MSES Domain Size Sensitivity Study

Mark Drela, September 96

Two inviscid airfoil cases are computed on a succession of grid domain sizes to determine the sensitivity of C_L, C_M, and C_D to the location of the outer grid boundaries. The two cases are summarized in Table 1. Figure 1 shows the grid near the airfoil for case A. The rather fine grid resolution is intended to remove any uncertainties from grid truncation errors. The C_p distributions for the two cases are shown in Figure 2.

Table 1: Computed airfoil cases

Airfoil	t/c	M_∞	α	C_L	C_M	C_D
A	18.2%	0.005	5.0°	1.346	-0.180	0.00000
B	6.0%	0.800	0.5°	0.543	-0.109	0.00551

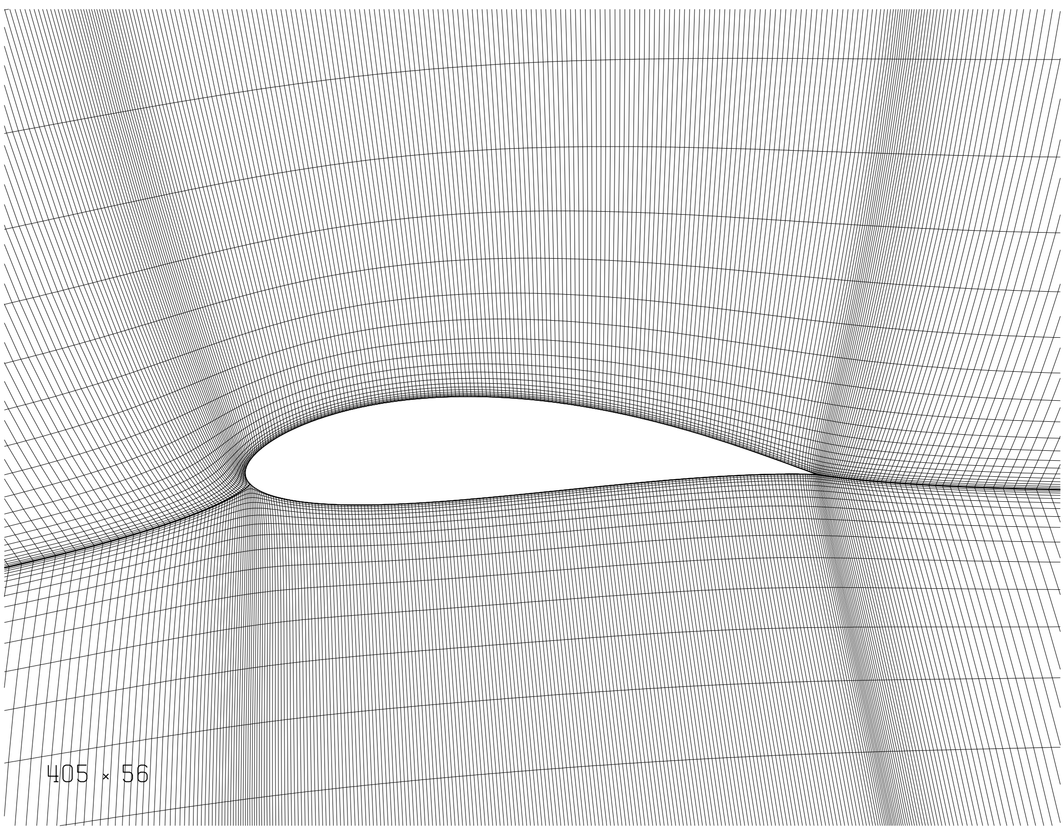
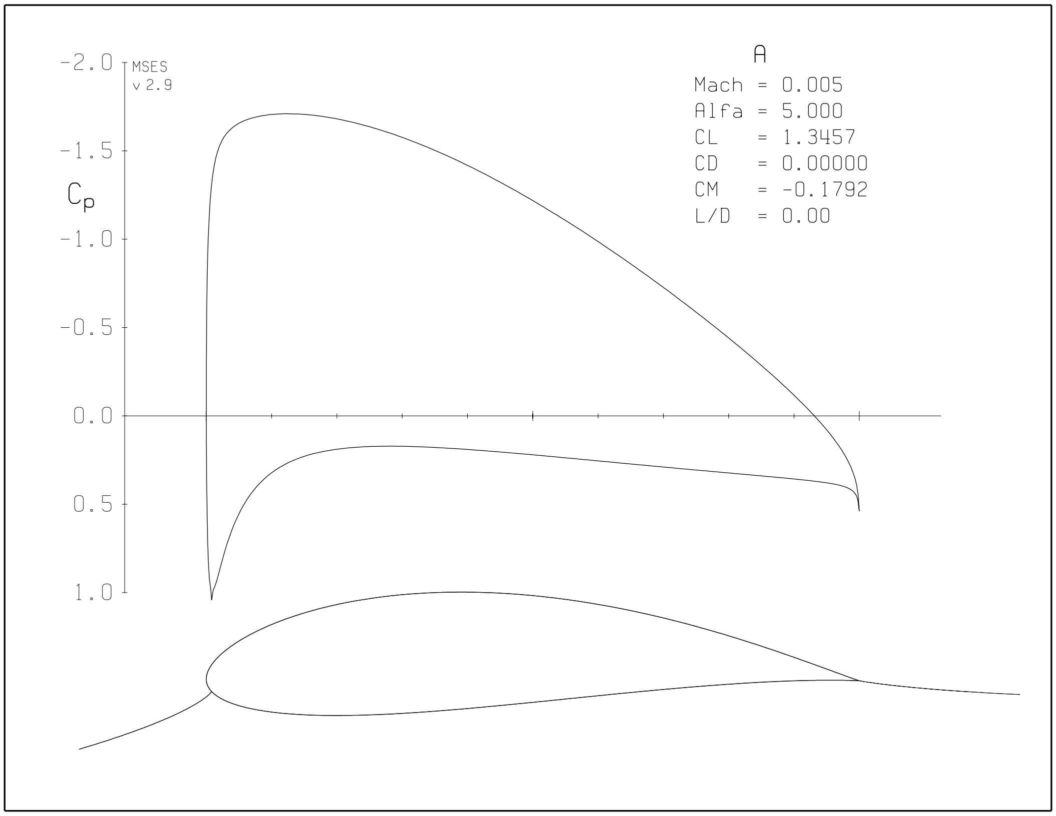


