MOLYREVIEW

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Moly takes off on Super Jumbo

Photo: AIRBUS S.A.S. 2007 by e'm company/H. Goussé

The latest-generation Jumbo plane, the A380, is jumbo in more than just size and weight. It carries more passengers farther, with greater comfort, safety, and economy, than previous jumbo jets. These features demand parts that are stronger, lighter and more reliable than ever before. Molybdenum is an essential component in the alloys that enable the A380 to accomplish these goals.

Bigger, but with lighter components: an "impossible" contradiction that the designers of this flagship of European aeronautics had to balance, resulting in intense competition between composite materials, which account for 25% of the aircraft's structure, and metallic alloys in which molybdenum plays an important role.

In the weight loss race, aluminium claims the lion's share, about 60% of the total weight of the plane. It is found in many traditional structural applications: wings, airframe, and stub wings, for example. The requirement for stronger, lighter components means that material density is less important than the strength-to-density ratio. When this is considered, aluminium alloys have fierce competition from titanium alloys for highly stressed parts, particularly for the critical parts like the engines. Titanium and nickel-based superalloys are widely used in these parts that operate at elevated temperature. Molybdenum increases the strength, the high-temperature stability and in some cases the corrosion resistance of these materials.

However, as emphasised by a metallurgical engineer of one of the major suppliers of forged parts for the aeronautics industry: "The A380 is a 'classic' plane. Compared to the rest of the Airbus range, in terms of alloys, it's just a larger version of a smaller plane!" In other words, many of the alloys used in its construction (several of them molybdenum-containing) have proven their worth, both on the existing Airbus range and, earlier, on the Concorde.

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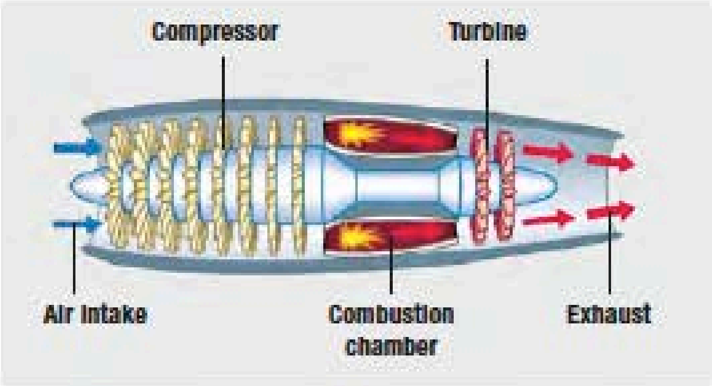
Super requirements for superalloys

The engines, which must propel the aircraft and up to 800 passengers over 15,000 kilometres (the non-stop distance from New York to Hong Kong), must operate reliably throughout a huge temperature range. The air inlet of the compressor fan experiences temperatures of -50°C at cruise altitude, while the turbine's fixed and moving parts reach 600°C, and the combustion chamber must withstand 1,000°C.

The engine's compressor blades are made from the iron-based, high-temperature austenitic alloy 286, containing 1.25% molybdenum (table), and the disks supporting them are made from a titanium alloy that contains 3% molybdenum. Molybdenum gives strength at temperature and corrosion resistance to these alloys, minimising the weight of the components.

In the turbine section of the engine, nickel-based superalloys containing 3–10% molybdenum are the materials of choice. Molybdenum improves high-temperature strength and creep resistance in these alloys. Alloy 718, an austenitic nickel-based alloy containing chrome and iron, and hardened with molybdenum (3%), niobium and titanium, offers very high strength up to 700°C with excellent weldability. It is also found in the vanes and disks of compressors. More than a third of the alloys used in modern turbine engines are nickel-based superalloys containing molybdenum.



Molybdenum is an essential component of alloys used in aircraft propulsion systems. It imparts high-temperature strength and creep resistance, making it an essential constituent of alloys for rotating parts (turbine blades, compressor vanes, and the disks that support them).

