THE CONCEPT OF HIGHLY MANOEUVRABLE AIRPLANE CONTROL

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Abstract. Highly manoeuvrable airplanes are equipped with special devices to increase in a lift force on high angle of attack. Delta wings, closely coupled canards and strakes are the most popular configurations. All these configurations are based on tip vortices that are generated an additional lift force. The phenomenon of vortex lift increases lift force but also increases a drag force. Furthermore vortex brake down is caused rapidly loss of a lift force and problem with longitudinal and lateral stability.
The paper presents the initial concept of controls highly manoeuvrable airplane. The vehicle has been designed as a tailless configuration with the all moving tip plates. Moreover the airplane has been equipped with the strake. Calculations of aerodynamic and static stability for sub and supersonic flow is included. The research is financed by National Science Centre.

Keywords. Highly manoeuvrable airplanes, aerodynamic calculation, static stability.

1 Introduction

Highly manoeuvrable airplanes are able to operate at high angles of attack and at high angular velocity. The high lift coefficient is necessary to fulfill these requirements. One of a method to increasing in lift coefficient is utilize phenomenon of vortex lift (Figure 1) [1]. In that case an airplane is equipped with special devices which generate a vortex flow. The most simply configuration is a delta wing [2] but is also the least effective method. The second possibility is a close coupled canard [3] which is additional surface pleased at a distance of a main wing. Another concept is a strake [4] which is an additional surface in front of a main wing. These surfaces are use as an edge vortices generator, which produce an additional component of lift force. This phenomenon increase in a lift force but also increases a drag force. Moreover a vortex structure have tendency to break down [5] this is a reason for rapidly decrease of a lift coefficient. Another problem is how and where a brake down is occurs. If the vortex structure break down asymmetrical than appears problem with a control. If the control surfaces will be inside of stream cause by the vortex break down than those surfaces are ineffective.

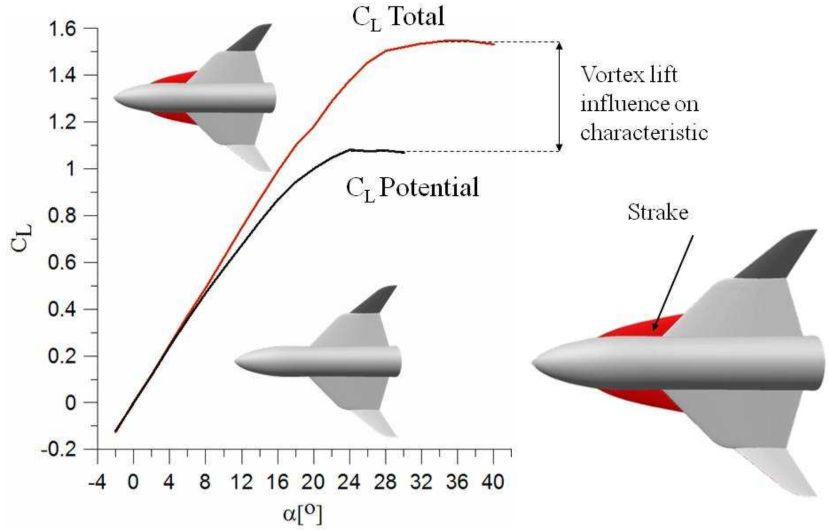

Figure 1: Vortex lift

General Dynamics F-16 Fighting Falcon, McDonnell Douglas F/A-18 Hornet and Super Hornet, Sukhoi Su-27 and Mikoyan MiG-29 are the most know aircraft which utilize a strake to increasing a lift force.

2 Highly manoeuvrable airplane

Purpose of the research is designed the control system for highly manoeuvrable airplane [6] which allow obtain an equilibrium state. This paper presents results of the initial investigation of the highly manoeuvrable airplane which is designed as a tailless configuration (Figure 2). The vehicle consists of: an axially symmetrical body, a sweep main wing, a strake and site plates on the tips of the main wing. The vehicle has been designed for subsonic and supersonic range of speed and will be able operating on high angle of attack.