Figure 1: Typical grid near the airfoil for case A.

Eight grid domain sizes were run for each airfoil. These are shown in Figure 3. The supersonic bubble of airfoil B is also shown. The largest domain used a 405×56 grid. Smaller grid dimensions were used for the smaller domains, so that the resolution near the airfoil remained very nearly the same. The surface grid spacing remained exactly the same for all domain sizes, with 180 grid points placed on each airfoil side.

Table 2 shows the computed force coefficients for airfoil A for each domain size, normalized to the reference baseline value of the largest domain. The r value is roughly the distance from the



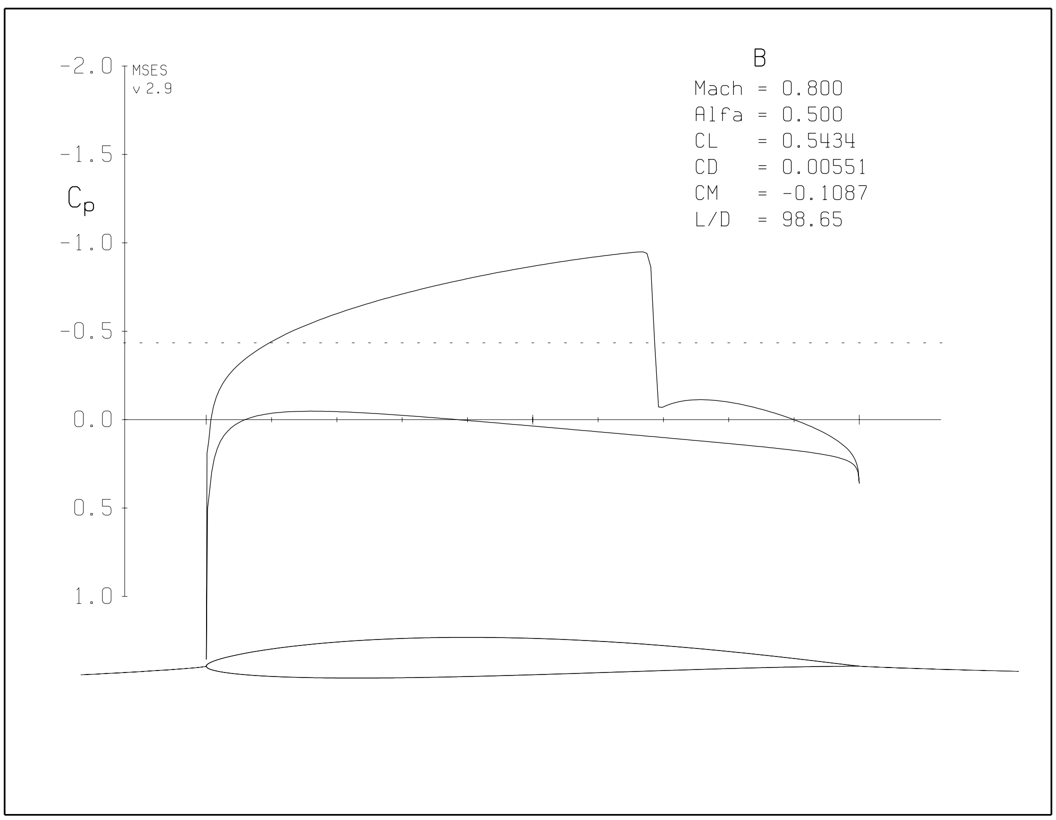


Figure 2: Surface C_p distributions for test airfoil cases.

