Graphical interpretation of Center of lift versus Neutral point for a 2D airfoil

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Some results on airfoil shape or Re effect

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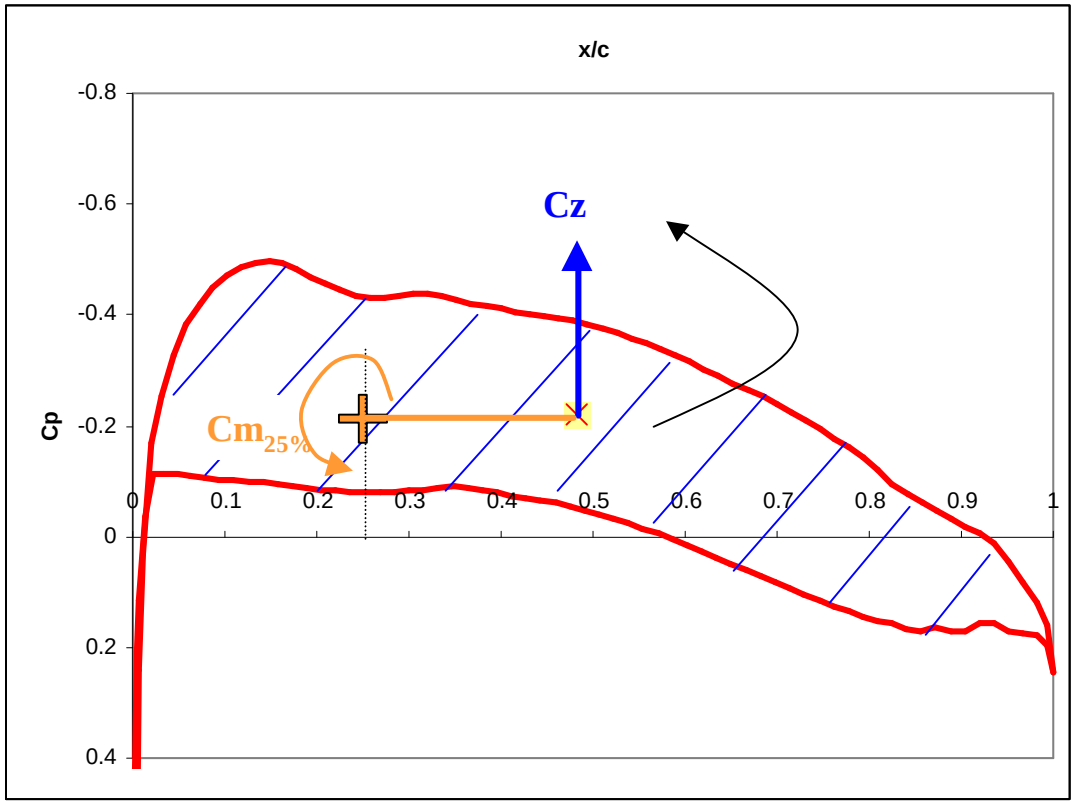
Definition : Center of Lift