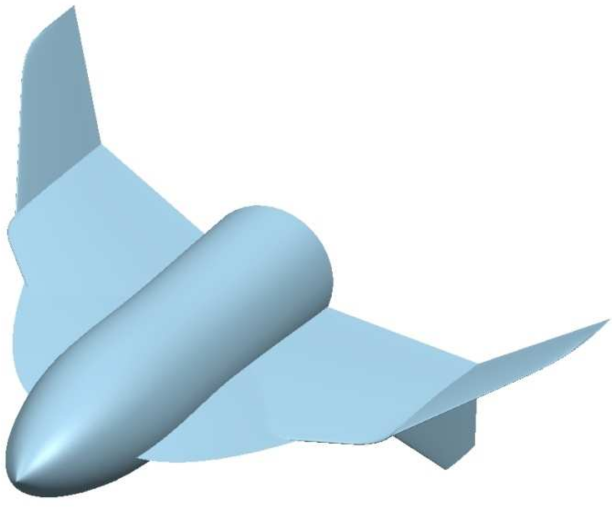

Figure 2: Layout of the highly manoeuvrable airplane

2.1 Concept of control

A concept of control assumes two segments elevon on the main wing and all moving plate on the tips of the main wing (Figure 3). The inner part of the elevon will be used during low Mach number flights. The outer part of elevon will be supported control on high angles of attack and high Mach number flights. The all moving plates will be in particularly useful during supersonic flights.

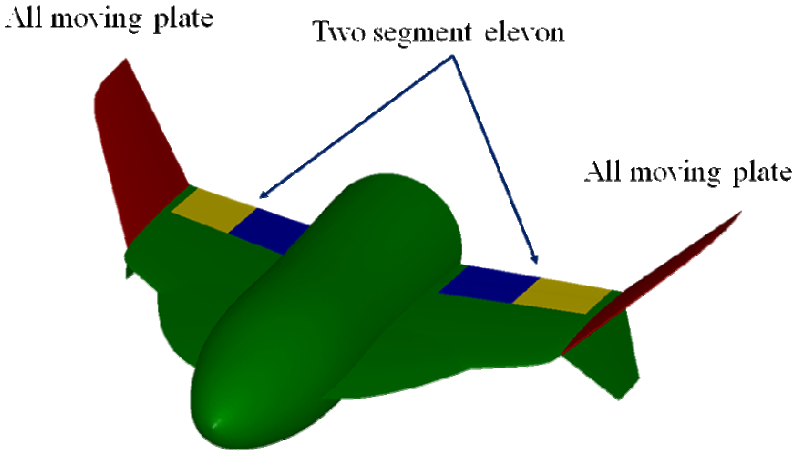

Figure 3 Concept of the highly manoeuvrable airplane control

The elevon is responsible for roll and pitch control and incrising a lift ceofficient. The all moving plates is responsible for pitch and yaw control. The paper focus on aerodynamic and stability calculations for the vehicel with defleted control surfaces. The analysis were cary out for supsonic and supersonic regime of flow as well.

3 Aerodynamic investigation

The chapter presents results of numerical aerodynamic investigation of high manoeuvrable airplane with control surfaces defeting. The folowing configurations were examined: symetrical deflection inner part of elevon, symetrical deflection of both elevon parts, symetrical deflection all moving plates and symetrical deflection all moving tall with symetrical both elevon parts. Delfection of the traling edge of the elevon to up is asume as a negative elevon delection. Rotation the traling egde of all moving plate to inword is asume as negative all moving plate deflection (Figure 4).

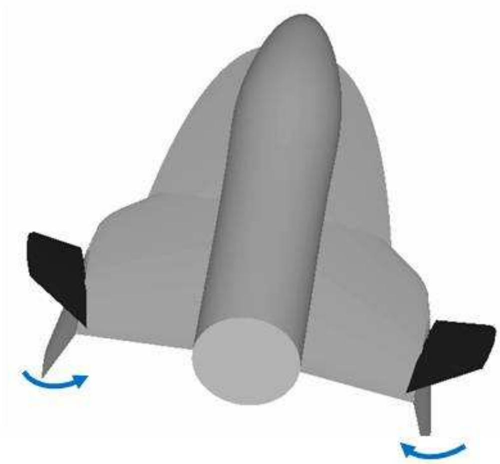

Figure 4Negative all moving plate deflection

3.1 Method

Numerical aerodynamic calculations were conducted by software [7] which base on Euler [8] equations and multi-grid scheme [9]. This method can be use for vortices flow but vortex breakdown cannot be simulation. The investigation includes subsonic and supersonic calculations and cases for high angle of attack as well. A sideslip angle is equal zero for all consider calculation. The Figure 5 shows numerical model of the vehicle with both part of the elevon deflection. The numerical model consists of seven levels of blocks.

