Pupil worksheet

Jet conditions

Conditions are hostile inside a jet engine. Temperatures reach 2,100 ºC – that's hotter than lava from a just-erupted volcano. Pressures reach 5 to 6 million pascal (MPa.) You would have to dive to the bottom of a deep lake to feel the same pressure, or get a horse to stand on your thumb.

And then there is moving air. As air travels through the engine it speeds up. Its speed is about 10 times faster than the speed of a racing car.

Which materials can cope with these conditions? Today you will find out.

Jet engine

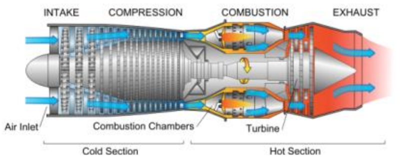

Illustration: Jeff Dahl, Wikimedia Commons

A turbofan jet engine has four main sections.

- **Fan** – takes in air
- **Compressor** – squashes the air
- **Combustor** – burns fuel using air from the compressor
- **Turbine** – extracts energy from hot gases to drive the fan and compressor

Each section experiences particular conditions of temperature and pressure. So each section must be made from a material that can withstand these conditions.

- ➢ Study the information about engine conditions.
- ➢ Use the data table to work out the best material for each engine section.
- ➢ Present your findings on a poster. If you wish, use headings from the help sheet and images from the image bank.

Key Stage 3 - Jet
Perfect properties

Engine conditions in a typical turbofan engine

Fan blades

Fan blades operate at temperatures between −50 ºC and +50 ºC. They are the most exposed part of the engine. They must be resistant to collisions with birds or other objects.

Bigger fans work better than small ones and are less noisy. A low density material keeps their mass to a minimum.

Compressor

Compressor blades turn 10,000 times every minute. They experience huge – and constantly changing – forces, so must be strong and have a stiffness greater than 120 billion pascal (GPa.) Temperatures in the compressor are between 150 ºC and 700 ºC. Compressor blade material must not corrode at high temperatures. If it did, the blades would get weaker and weaker over time.

Thermal barrier coating inside the combustor

Temperatures in the combustor reach 2,100 ºC. Cooler air cools its walls to around 1,400 ºC. The main priority for the thermal barrier coating material is that it has a low thermal conductivity.

Turbine blades

Turbine blades rotate 10,000 times every minute. They can be hotter than 1,000 ºC and are cooled to lower temperatures by air flowing through holes in the blades, and over their surface. Turbine blades must be resistant to creep (being gradually deformed by forces at high temperature). For this reason each blade casting must consist of a single crystal of metal.

Key Stage 3 - Jet

Perfect properties

Data table

Material	General information	Melting temperature (°C)	Thermal conductivity (W/mK)	Density (g/cm^3)	Tensile strength (MPa)	Stiffness (GPa)	Does it catch fire easily?	Does it corrode when hot?	Can it be cast into a single crystal blade?
Nickel-based alloy	An mixture of metals, mainly nickel.	1260 – 1340	11	8.2	1440	~200	no	no	no
Nickel superalloy	A mixture of metals, mainly nickel. A superalloy is an alloy that is strong. It is not damaged at high temperatures.	1350	~29	8.4	1000	110	no	no	yes
Titanium 6/4 alloy	A mixture of metals, mainly titanium, with: • 6% aluminium • 4% vanadium	1600 – 1660	4.0	4.5	1000	115	yes, at 600 °C if it rubs against something	no	no
Yttria stabilised zirconia	A ceramic. Ceramics are materials prepared by the action of heat followed by cooling. This ceramic includes zirconia (ZrO_2) and yttria (Y_2O_3).	2700 – 2850	0.7	5.1	25	20	no	no	not known

- Thermal conductivity is a measure of how well a material conducts heat. The bigger the value, the better it conducts.
- Tensile strength is a measure of the strength of a material when subjected to pulling forces. The bigger the value, the stronger the material.
- Stiffness is given by Young's modulus. The bigger the value, the stiffer (and less flexible) the material.
- If a material corrodes it reacts slowly with oxygen or water from the air, and is damaged over time. The rusting of iron is an example of corrosion.

Key Stage 3 - Jet

Perfect properties

Help sheet

Fan blades	
Material chosen	
Properties that make this material suitable for fan blades	

Combustor wall lining	
Material chosen	
Properties that make this material suitable for the combustor wall lining	

Compressor	
Material chosen	
Properties that make this material suitable for the compressor	

Turbine blades	
Material chosen	
Properties that make this material suitable for turbine blades	