

Compressibility Effects

With the previous simulations showcasing the effects of changes in airfoil geometry to the lift spectrum, it is now of interest to understand the effects of compressibility to the current method. The first step in validating the code is to check the compressibility effects on a flat plate. The Prandtl-Glauert Transformation was applied to the BEM code in order to simulate compressibility effects.

As stated by the transform, it is desired that a 2D compressible plane (x,y) be transformed to an equivalent incompressible flow plane (ϵ, η). The calculations can be then performed in the transformed incompressibility plane and then transformed back to the compressible plane in order to obtain required parameter data such as c_L and c_p . The typical formulation used is shown below:

$$\begin{aligned}\beta^2 \phi_{xx} + \phi_{yy} &= 0 & \beta &= \sqrt{1 - M_\infty^2} \\ \epsilon &= x & \eta &= \beta y \\ c_p &= \frac{c_{p_o}}{\beta} & c_L &= \frac{c_{L_o}}{\beta}\end{aligned}$$

The first case being considered is a flat plate with a freestream mach number of $M_\infty = 0.2$. In order to validate the current method, the results will be compared to the Possio Code developed by "....". This code produces blade vortex interaction response of a flat plate for compressible cases. The figure below shows a comparison of the BEM code with compressibility modifications made, and the Possio code. The various lines on the graphs show the result of the BEM code for different discretization models. As can be seen from the figure, the linear discretization best matches with the results from the Possio code.

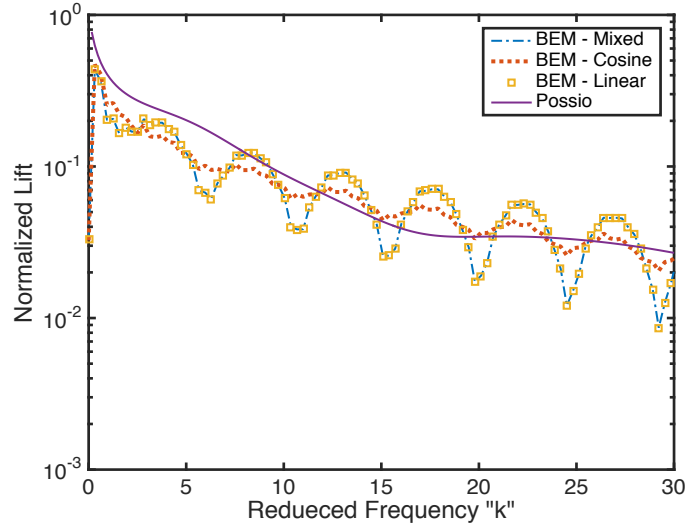


Figure 1: Comparison of discretizations of BEM results to Possio code results

Using the linear discretization, the simulation was run for several mach numbers ranging from $M_\infty = 0.2$ to $M_\infty = 0.6$. The figure below shows the response of the flat plate to the imposed vortex for the aforementioned mach numbers compared to the flat plate run results obtained from Possio.

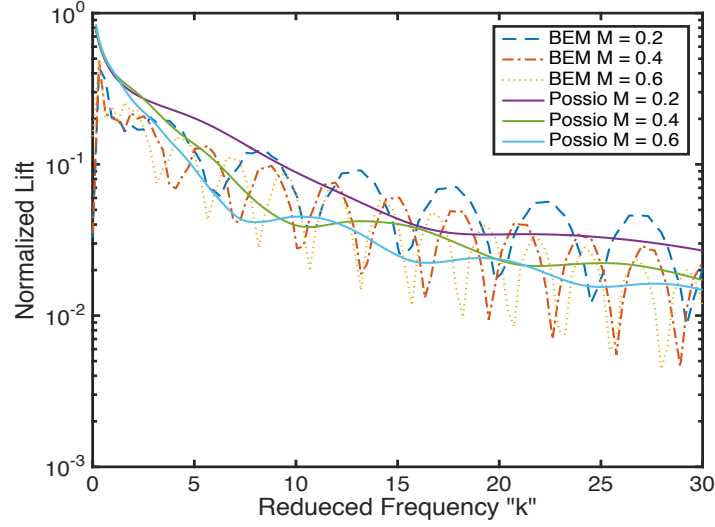


Figure 2: BEM Code Results for Various Mach numbers compare to Possio

The results of the BEM code was checked against results from an Asymptotic method, and a method from Ayton [1]. The figures below show, for different Mach numbers and airfoils, the comparison of the BEM results to the aforementioned methods.