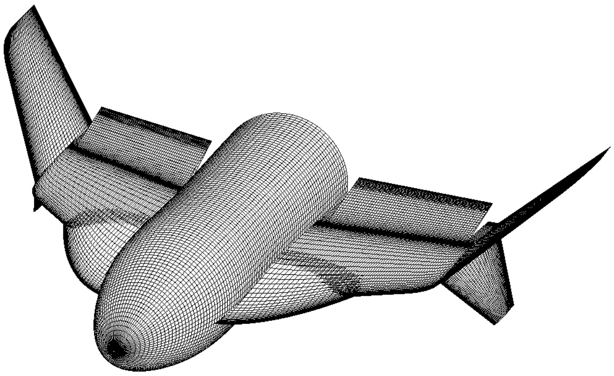

Figure 5: Numerical model

3.2 Results

The Figure 6 presents aerodynamic characteristics for various the elevon deflections. The calculations were conducted for Mach number Ma=0.5. The referent point for moment calculations is one of the possible positions of the center of gravity of the vehicle.

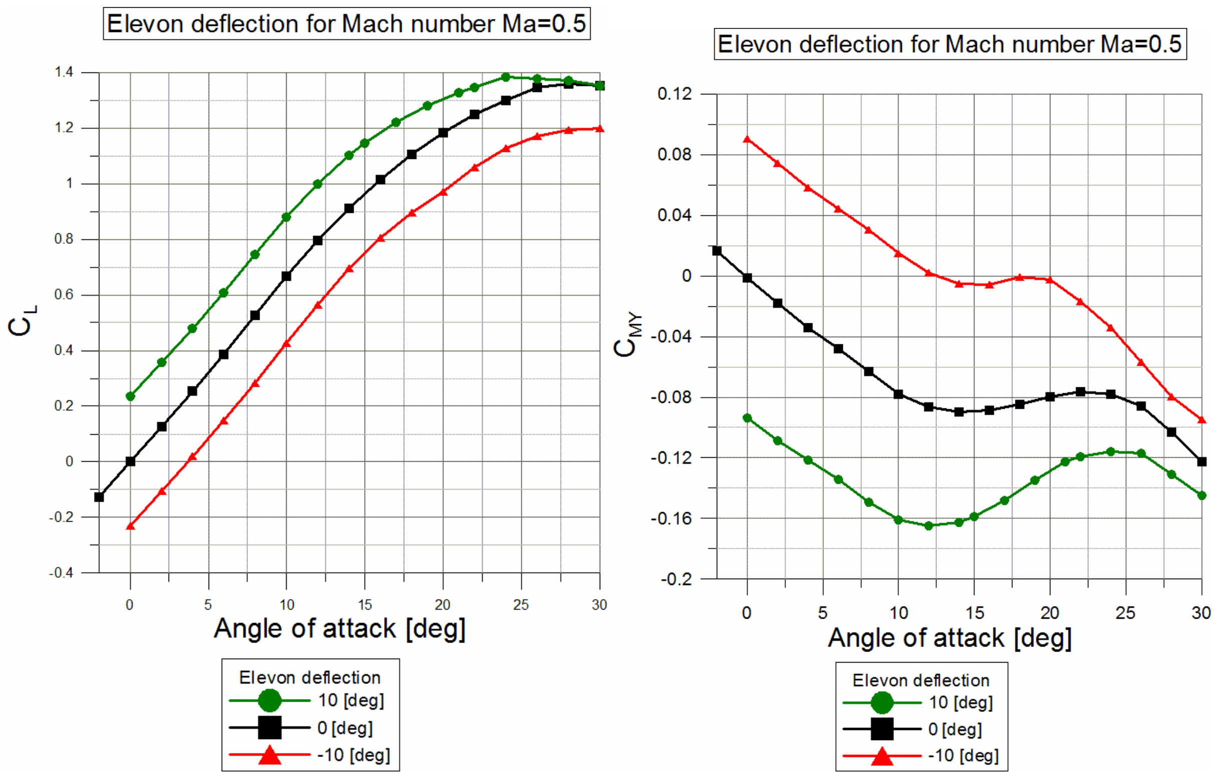

Figure 6: The left chart presents lift coefficeny as a function of angle of attack, the right chart presents momnetum coefficient as a function of angle of attack.