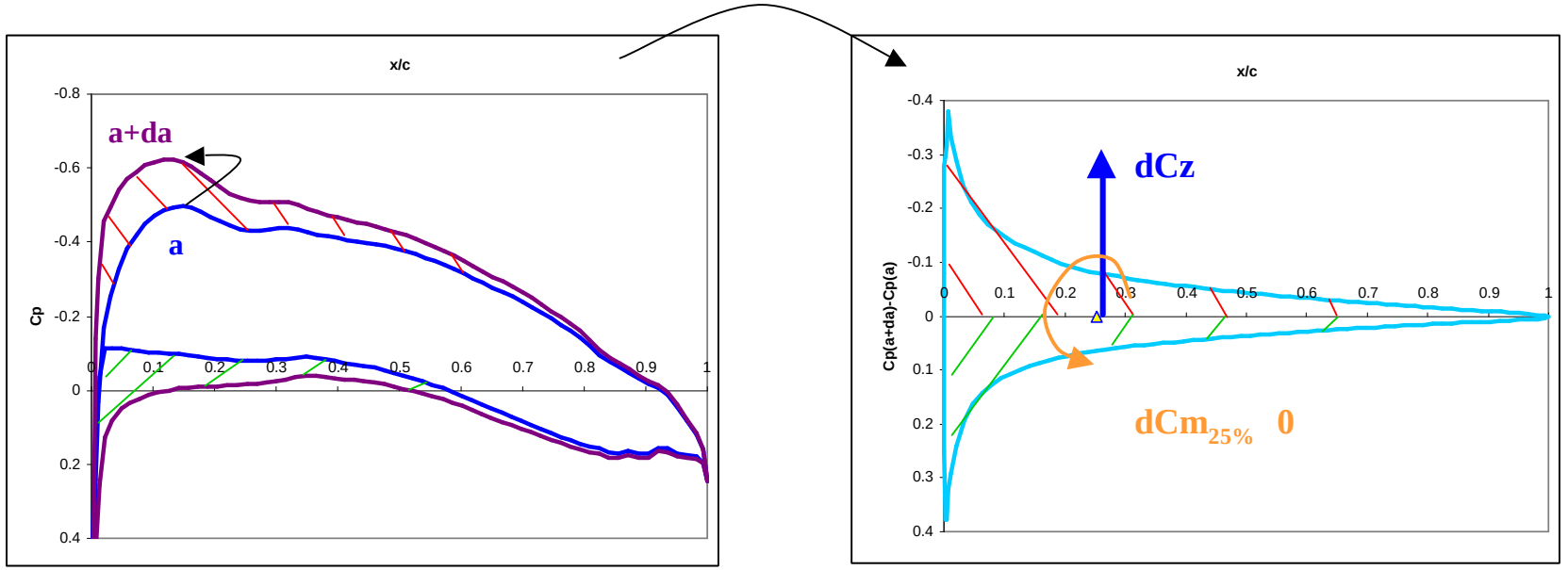


Once you have a **Cp distribution** over an airfoil

- Lift coefficient Cz if given by ***the area*** between Cp curves
- Center of lift is given by ***the center of area*** between Cp curves
- $Cm_{25\%}$ is given $(0.25\text{-}x/c_{\text{Center Lift}})*Cz$

Definition : Neutral Point

Neutral point is related to the evolution of lift and pitching moment during a change in alpha da



Once you have the **<u>evolution of Cp distribution</u>** over an airfoil vs alpha

- Lift gradient dCz/da if given by ***<u>the area</u>*** between dCp/da curves
- Neutral point is given by ***<u>the center of area</u>*** between dCp/da curves
- $dCm_{25\%}/da$ is given $(0.25-x/c_{\text{neutral point}})*dCzda$

Thin airfoil theory

Thin airfoil theory is a way to compute Cp distribution over a given simplified airfoil geometry, in non-viscous flow.
Here are well known results coming from computation using thin airfoil theory :