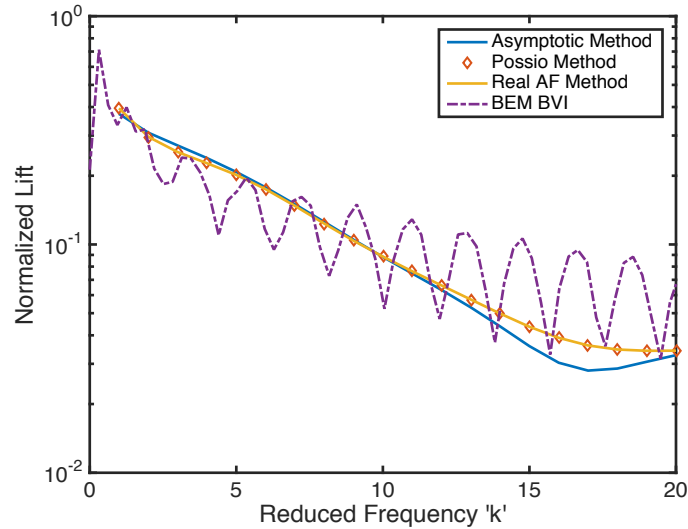


Figure 3: BEM Results compared to other simulations - NACA 0001 - $M_\infty = 0.2$

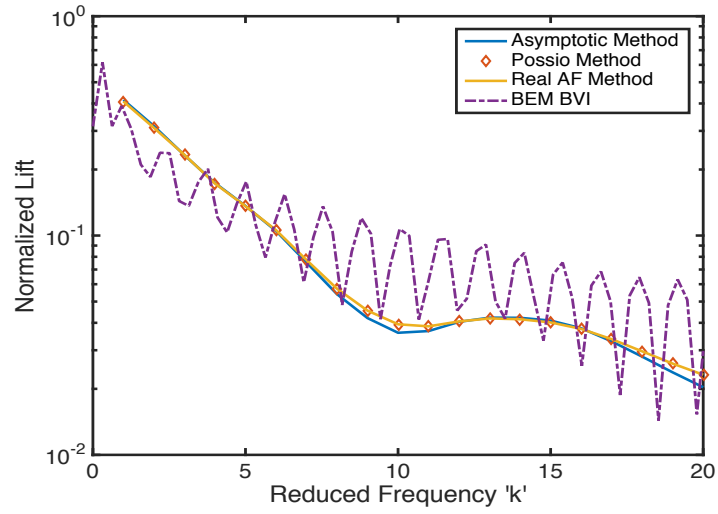


Figure 4: BEM Results compared to other simulations - NACA 0001 $M_\infty = 0.4$

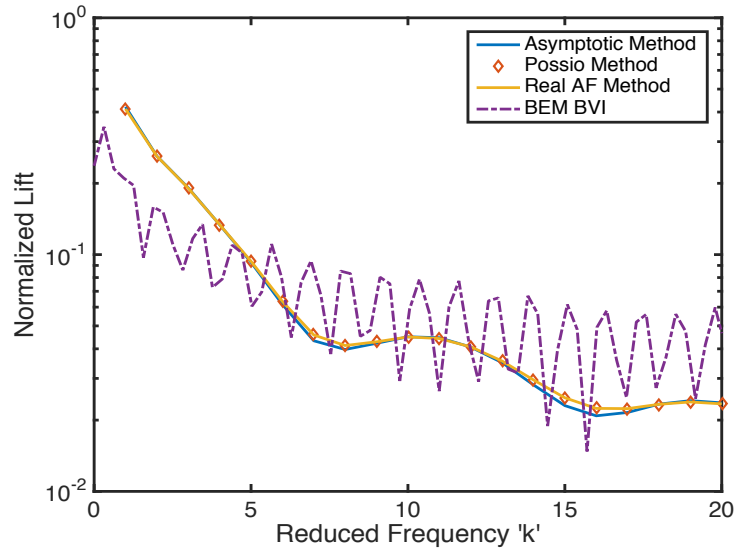


Figure 5: BEM Results compared to other simulations - NACA 0001 $M_\infty = 0.6$