The Figure 7 presents aerodynamic characteristics for various the all moving plate deflections. The calculations were conducted for Mach number Ma=0.5. The referent point for moment calculations is one of the possible positions of the center of gravity of the vehicle.

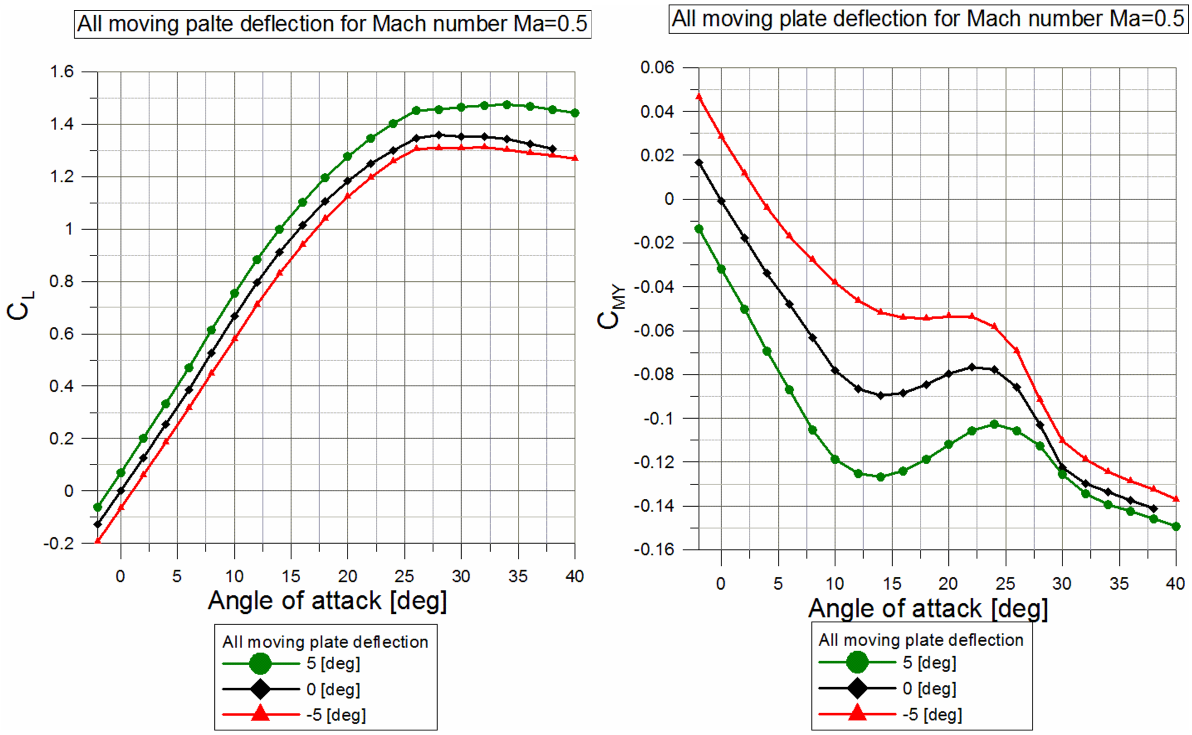

Figure 7: The left chart presents lift coefficeny as a function of angle of attack, the right chart presents momnetum coefficient as a function of angle of attack.

The Figure 8 and Figure 9 present pressure coefficient distribution for the vehicle with positive and negative the elevon deflection.

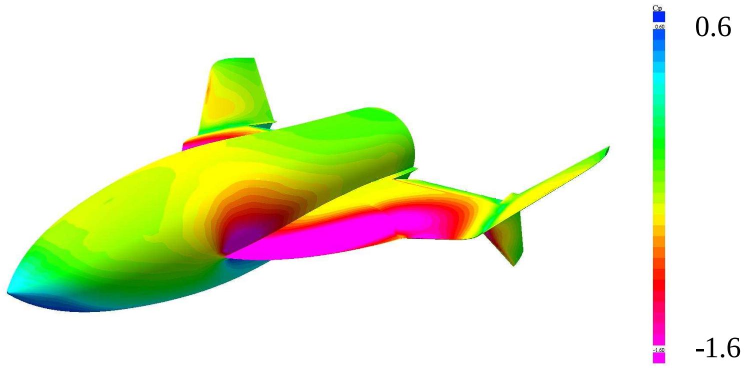

Figure 8: Pressure coefficient distribution for Ma=8, α= 22 degree and elevon deflection δ_E=10 degree