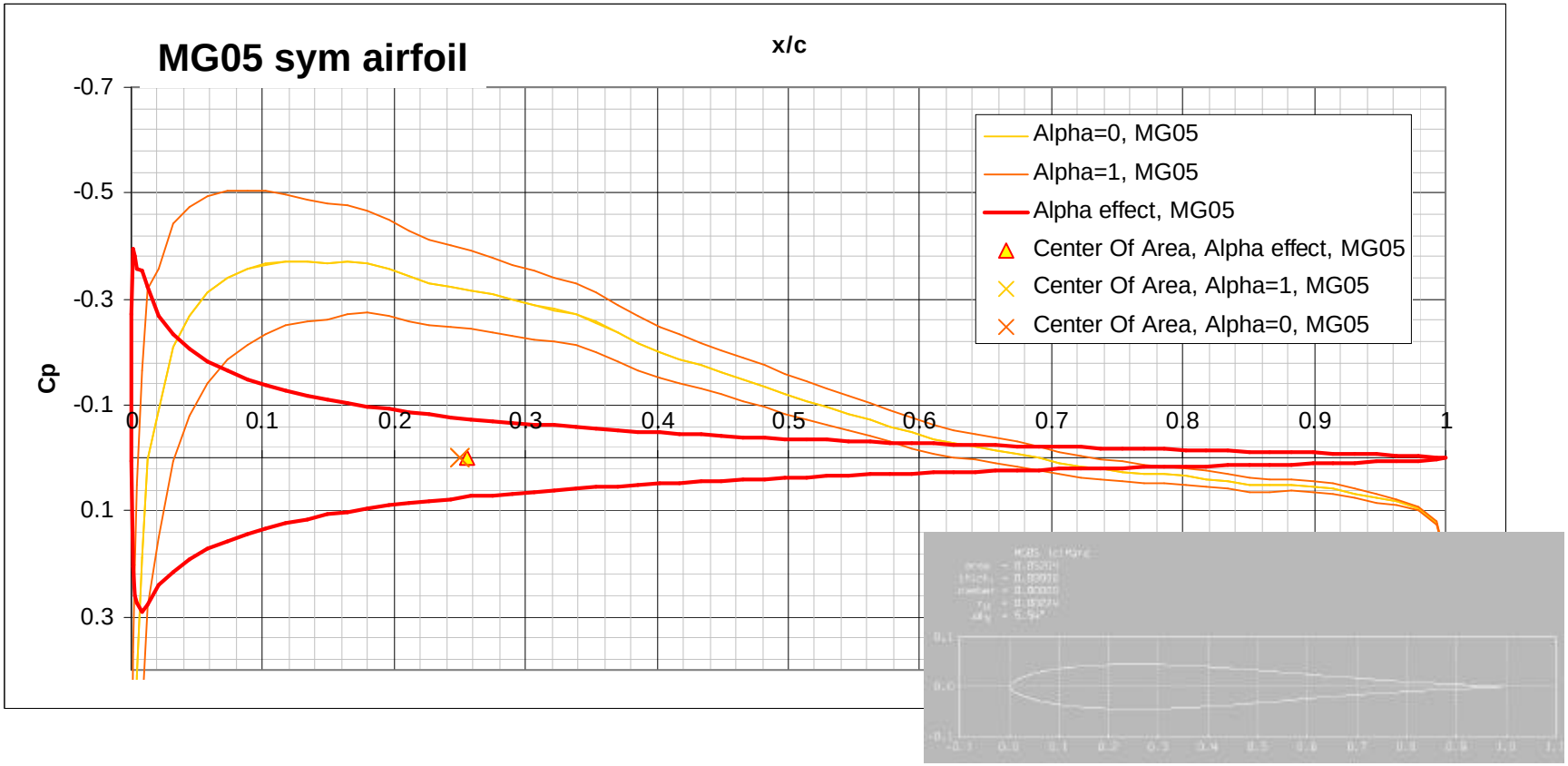
- ***Neutral point stands at 25% of chord***
- ***Neutral point is not a function of airfoil geometry***
- ***For a symmetrical airfoil, lift centre & neutral point are the same***

So the questions are :

- Does those results based on simplified theory stands in real life ?
- Is viscosity effect that negligible, particularly for models ?

Let's check this with Xfoil, that gives Cp distribution over true airfoil geometry, with simplified viscous effects.