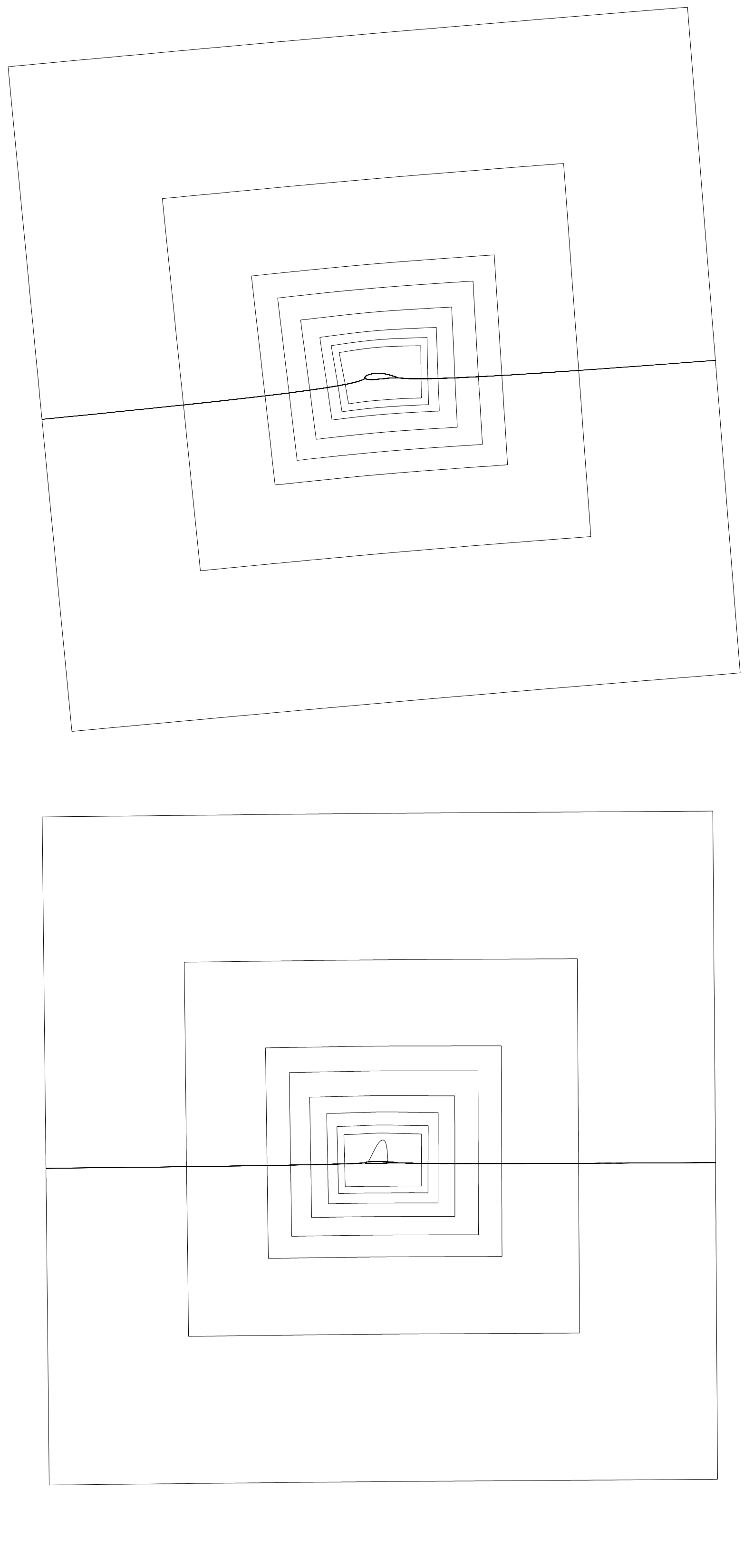


Figure 3: Grid domains used for test airfoil cases.

airfoil to the outer boundaries, and is defined as $r = \sqrt{A}/2$, where A is the area of the nearly-square domain. Table 3 shows the same results for airfoil B.

Table 2: Computed force coefficients for range of domain sizes for airfoil A.

	Vortex+Doublet farfield			**Vortex farfield**		
r/c	$C_L/C_{L\text{ref}}$	$C_M/C_{M\text{ref}}$	$C_D/C_{D\text{ref}}$	$C_L/C_{L\text{ref}}$	$C_M/C_{M\text{ref}}$	$C_D/C_{D\text{ref}}$
10.0	1.0000000	1.0000000	—	1.0000000	1.0000000	—
5.8	1.0001485	1.0001116	—	1.0004606	0.9994978	—
3.3	1.0005796	1.0004462	—	1.0020509	0.9982703	—
2.6	1.0011816	1.0007808	—	1.0037749	0.9973777	—
2.0	1.0022146	1.0012270	—	1.0075424	0.9957038	—
1.5	1.0070971	1.0035697	—	1.0192610	0.9955922	—
1.2	1.0134808	1.0062469	—	1.0192610	0.9955922	—
1.0	1.0313907	1.0137765	—	1.0569880	1.0029012	—

Table 3: Computed force coefficients for range of domain sizes for airfoil B.