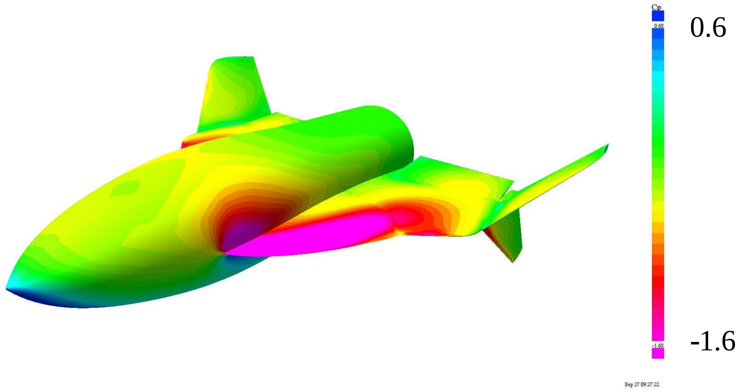

Figure 9: Pressure coefficient distribution for Ma=8, α= 21 degree and elevon deflection δ_E= -10 degree

The Figure 10 and Figure 11 present pressure coefficient distribution for Mach number for the vehicle with positive and negative the all moving plate deflection.

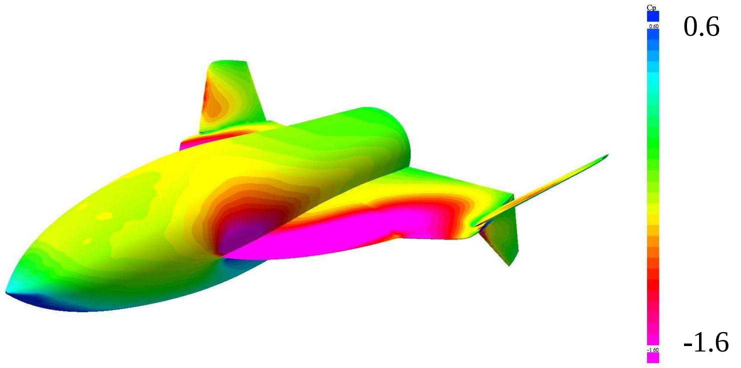

Figure 10: Pressure coefficient distribution for Ma=0.5, α= 22 degree and all moving plate deflection δ_R=5 degree

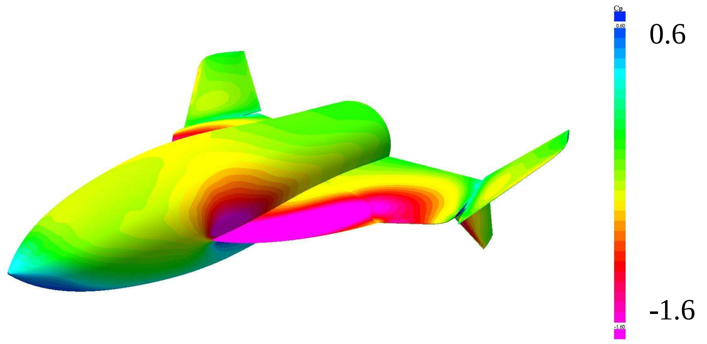

Figure 11: Pressure coefficient distribution for Ma=0.5, α= 22 degree and all moving plate deflection δ_R=-5 degree

The Figure 12 and Figure 13 present Mach number distribution for the airplane with positiv and negative the all moving plate deflection.

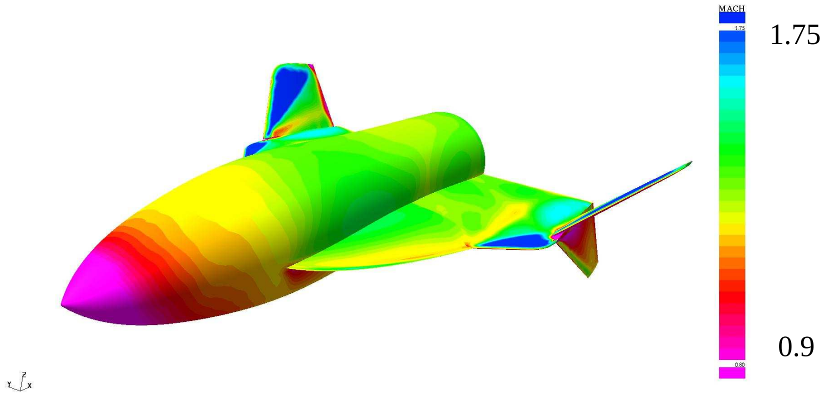

Figure 12: Mach number distribution for Ma=1.2, α= 8 degree and all moving plate deflection δ_R=5 degree