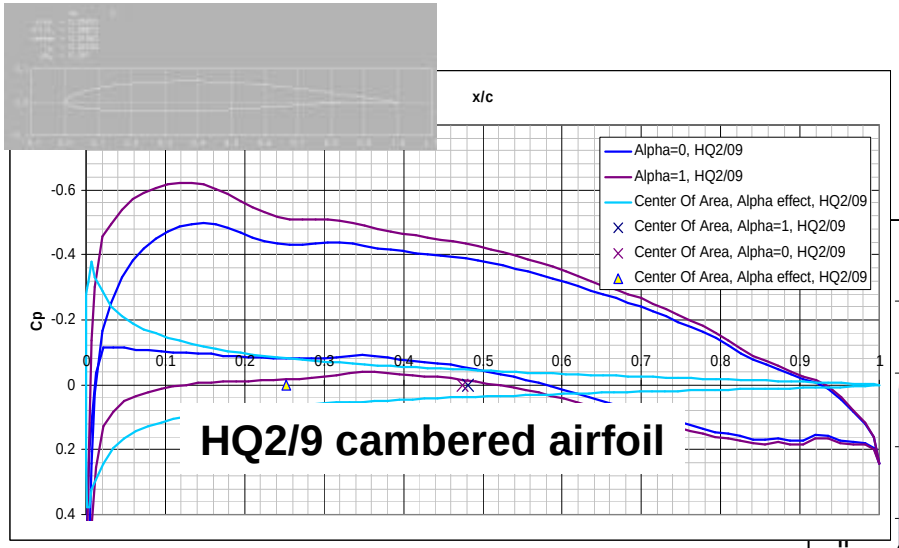
Xfoil check of thin airfoil result 1/2

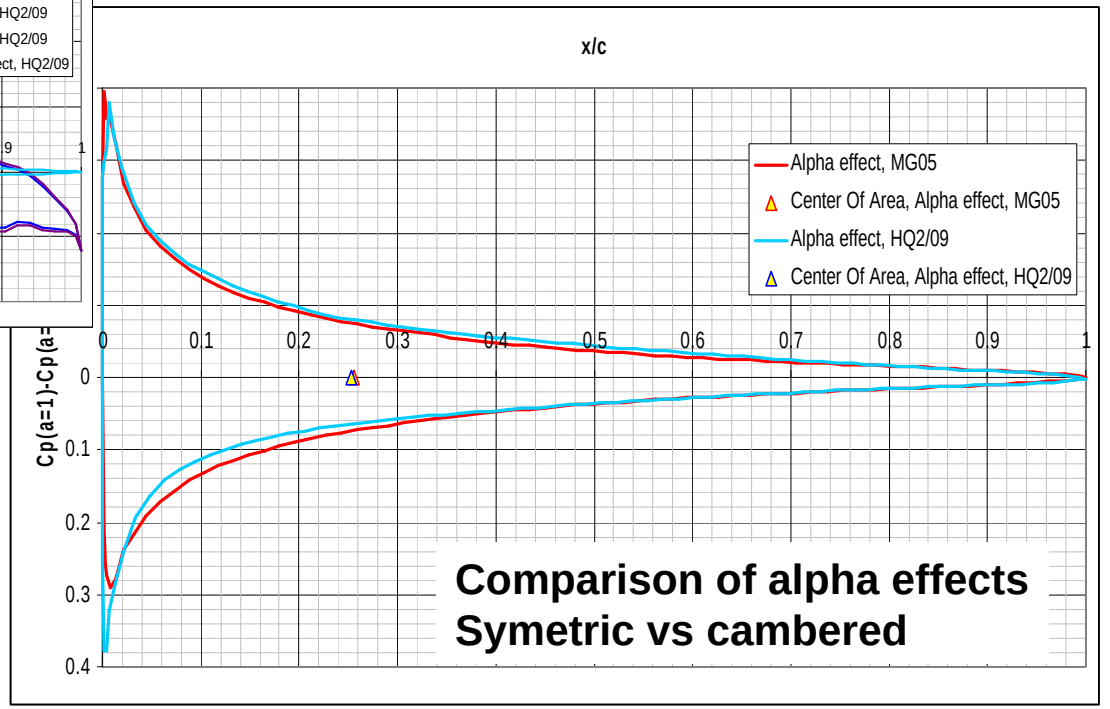


Based on Cp curve reading & centre of area determination :

- Centre of lift & neutral point are very close to each other
- This position is very close to 25% of chord (then $Cm_{25\%}$ 0)

