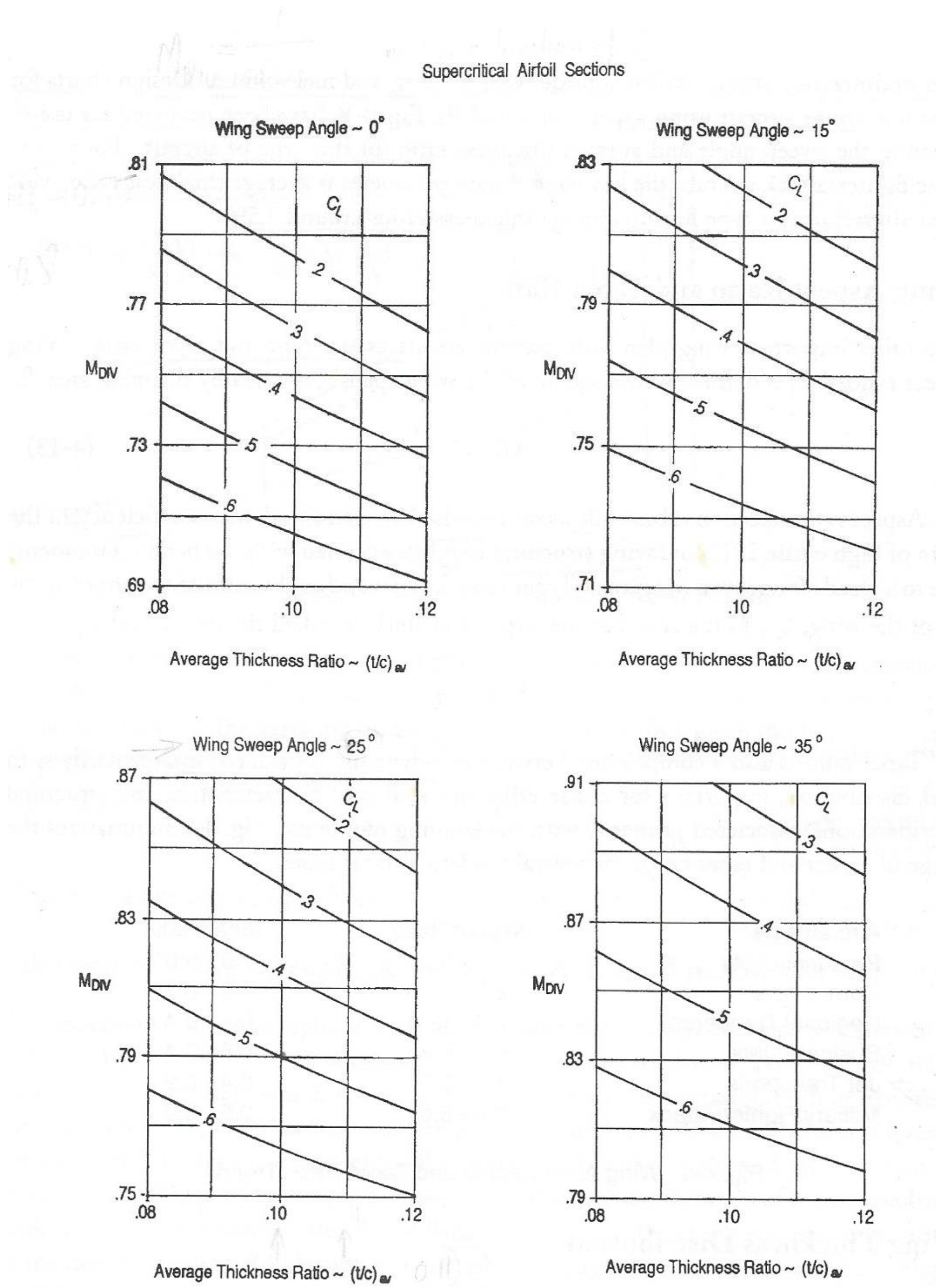
12.1 Introduction

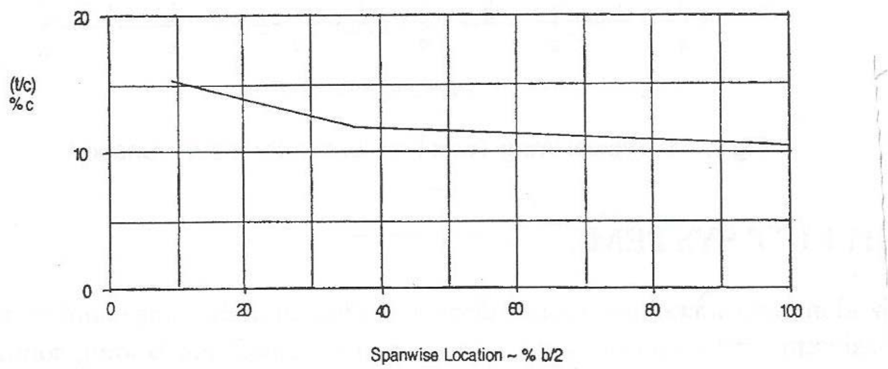
Some guidance is required for the selection of sweep and t/c for a high subsonic speed commercial transport. The optimum values are the result of detailed parametric analysis, requiring knowledge of wing weight and aerodynamic drag at different cruise lift coefficients. At this early stage in the design it is not yet possible to do the necessary analysis, so some values must be selected.



Source: Schaufele

Fig. 12.1.1 Wing Design Charts for Transonic Cruise Aircraft

Nearly all large transport aircraft use supercritical airfoils. Fig. 12.1.1, from Schaufele (Ref. 12.1.1), shows the relationships between drag divergence Mach number, shown as M_{DIV} in this figure, sweep, average t/c, and C_L. As Raymer states, there is no consensus as to the definition of drag divergence Mach number, and this chart appears to apply to a low value, for which M_{DIV} occurs at a drag rise of only 16 counts. In addition, the state of the art in supercritical wing design has advanced considerably since this chart was produced, so that a value of Mach 0.04 can be added to the value of M_{DIV} to obtain a value of M_{DD} (Boeing definition), which can be taken as the cruise Mach number. Typical average t/c is in the range 10 - 12%, and cruise Mach number about 0.82. Assuming the aircraft cruises at the drag divergence Mach number at a typical cruise C_L = 0.5, then wing sweep can be determined.

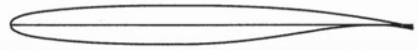


Source: Schaufele

Fig. 12.1.2 Typical Wing Thickness Distribution for a Jet Transport