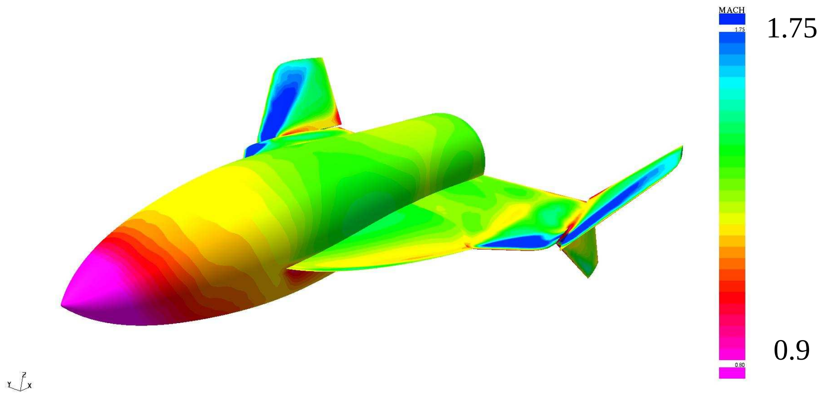

Figure 13 Mach number distribution for Ma=1.2, α= 8 degree and all moving plate deflection δ_R=-5 degree

The Figure 14 and Figure 15 present pressure distribution with vortex vizualization for the airplane with the control surfaces deflection.

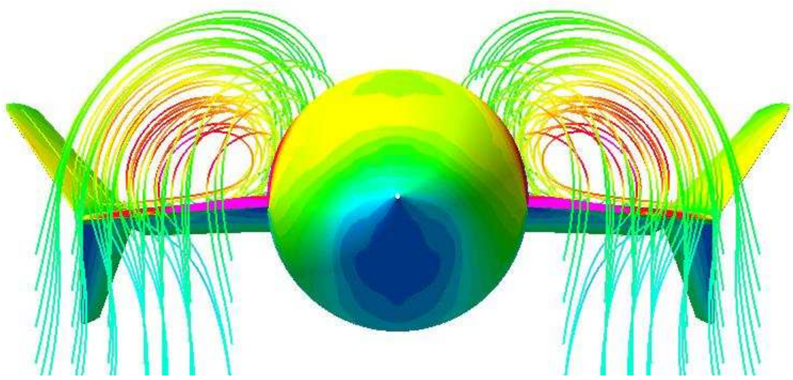

Figure 14: Vortex vixualization, Ma=0.5 and α=24 degree, elevon deflection δ_E= 10 degree

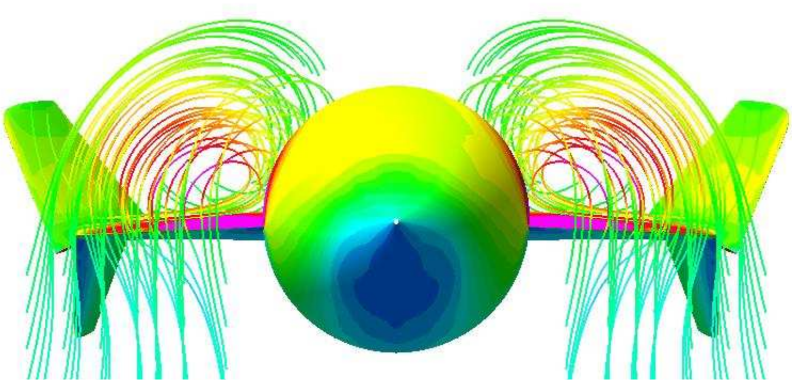

Figure 15: Vortex vixualization, Ma=0.5 and α=24 degree, elevon deflection δ_R= -10 degree

4 Static stability

This paper includes inital investigation and focus on logitudinal static stability, a sideslip angle is equal zero for all presented calculations. The referent point for moment calculations is one of the possible positions of the center of gravity of the vehicle. The Figure 16 presents comparison of surfaces control efficiency for subsonic and supersonic reasearch. The Mach number and angle of attack are constant, the control surfaces deflection is change. For a subsonic flight is consider three configuration: the inner part of elevon deflection, the both parth of elevon deflection and the all moving palte deflection. For a supersonic flight is consioder three configuration as well: the both part of elevon deflection, the all moving plate deflection and the all moving plate defletion simultaneous constant elevon deflection equal δ_E= -5 degree. All consider deflections are symetrical.