Xfoil check of thin airfoil result 2/2

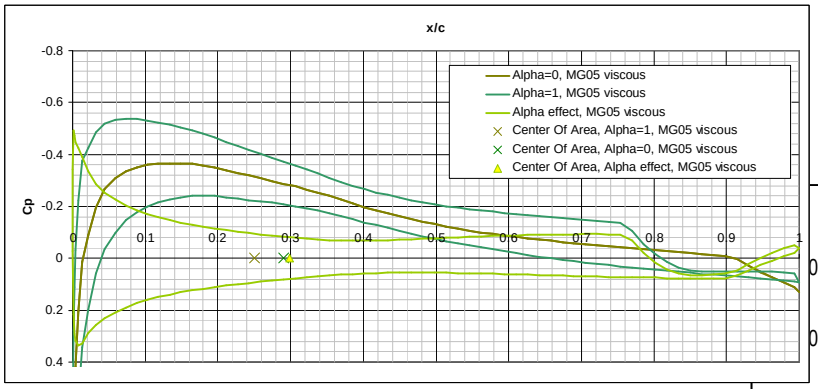




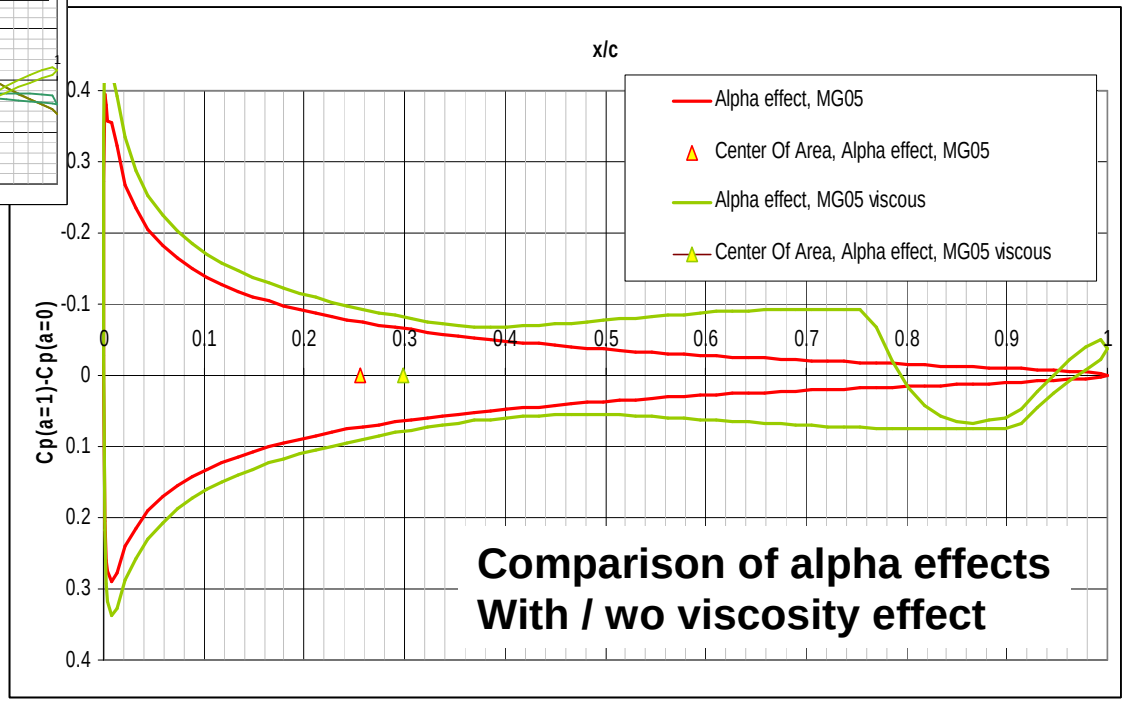
Based on Cp & ΔCp curve reading & centre of area determination :

- Cp curve is highly dependant on airfoil camber
- Centre of lift is distinct from neutral point
- Alpha effect on Cp (ΔCp) is little dependant on airfoil camber (and thickness as well)
- Then neutral point position is still very close to x/c=25% for any airfoil in non viscous flow

Xfoil check of viscous effect



MG05 symmetric airfoil, Re=100 000



Based on Cp & ΔCp curve reading & centre of area determination :

- Cp curve is very dependant on Reynolds
- Due to viscous effect, centre of lift is distinct from neutral point even if geometrically the airfoil is symmetric.
- Alpha effect on Cp (ΔCp) is also very dependant on viscous effect
- As a result with viscous effect, neutral point is not necessarily at 25%.

Conclusion

If some conclusion are to be drawn from all this :

- If we consider unviscous flow, thin airfoil theory is a very reasonable approximation, and the three results were verified :
  - Neutral point stands very near 25% of chord
  - Alpha effect on Cp, hence neutral point is very little function of airfoil geometry
  - For a symmetrical airfoil, lift centre & neutral point are very close

- Viscous effect for typical models Re number acts more than actual geometry in the former case (non viscous flow).

  NB : for high Re number as in the case of full scale plane, viscous effect plays much less.

- As boundary layer development is highly dependant upon detailed geometry, at the end for models the Re effect on neutral point is different for each airfoil.
  - +/-5% of variation along chord with regards to thin airfoil theory can be very easily obtained for centre of lift & neutral point