Carbon brakes for Concorde

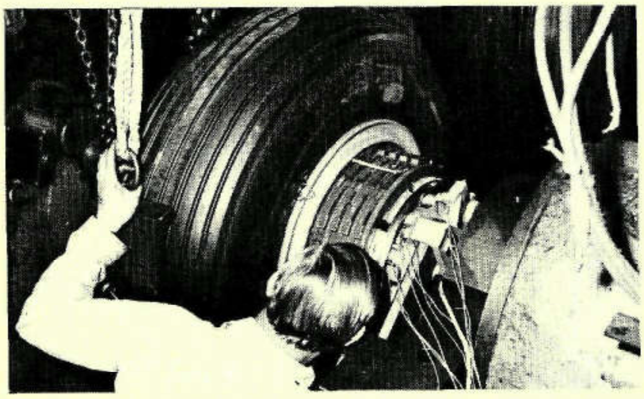
SUCCESSFUL DEMONSTRATION by Dunlop of the first 22in fully representative Concorde brake with carbon stators and rotors (see *Flight* last week, page 994) marks a turning point in the development of such units. Previously, a major disadvantage had been that water ingestion seriously impaired the frictional properties of carbon brakes, but Dunlop (which uses a vapour-deposition technique in the fabrication of its material to gain high density) has overcome the problem.

The first three production Concordes will have 22in steel-rotor brakes of Dunlop manufacture. Aérospatiale, which has design authority for the component, wants to use lightweight carbon for subsequent units, and the competition to supply them is between Goodyear and Dunlop. The American company holds development contracts for the F-15 fighter and B-1A strategic bomber.

Beryllium brakes, which offer a lower-development-risk lightweight unit, are out of favour because of possible toxicity problems, but Dunlop is in a position (with ten years of Concorde experience behind it) to supply structural or segmented production Concorde brakes in the material if endurance testing of 20in carbon brakes of identical basic design to those of Concorde on a BOAC Super VC10 show any unforeseen weakness. A major problem could be of brittleness.

Carbon can probably return 3,000 landings (predicted from a 15in carbon test brake) as opposed to 500-600 for steel. The material can save 1,200lb (or five per cent of the estimated transatlantic payload of Concorde). Cost at present is very high—in prototype form each of the five rotors and six stators costs $1,000, but this could drop

The ability of carbon to operate at very high temperatures allows the heat sink to be lighter on a Concorde brake



substantially once they were on the production line, according to Ian Stimson, advanced projects manager. If the value of weight saved is reckoned at £15/lb/year per aircraft, then carbon should be viable. Beryllium could provide comparable weight savings but, because it is a rare metal, it promised little prospect of ever becoming cheap.

Each of the eight brakes on a production Concorde has heat-sink weights of approximately 250lb in steel with sintered iron pads, or 150lb in beryllium with sintered iron pads, or 100lb in carbon. But both the beryllium and carbon brakes occupy a larger volume than a steel one and this is particularly limiting on Concorde, where the ratio of box volume available to rejected take-off energy is low. A deep bowl-shaped wheel has been adopted to overcome the problem.

The carbon/carbon composite is made from filamentary material contained in a carbon matrix. It may be carbon fibre, of the type developed at RAE Farnborough and used in carbon fibre/resin composites, but for this application a cheaper type of filamentary material is usually considered both adequate and desirable. It is formed by charring wool, rayon, nylon, or any organic material, which are in the form of a tow, felt, or woven cloth. The filamentary material is then infiltrated by resin, pitch or an organic gas. In the first two cases the resin or pitch are subsequently charred, leaving the carbon behind and driving off all the other radicals. In the case of the organic gas this is passed into the heated mass of filamentary material. It decomposes, leaving behind a deposit of carbon. These processes are repeated several times until the composite achieves the highest economic density. There are therefore an enormous number of alternative carbon/carbon composites.

The materials are anisotropic to varying degrees, and the uneven heat-flow and thermal-expansion characteristics considerably complicate the brake designers' problems and give scope for experiment in laying up the composite layers. The composite material is relatively weak in tension and shear and has a low impact strength.

Materials used in brakes for the heat sink have hitherto been primarily copper, iron and steel. These have been used extensively because of their price and availability. Developments over the past seven years have used beryllium (in its pure metallic state) and carbon. Steel and beryllium brake discs have separate, replaceable, ceramic or sintered iron friction pads. The carbon disc uses its own surface as the friction member.

The material selected for development by Dunlop is an American product, the basic development of which was done to meet US missile, rocket and space requirements. Ironically, some of the initial work was done years ago at RAE Farnborough. It is intended that these developed carbon composite materials will be made by Dunlop in due course. The material has a high density (compared with other carbon/carbon composites), good strength properties and good friction characteristics even when the brake has water sprayed on to it before and during the brake stop.

One of the benefits of a high density of the material is its increased resistance to oxidation, which takes place at temperatures in excess of about 500°C. The most dense of the carbon materials likely to be used for this brake application oxidises at a very low rate up to and over 800°C. The aluminium alloy wheel has a new system of drive dogs which reduce the heat transfer to the wheel and tyre. The wheel has already undergone fatigue and strength development tests.

The performance of the brake is very different from existing aircraft brakes. Static torque (for engine holding cases) on a steel brake is normally achieved at approximately half pressure. Normal measured-landing performance is often achieved at 2/3 brake pressure and the full pressure is required for the rejected take-off. With this carbon brake the design case for piston size and for system pressure is the static torque. The RTO is then achieved at perhaps 3/4 pressure and the normal at 2/3 pressure.

The slight fall-off in drag with this carbon brake when it is wet is sufficiently small to be readily acceptable—this phenomenon does not arise with a ceramic or sintered iron friction material. On some carbon composite materials the first brake stop after an overnight rest produces a rather poor frictional "mu", according to Dunlop. This has been called the "morning sickness effect," and is due to resistance absorption by the carbon material. The Dunlop material does not suffer from this to any noticeable extent, says the company.

Research and development are proceeding with a two-fold objective: to improve the existing materials; and to reduce the cost of those materials—the present development price being about £65/lb.