	Vortex+Doublet farfield			**Vortex farfield**		
r/c	$C_L/C_{L\text{ref}}$	$C_M/C_{M\text{ref}}$	$C_D/C_{D\text{ref}}$	$C_L/C_{L\text{ref}}$	$C_M/C_{M\text{ref}}$	$C_D/C_{D\text{ref}}$
10.0	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000
5.7	1.0002208	0.9999080	1.0012709	1.0029782	0.9963113	0.9930645
3.3	1.0006993	0.9984359	1.0003631	1.0130529	0.9857986	0.9739004
2.6	1.0013250	0.9959518	1.0000201	1.0228701	0.9768536	0.9574740
2.0	1.0006073	0.9868433	0.9867465	1.0400229	0.9551826	0.9151305
1.5	1.0019139	0.9698225	0.9691358	1.0657058	0.9216157	0.8446797
1.2	1.0085393	0.9398289	0.9477124	1.1032650	0.8671155	0.7375433
1.0	1.0322800	0.9083632	0.9980029	1.1527742	0.8127075	0.6563241

These results are plotted in Figures 4 and 5. They clearly show the effectiveness of the higher-order vortex+doublet farfield representation in reducing the required grid domain size, especially for the transonic case B. The irregular behavior near $r/c = 1.0$ is not unexpected, since the "farfield" concept becomes rather suspect here.