Nickel-based alloy 625, containing 9% molybdenum, with its high corrosion and heat resistance, is used for the small-diameter fuel tubing that must endure high temperatures near the hot parts of the engine. For hydraulic systems not subjected to very high temperatures (landing gear actuation, braking system, flight controls), conventional 2% molybdenum Type 316L stainless steel is widely used.

The many hot bearings supporting the compressor and turbine shafts withstand very severe conditions. They must resist fatigue at temperatures up to 300°C, so they are made from a heat-resistant Cr-Mo-V steel that contains 4.25% molybdenum, the most widely used alloy in the world for this type of engine part.

No less important, the many rivets, bolts and attachments near hot engine parts must have high strength, corrosion resistance, and high-temperature stability. Austenitic alloy 286 is used for these applications.

Molybdenum plays a critical role in the engine beyond that of an alloy addition – lubrication. Molybdenum disulfide (MoS_2) provides robust lubrication of the engine's rotating parts, forming a strongly adherent film with high lubricity that resists other lubricants and protects surfaces against corrosion. →

The inlet fan diameter of the engine is about 3 m. Four of these engines are required to propel the A380 through the sky. Airbus A380 customers have a choice between two engines with similar characteristics and whose respective market is nearly equivalent: the Trent 900 produced by Rolls-Royce and the GP7200 manufactured by Engine Alliance, a consortium uniting two American companies, General Electric and Pratt & Whitney, with the participation of the French company, Snecma. Photo: Engine Alliance.

