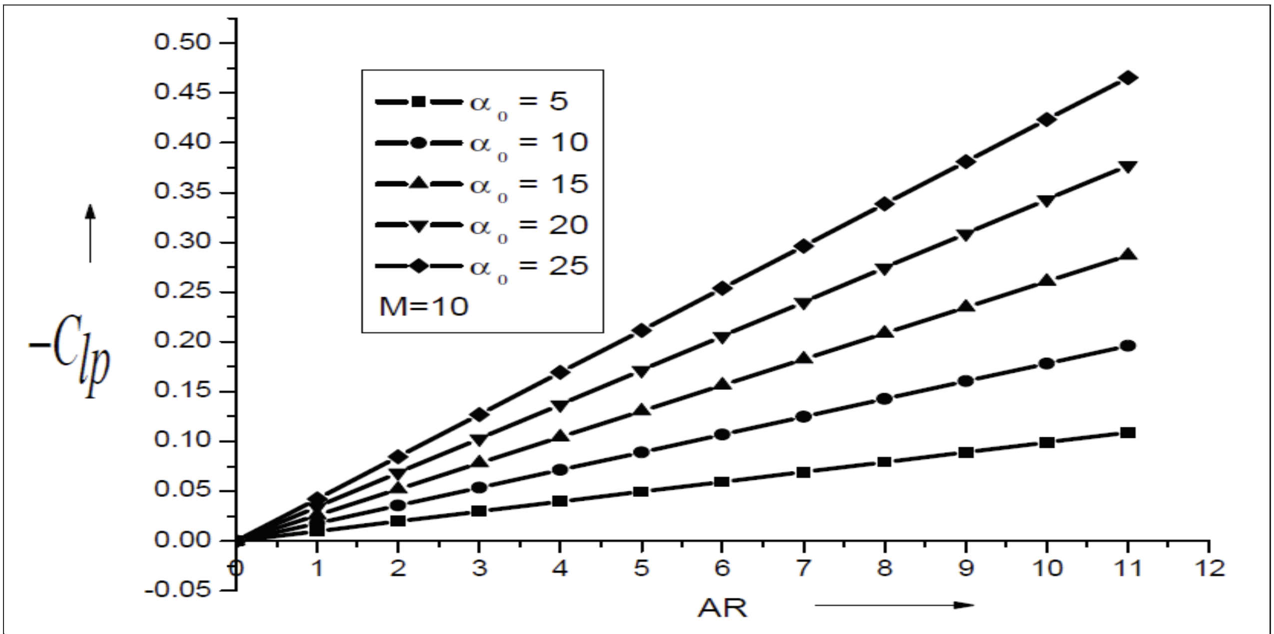

Fig. 4: Variation of Aspect Ratio with rolling moment derivative for Mach number = 10

Figure 4 shows the variation of rolling moment derivative with Aspect ratio for Mach number 10. The trend is same as discussed above but the magnitude of rolling derivative has reduced considerably with Aspect ratio with the progressive increase in the Mach number.