With the vortex+doublet farfield (IFFBC=2 in **MSES**), a domain size of $r/c = 2.0$ appears to be adequate for the low-Mach case A, and $r/c = 3.0$ appears suitable for the case B. The increase in required domain size for the compressible case corresponds fairly well to the Prandtl-Glauert scaling factor, which is $1/\sqrt{1 - M_\infty^2} = 1.67$ for case B.

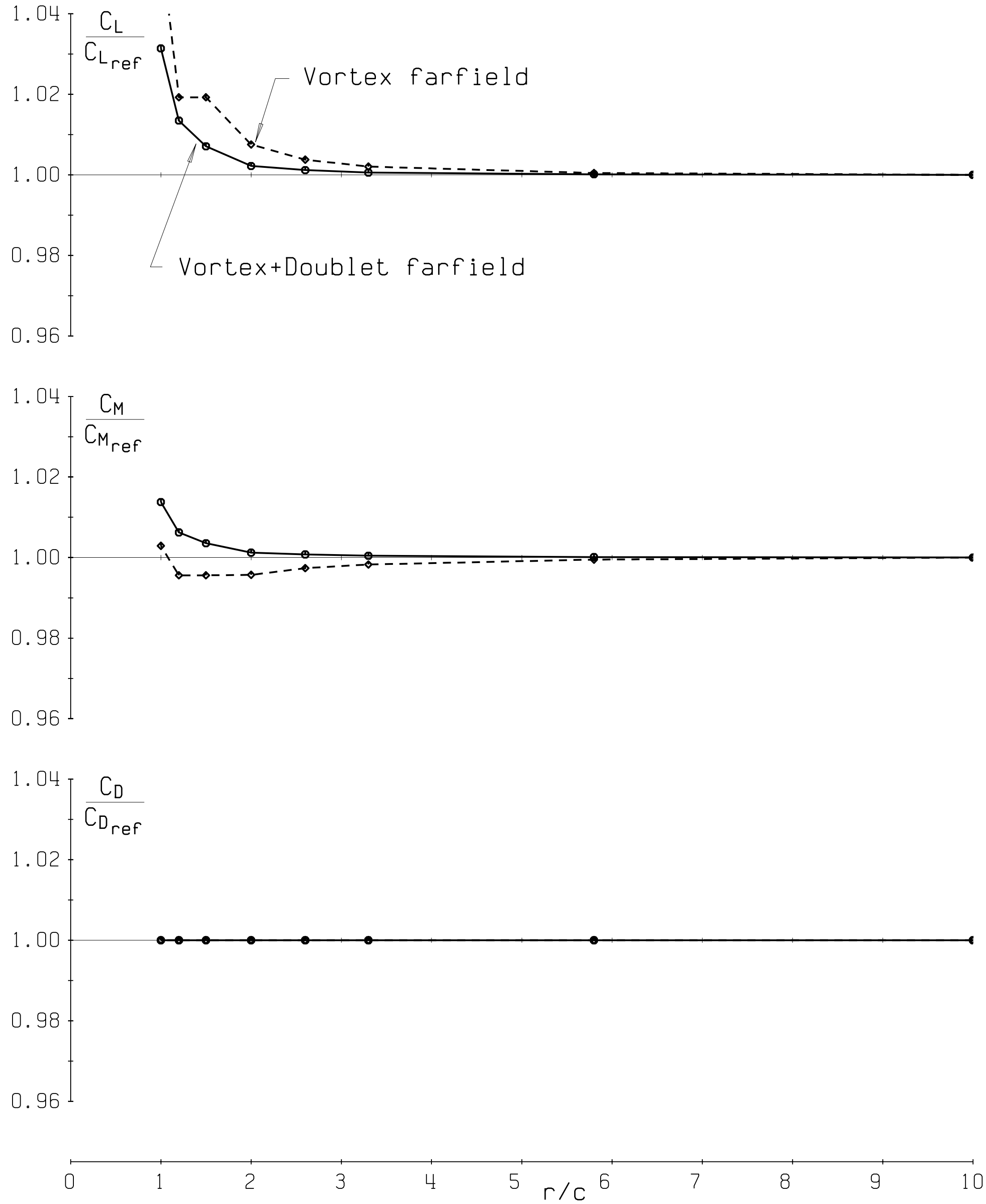


Figure 4: Computed force coefficients versus domain size for airfoil A.

