UNIT 5 - AERODYNAMIC FORCES

TYPES OF AEROFOILS

Aerofoils are designed to adapt to the cruising speed range, powerplant type and operational need of the aircraft. These, and many other factors affect aerofoil design. For example, modern (CS-25)[1] jet-transport aircraft wings are predominantly a supercritical profile, whereas supersonic aircraft have a longer and slimmer profile to account for the transonic drag rise and supersonic flow. Agricultural/Utility and STOL (Short Takeoff and Landing) aircraft require high lift at lower speeds and therefore a shorter and thicker profile.

Below is a chart showing the most common aerofoil types:

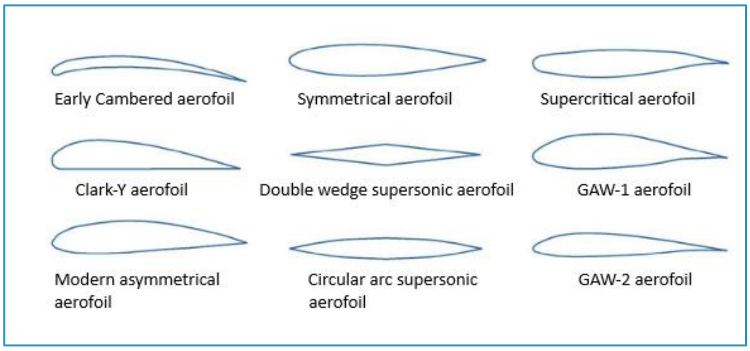

Figure 1 - Aerofoil types

The list that follows is an example of the wing profile types used on different aircraft along with their relative cruising speeds.

Aircraft Category	Aircraft Model	Average Cruising Speed	Wing Design	Wing Type
Early propeller	Curtiss F6C	120 Knots (222 km/h)	Clark-Y	Clark-Y
Propeller (Single Engine)	Cessna 172	122 Knots (226 km/h)	Modern Asymmetrical	NACA 2412
Utility (Crop Dusting)	Grumman Ag Cat	100 Knots (180 km/h)	Asymmetrical	NACA 4412
Aerobatic	Pitts Special	152 Knots (282 km/h)	Symmetrical	Symmetrical
Small Jet	Aermacchi MB-339	485 Knots (898 km/h)	Modern Asymmetrical	NACA 64A114
Turboprop	ATR-72	280 Knots (510 km/h)	Modern Asymmetrical	NACA 43018 *modified*
Jet Transport	Airbus A320	M 0.78/447 Knots (829 km/h)	Supercritical	Supercritical
Supersonic Aircraft	Concorde	Mach 2.02 (2154 km/h)	Supersonic	Supersonic
High Speed Aircraft	SR-71 Blackbird	Mach 3.2 (3951 km/h)	Supersonic	Supersonic

Table 1 - Aircraft types and associated wing profiles.

THE SUPERCRITICAL WING

Modern jetliners, business jet and military aircraft which have a cruising speed close to the speed of sound use a Supercritical wing design (SCW). These types of profiles delay the formation of supersonic shock waves on the upper surface, allowing the aircraft to fly at higher speeds.

[1] CS-25: Certification Specification 25 refers to the Certification requirements for civil (commercial) aircraft as determined by EASA. These certification requirements include aircraft performance, controllability, structure, design, construction as well as powerplant and operating limitations. EASA CS-25 is based on ICAO Annex 8 requirements.

These wings have a flat upper surface and rounded at the lower surface, which minimise the shockwave formations when the air around the wing reaches the speed of sound (Mach 1) and have a downward deflection towards the trailing edge.

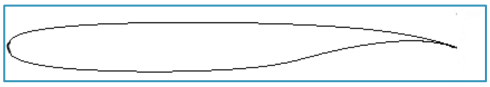

Figure 2 - Supercritical wing

If an aircraft with a conventional wing approaches speed of sound at Mach 1, the speed of the air above the wing moves faster, becoming supersonic. This gives rise to transonic (wave) drag, which causes supersonic shock waves to form – even if the aircraft speed itself has not yet reached Mach 1. This is called the critical Mach number (M_{CRIT}) and is defined as the speed at which the first supersonic shockwave formations appear.

The formation of wave drag also causes boundary layer separation, creating a turbulent layer which can cause speed decay, structural vibration, increased fuel consumption and in worst cases can have a detrimental effect on controllability.