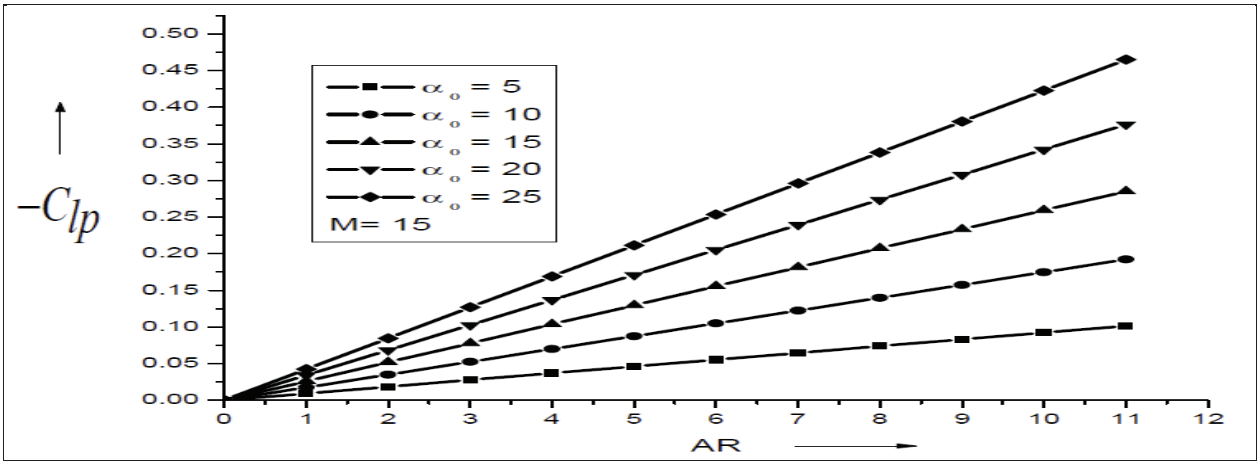

Fig. 5: Variation of Aspect Ratio with rolling moment derivative for Mach number = 15

Figure 5 shows the variation of rolling moment derivative with Aspect ratio for Mach number fifteen. The same trend is seen as above but with very low values and the reasons are same as discussed earlier.

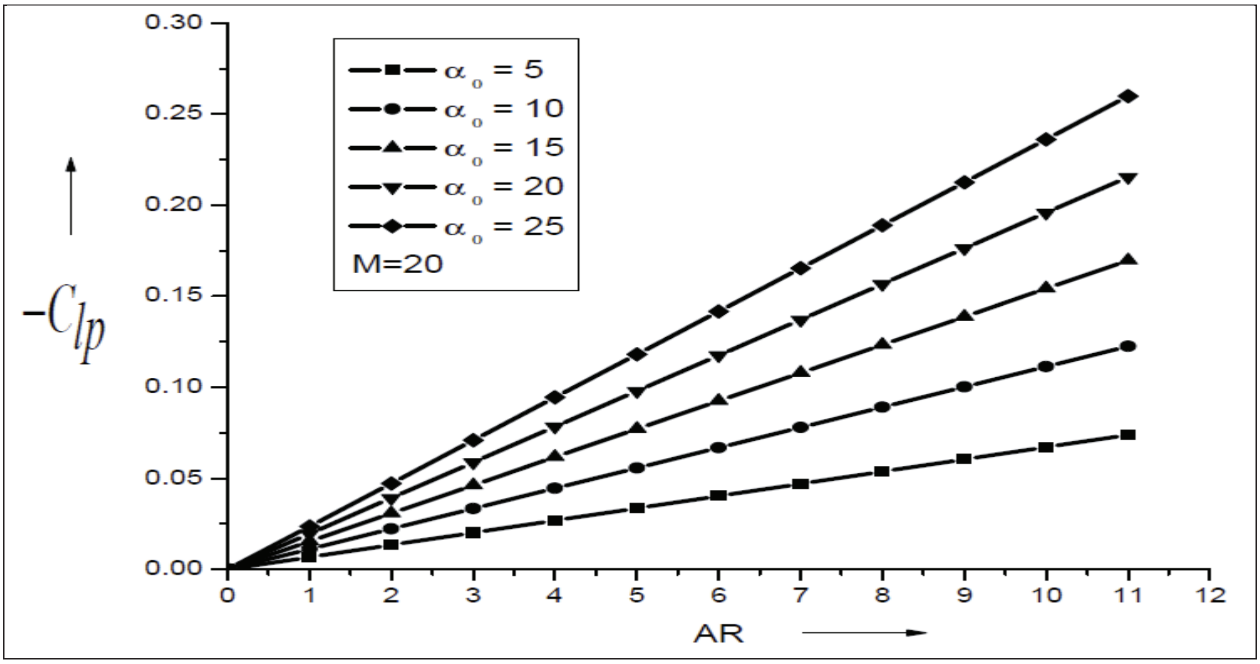

Fig. 6: Variation of Aspect Ratio with rolling moment derivative for Mach number = 20

Figure 6 shows the variation of rolling moment derivative with Aspect ratio for Mach number twenty. The trend is on the similar lines as discussed earlier. Further, the magnitude is has drastically reduced to less than 50% when compared to Mach number 15.