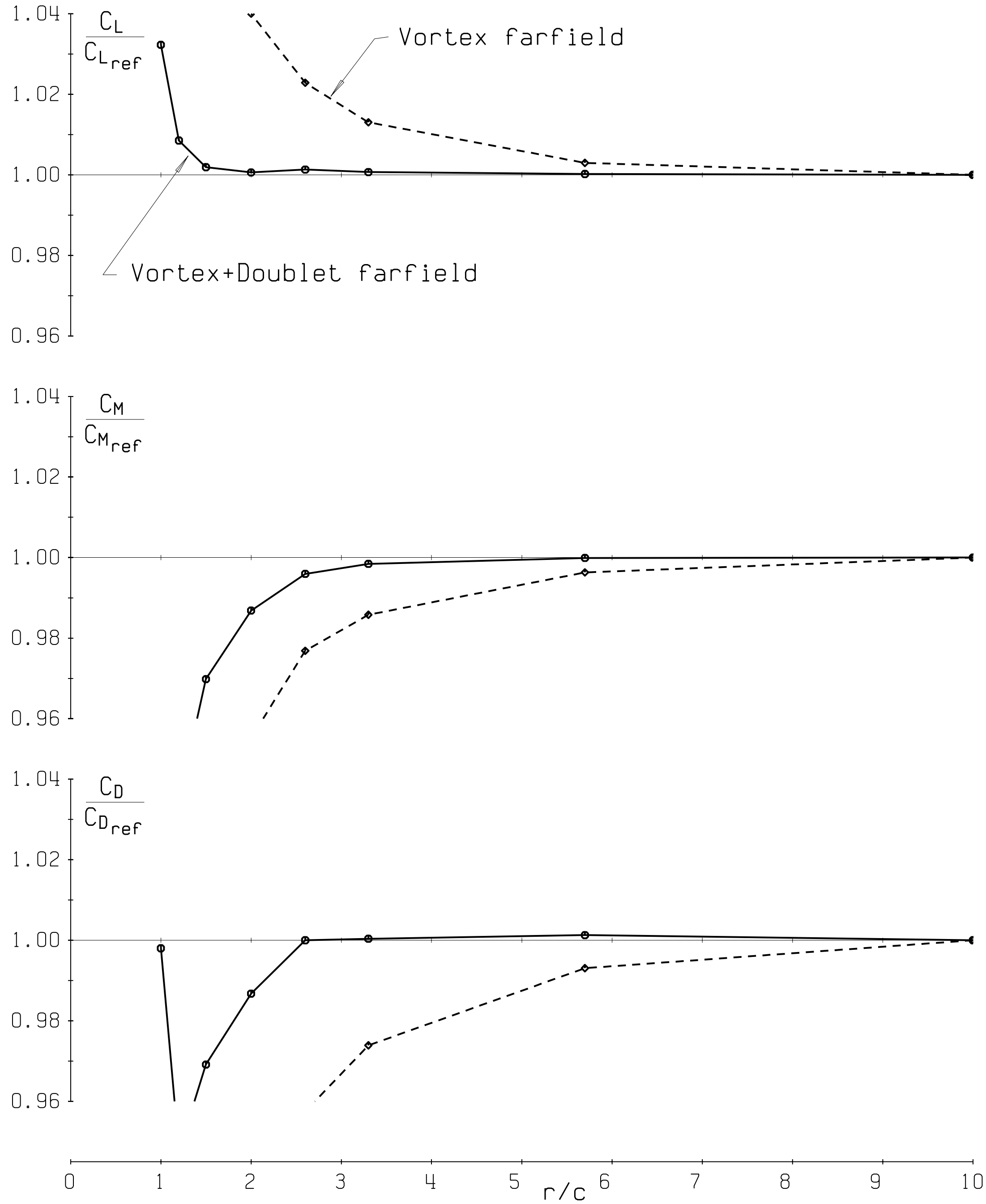


Figure 5: Computed force coefficients versus domain size for airfoil B.