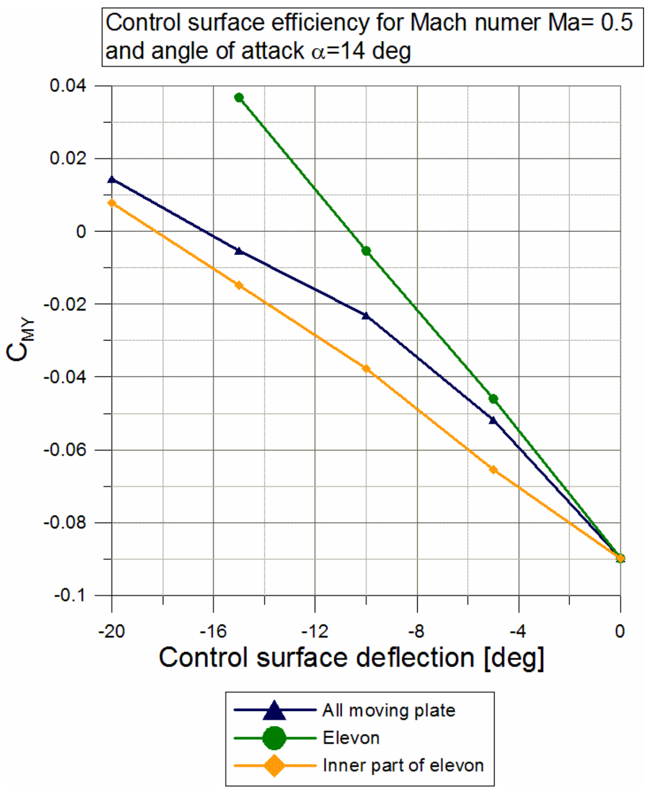

Figure 16 Control surface efficiency for subsonic research

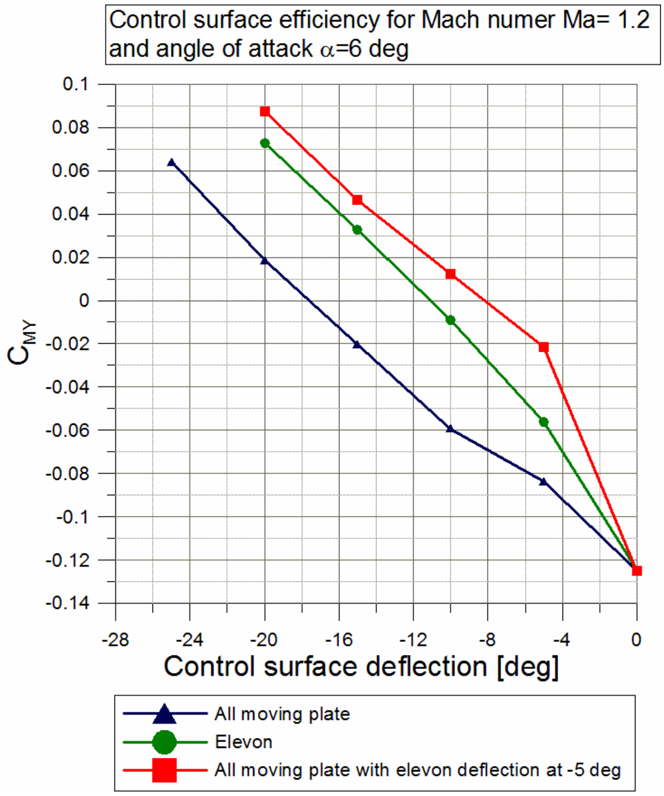

Figure 17 Control surface efficiency for supersonic research

The Figure 18 and Figure 19 present the all moving plate defletion and the elevon deflection requried to equiliburum state as a funtion of angle of attack for subsonic flight.