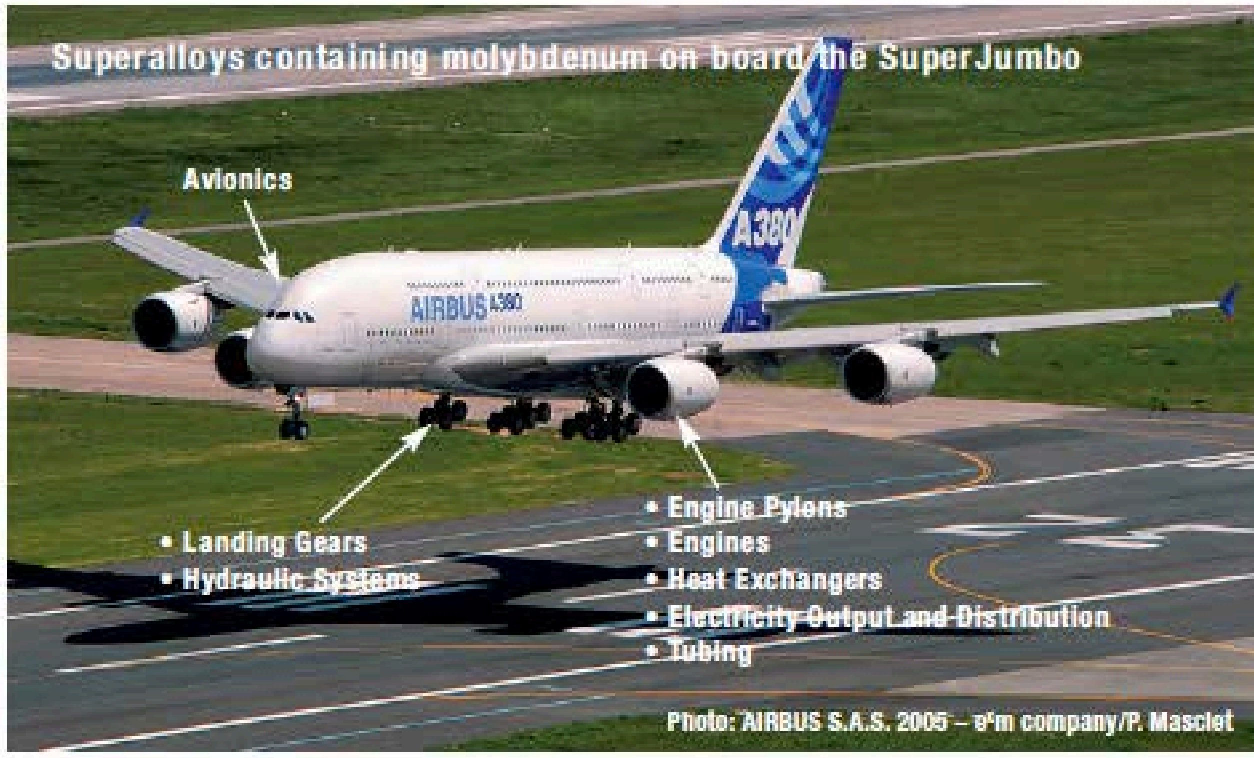
Producing electricity in flight

More than just a propulsion system, engines supply the plane with the electrical energy needed for internal operations: avionics, lighting, pressurisation, heating, control and hydraulic systems, for example. Over 600 kW of power are required to operate all these systems. To accomplish this task, a heat exchanger/power generator turbine unit is associated with each engine. Because they are exposed to hot gases from the engine, the heat exchangers use alloy 718 or corrosion-resistant alloy 625. The generator rotors and stators are made from soft magnetic iron-cobalt alloys containing 0.5% molybdenum. These alloys are more expensive than conventional iron-silicon alloys that fulfill the same function in cars and refrigerators, but at equal strength, they offer a 25% weight savings, a decisive criterion for the "giant of the skies"!

Moly for an easy landing

The enormous forged landing gear of the A380 must bear the shock loads that occur when the nearly 386-tonne aircraft lands. This is where alloy 300M, with 0.4% molybdenum takes the spotlight. The alloy's molybdenum content reduces the sensitivity of forged parts to annealing during their heat treatment, thereby preserving their strength and impact resistance. Alloy 300M has replaced aluminium in the A380 landing gear boxes, one of the largest parts ever forged (over 7 tonnes), because of its higher strength and stiffness combined with lower cost. →

When it lands, the A380 absorbs the shock of a total mass of nearly 386 tonnes travelling at 300 km/h. The landing gear (or leg), is made of alloy 300M, containing 0.4% molybdenum. Manufactured by Aubert & Duval, this is a critical forged part that responds to the extreme constraints of landing with surprising smoothness for the greater comfort of the 500 to 800 passengers. Photo: Florian Lindner.



System	Component	Material	Nominal composition[1], w-%	Mo, w-%	UNS number
Engines	Fan compressor	A 286	Fe-26Ni-15Cr-2Ti-1.25Mo-2Ti-Al	1–1.5	S66286
	Compressor disks	Ti6-3-2	Ti-6Al-3Mo-2Cr	3	NL[2]
	Turbine vanes and disks	Alloy 718	Ni-19Cr-18.5Fe-5.1Nb-3Mo-Ti-Al	2.8–3.3	N07718
	Compressor and turbine bearings	M50	Fe-4.3Mo-4Cr-1V-Si-Mn	4–4.5	T11350
	Fuel tubing	Alloy 625	Ni-21.5Cr-9Mo-2.5Fe-2.6Nb	9	N06625
	Lubricants	MoS_2	$100MoS_2$	60	NL[2]
	Fasteners (rivets, bolts)	A 286	Fe-26Ni-15Cr-2Ti-1.25Mo-2Ti-Al	1–1.5	S66286
Hydraulic systems	Landing gear, braking, flight control tubing	Type 316 SS	Fe-18Cr-12Ni-2.5Mo-Mn-Si	2–3	S31600
Power generation	Heat exchangers	Alloy 718	Ni-21.5Cr-9Mo-2.5Fe-2.6Nb	2.8–3.3	N07718
		Alloy 625	Fe-25Co-Mo	9	N06625
Avionics/electronics	Generators rotors and	25 Co	Fe-50Co-Mo	0.5	NL[2]
	stators	50 Co	Fe-80Ni-4.2Mo	0,5	NL[2]
	Shielding	A753 Alloy 4	Fe-25Co-Mo	4.2	N14080
	Displays	Mo	99.95Mo min	100	NL[2]
Landing gear	Landing gear boxes	300 M	Fe-1.8Ni-1.67Si-0.8Cr-0.8Mn-Mo-V	0.3–0.65	K44220
	Potential new alloy	X1CrNiMoAlTi 12-11-12	Fe-12Cr-11Ni-2Mo-1.5Al-Ti	2	NL[2]

1 Alloying elements with less than 1 weight per cent are listed by name only
2 Not listed

A new alloy taking flight?