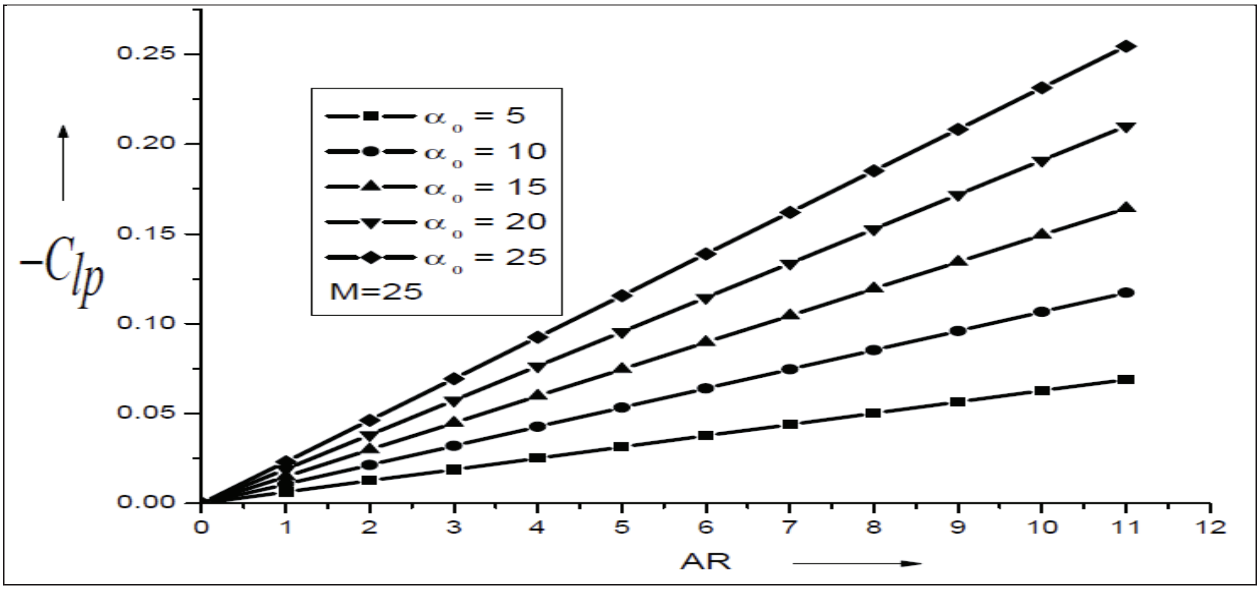

Fig. 7: Variation of Aspect Ratio with rolling moment derivative for Mach number = 25

Figure 7 shows the variation of rolling moment derivative with Aspect ratio for Mach number twenty five. The trend is same as we have seen in the previous cases. The Magnitude is almost the same as that of for Mach number 20 thus exhibiting Mach number independence principle.

Conclusion: It is seen that rolling moment derivative increases with aspect ratio for various angle of attack and Mach number. With the increase in the Mach number resulting in higher values of inertia leads to linear decrease in the roll damping derivative then with further increase in the Mach number the steady state is achieved which confirms the Mach number independence principle. It is also observed that as Aspect ratio increases the wing span area increases, so when the angle of attack increases this will result in higher values of lift. Because of high sweep, the critical local Mach number on the wing surface can be delayed and hence the flow separation and boundary layer separation can be delayed which will ultimately will delay the stalling of the wing.

References:

1. Light Hill, M. J., "Oscillating Aerofoil at High Mach Numbers", Journal of Aeronautical Sciences, Vol. 20, June 1953, pp. 402-406.
2. Ghosh K, "A new similitude for aerofoil in hypersonic flow", Proc of the 6th Canadian Congress of applied mechanics", Vancouver, 29th May 3rd June, 1977, pp. 685-686.
3. *M.Devi,* Fuzzy Critical Path Method Using; Mathematical Sciences International Research Journal ISSN 2278 – 8697 Vol 2 Issue 2 (2013), Pg 538-547
4. Miles, J. W., "Unsteady flow at hypersonic speeds, Hypersonic flow", Butterworths Scientific Publications, London, 1960, pp. 185-197.
5. Ghosh, K and Mistry B. K., "Large incidence hypersonic similitude and oscillating non-Planar wedges", AIAA Journal, August 1980, 18, 8, pp. 1004-1006.
6. Ghosh K., "Hypersonic large deflection similitude for oscillating delta wings", the Aeronautical journal", Oct.1984, pp. 357-361.
7. Asha Crasta and Khan S. A., "High Incidence Supersonic similitude for planar wedge", International Journal of Engineering research and Applications, Vol. 2, Issue5, Sep-Oct 2012, pp. 468-471.
8. Khan S. A. and Asha Crasta, "Oscillating Supersonic delta wings with curved leading edges", Advanced Studies in Contemporary mathematics, Vol. 20(2010), No.3, pp.359-372.
9. Asha Crasta and S. A. Khan, "Estimation of Stability derivatives of an Oscillating Hypersonic Delta wings with curved leading edges", Vol.3, Issue3, Dec 2012pp.483-492.,
10. Asha Crasta and S.A. Khan, 2014, 'Effect of Angle of Incidence on Stability derivatives of a Wing', International Journal for Research in Applied Science and Engineering Technology, Vol. 2, Issue V, May, pp. 411-422.
11. Asha Crasta and S. A. Khan, 2014, "Hypersonic Similitude for Planar Wedges", The International Journal of Advanced Research in Engineering