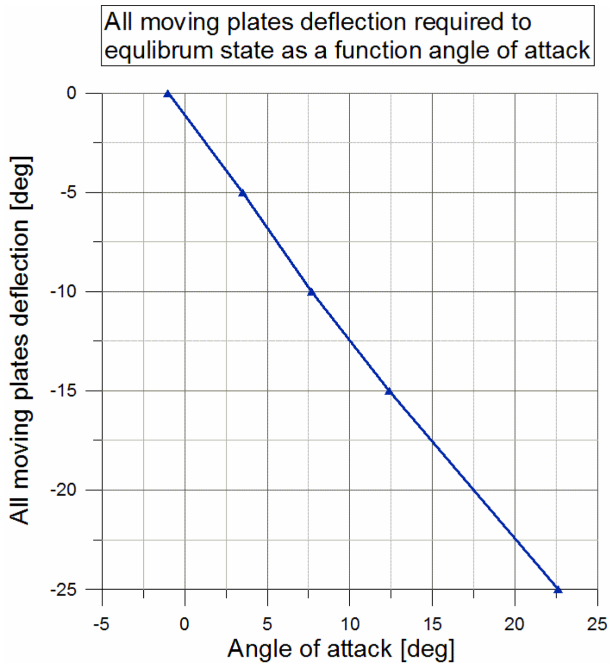

Figure 18: All moving plate deflection requried to equlibrum state. Ma=0.5

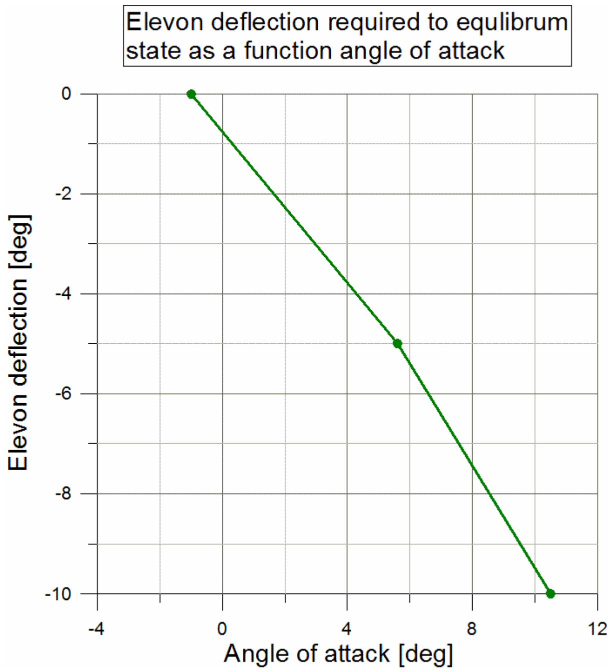

Figure 19: Elevon deflection requried to equlibrum state, Ma=0.5

5 Conclusion

The results of initial investigation seem to be promising. The highly manoeuvrable airplane is equipped with the control surfaces which are effective for both subsonic and supersonic range of speed. For subsonic case the elevon is the most effective type of control surfaces. For supersonic condition to obtain equilibrium state the best solution is deflection the elevon and the all moving plate at the same time.

More increase lift coefficient for the all moving plate deflection than for the elevon at the same angle of deflection.

Future calculation will be conducted by software base on Navier Stokes equation due better simulated vortex flow.

Acknowledgment

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References

[1] John E. Lamar, Neal T. Frink “Experimental and Analytical Study of the Longitudinal Aerodynamic Characteristics of Analytically and Empirically Designed Strake-Wing Configurations at Subcritical Speeds”, NASA Technical Paper 1803, 1981

[2] H.W.M. Hoeijmakeres, W.Vaatstra, “Vortex Flow Over Delta and Double-Delta Wings”, Journal of Aircraft, Vol. 20, No.9,1983

[3] James M. Luckring, “Aerodynamics of Strake Wing-Wing Interactions”, Journal of Aircraft , Vol. 16, No. 11, 1979

[4] John E. Lamra, Neal T. Frink, “Aerodynamic Features of Designed Strake-Wing Configurations” , Journal of Aircraft Vol.19, No8, August 1982

[5] Anthony M. Mitchell, Jean Delery, „Research into vortex breakdown control”, Progress in Aerospace Sciences 37 (2001)

[6] M.Figat, C.Galiński, A.Kwiek „Modular Aeroplane System. A Concept and Initial Investigation“, 28th International Congress in the Aeronautical Sciences, 2012

[7] MGAERO User’s Manual version 3.1.4

[8] John J. Bertin, “Aerodynamics for Engineers”, Prentice Hall, 2002

[9] D.J Mavriplis, “Three-Dimensional Unstructured Multigrid for the Euler Equations”, Journal of Aircraft, Vol. 30, No 7, July 1992