For analysis of aerodynamic characteristics, detailed airfoil shape must also be known. In reality, both t/c and airfoil shape are a function of spanwise location, as shown in Fig. 12.1.2. For the purpose of initial analysis, a single airfoil shape must be assumed. For an airplane designed to cruise in the high subsonic region, a supercritical airfoil is appropriate. From a suitable source, such as Ref. 12.1.2, detailed geometric data are available for an airfoil that is close to the design C_L and t/c. An example is shown in Fig. 12.1.3. Designers of large commercial airplanes use proprietary airfoil sections, tailored to achieve desired isobars on the upper and lower surface planforms, as described in Raymer section 8.2.2.

Table XII. Coordinates of 10-Percent-Thick Supercritical Airfoil SC(2)-0610
Designed for 0.6 Lift Coefficient



x/c	$(y/c)_u$	$(y/c)_l$
0.000	0.0000	0.0000
.002	.0076	-.0076
.005	.0116	-.0116
.010	.0155	-.0155
.020	.0206	-.0206
.030	.0241	-.0241
.040	.0268	-.0268
.050	.0290	-.0290
.060	.0309	-.0309
.070	.0326	-.0326
.080	.0341	-.0341
.090	.0355	-.0355
.100	.0367	-.0367
.110	.0378	-.0379
.120	.0389	-.0390
.130	.0399	-.0400
.140	.0408	-.0409
.150	.0417	-.0418
.160	.0425	-.0426
.170	.0432	-.0433
.180	.0439	-.0440
.190	.0445	-.0446
.200	.0451	-.0452
.210	.0456	-.0458
.220	.0461	-.0463
.230	.0466	-.0468
.240	.0470	-.0472
.250	.0474	-.0476
.260	.0478	-.0480
.270	.0481	-.0483
.280	.0484	-.0486
.290	.0487	-.0489
.300	.0489	-.0491
.310	.0491	-.0493
.320	.0493	-.0495
.330	.0495	-.0496
.340	.0496	-.0497
.350	.0497	-.0498
.360	.0498	-.0498
.370	.0499	-.0498
.380	.0500	-.0498
.390	.0500	-.0497
.400	.0500	-.0496
.410	.0500	-.0495
.420	.0500	-.0493
.430	.0499	-.0491
.440	.0498	-.0489
.450	.0497	-.0486
.460	.0496	-.0483
.470	.0494	-.0479
.480	.0492	-.0475
.490	.0490	-.0470