and Technology, Volume 5, Issue2, Feb., pp. 16-31.

12. Asha Crasta and S.A. Khan, 2014, 'Estimation of Stability Derivatives for a Planar Wedge In the Newtonian Limit', IOSR Journal of Mathematics, Volume10, Issue 2 Version I, March-April, pp. 01-06.
13. Dr.K.Chithra, P.Backialakshmi, N.Sudha, Status Sequence and Detour Status Sequence; Mathematical Sciences international Research Journal ISSN 2278 – 8697 Vol 3 Issue 2 (2014), Pg 833-834
14. Asha Crasta and S. A. Khan, 2014, 'Effect of Mach number on Stiffness and Damping Derivatives for Oscillating Hypersonic Non-Planar Wedge', IOSR Journal of Mechanical and Civil Engineering, *Volume* 11, Issue 2 Ver. VIII (Mar-Apr.), pp. 04-11.
15. Asha Crasta and S.A. Khan, 2014, 'Effect of Angle of Incidence on Stiffness and Damping Derivatives for Oscillating Hypersonic Non-planar Wedge', International Journal for Research in Applied Science and Engineering Technology, Vol. 2, Issue IV, April, pp. 229- 242.
16. Asha Crasta and S. A. Khan, 2014, 'Supersonic Similitude for Oscillating Non-Planar Wedge', IOSR Journal of Mathematics, Volume10, Issue 2 Ver.VI, Mar-Apr, pp.15-24.
17. *R.B. Gnanajothi, A.Umadevi,* Edge topogenic Graphs; Mathematical Sciences International Research Journal ISSN 2278 – 8697 Vol 2 Issue 2 (2013), Pg 494-500
18. Asha Crasta, M. A. Baig, S. A. Khan, 2012, 'Estimation of Stability derivatives of a Delta Wing in Hypersonic flow', International Journal of Emerging trends in Engineering and Developments, Vol. 6, Issue2, Sep., pp. 505-516.
19. A.Arokia Lancy, I.Arockiarani, Soft interval Valued intutionistic Fuzzy Semi; Mathematical Sciences international Research Journal ISSN 2278 – 8697 Vol 3 Issue 2 (2014), Pg 835-837
20. Asha Crasta and Khan S. A, 2012, 'Oscillating Supersonic delta wing with Straight Leading Edges', International Journal of Computational Engineering Research, Vol. 2, Issue 5, September, pp. 1226-1233.
21. Asha Crasta and Khan S. A., 2014, 'Stability derivatives of a Delta Wing with Straight Leading edge in the Newtonian Limit', International Journal of Engineering research and Applications, Vol. 4, Issue 3, Version 2, March, pp. 32-38.
22. Priti Gupta,Prince,Vijay Kumar, Comparative Analysis Between intuitionistic Fuzzy Set; Mathematical Sciences International Research Journal ISSN 2278 – 8697 Vol 3 Issue 1 (2014), Pg 436-440
23. Asha Crasta and S. A. Khan, 2013, 'Stability Derivatives in the Newtonian Limit', International Journal of Advanced Research in Engineering and Technology, Volume 4, Issue 7, Nov-Dec., pp. 276-289.
24. Asha Crasta, S. A. Khan , 2014, 'Effect of angle of incidence on Roll damping derivative of a delta Wing', International Journal of Emerging trends in Engineering and Developments Vol. 2, Issue4, March 2014, pp. 343-356.

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