x/c	$(y/c)_u$	$(y/c)_l$
.500	.0488	-.0465
.510	.0486	-.0459
.520	.0483	-.0453
.530	.0480	-.0446
.540	.0477	-.0439
.550	.0474	-.0431
.560	.0470	-.0422
.570	.0466	-.0412
.580	.0462	-.0401
.590	.0458	-.0390
.600	.0453	-.0378
.610	.0448	-.0366
.620	.0443	-.0353
.630	.0438	-.0340
.640	.0432	-.0327
.650	.0426	-.0313
.660	.0419	-.0299
.670	.0412	-.0284
.680	.0405	-.0269
.690	.0397	-.0254
.700	.0389	-.0238
.710	.0381	-.0222
.720	.0372	-.0206
.730	.0363	-.0190
.740	.0353	-.0174
.750	.0343	-.0158
.760	.0332	-.0142
.770	.0321	-.0126
.780	.0309	-.0111
.790	.0297	-.0096
.800	.0285	-.0081
.810	.0272	-.0068
.820	.0259	-.0056
.830	.0245	-.0045
.840	.0231	-.0035
.850	.0216	-.0026
.860	.0201	-.0018
.870	.0185	-.0012
.880	.0169	-.0007
.890	.0153	-.0004
.900	.0136	-.0003
.910	.0119	-.0004
.920	.0101	-.0007
.930	.0083	-.0012
.940	.0064	-.0020
.950	.0045	-.0030
.960	.0025	-.0042
.970	.0004	-.0056
.980	-.0018	-.0073
.990	-.0042	-.0093
1.000	-.0067	-.0116

27

Fig. 12.1.3 Example of Supercritical Airfoil Coordinates

For an aircraft designed for supersonic cruise, a much thinner airfoil is required. The F-22 has a modified 6-series NACA airfoil:

Location	Designation	Incidence
Root	64A?05.92	$+5.0^0$
Tip	64A?04.29	-3.1^0

For the root, the designation defines the following:

- 6 Series airfoil
- 4 (Fraction of chord)X10 where negative pressure is maximum
- A Modification to section from 80% chord to trailing edge, which removes concavity and substitutes a straight line
- ? Camber (unknown)
- 05.92 Section maximum t/c (%)

The airfoil section with zero camber is shown in Fig. 12.1.4. The F-22 wing undoubtedly has some camber, increasing towards the tip, but the values are unknown.

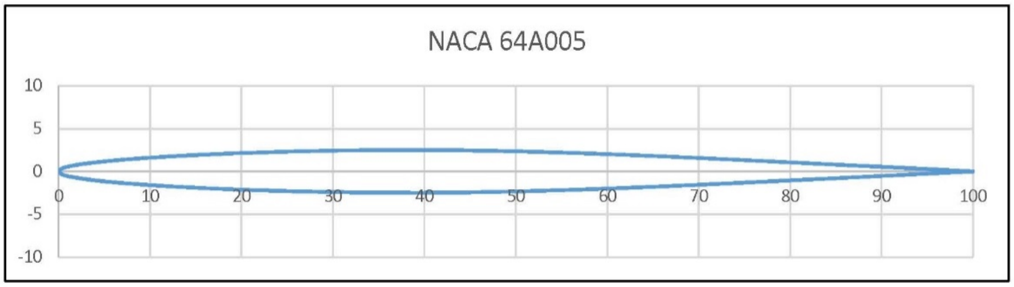


Fig. 12.1.4 NACA 64A005 Airfoil Section

References

12.1.1 Schaufele, R.D., “The Elements of Aircraft Preliminary Design”, Aries Publications, 2007.

12.1.2 Harris, C.D., “NASA Supercritical Airfoils”, NASA TP-2969, March 1990.