Aircraft designers must balance complex and often conflicting technical and economic demands. They strive to limit aircraft weight to maximize fuel economy and reduce maintenance costs. To make matters worse, materials like alloy 300M require chromium plating for corrosion resistance, and may be rendered obsolete by environmental regulations. In this rapidly evolving area where engineering, economics, and regulation overlap, a new alloy offers great promise. Alloy MLX17, a precipitation hardening martensitic steel containing 2% Mo to provide intrinsic corrosion resistance, is a stainless steel par excellence. Surface treatments harmful to the environment are unnecessary for this alloy, making it an interesting material choice for new projects. Alloy MLX17 represents a likely alternative for aerospace projects currently in development like the Airbus A350, the Boeing 787 Dreamliner and the 747-8 (the improved version of Boeing's large airliner).

Hundreds of thousands of passengers carried by the airlines annually present other problems for designers. In seat components, strength and fatigue resistance are required, and liquid spills and cleaning solutions can cause corrosion problems. For these reasons, some airlines choose a titanium alloy containing molybdenum for the upper part of the seat slides.

Molybdenum makes it happen

Molybdenum plays an important role in the materials used to build and operate the record-setting A380, boosting the performance of metal alloys across a wide spectrum including steels, nickel-based superalloys, titanium, and specialty electronic and magnetic alloys. Wherever one looks in the aircraft molybdenum is present, increasing strength and corrosion resistance, reducing friction, generating power, and assuring the stability and safety of control systems.

The A380's avionics: a heavily shielded civil aircraft

"Fly-by-wire" control systems use soft magnetic shielding alloys against electromagnetic interferences, while molybdenum metal is an important part of the displays that keep the crew informed about the aircraft. Photo: AIRBUS S.A.S. 2007, by e*m company/H. Goussé.

Severe or even violent weather conditions such as cumulus-nimbus clouds, thunderstorms and lightning may often add to an already cluttered magnetic environment (radio communications, "fly-by-wire" control systems, etc.) in the cockpit. Shielding of all related sensitive equipment of the aircraft is achieved through specific materials with significant molybdenum content.

A modern plane is nothing without quality avionics. "Fly-by-wire" control systems combined with computers use full-electrical control circuits. They have replaced most of the mechanical and hydro-mechanical systems using cables, cranks, wires, pulleys, etc. Airbus A380 "fly-by-wire" control systems feature a state-of-the art cockpit equipped with interactive flat screens, an embedded information system and integrated modular avionics systems connected via a large-capacity Ethernet network. This requires hundreds of metres of electric cables, actuators, rectifiers and miniaturised electronic power components that have more stringent shielding requirements than their ground-based equivalents. All this equipment must be shielded from energy conversion and transmission devices to avoid electromagnetic interference with aircraft controls, which can lead to dramatic consequences… The aircraft's gyroscopes, crucial instruments for constantly maintaining the stability (or "trim") of the aircraft, must also be protected from geomagnetic fields that could interfere with their operation.

Shielding requires specific materials that offer high permeability, low loss level and low coercive force. This is where the use of soft magnetic iron-nickel alloys containing about 5% molybdenum comes into play. These alloys shield the circuit breaker relays, magnetic sensors such as read/recording heads and other electronic components. They are also used to produce magnetic cores in measuring instruments, differential circuit breakers and line transformers used in modems.

The cockpit displays, which present all the A380's information to the pilots, use pure molybdenum thin films. They are applied atom-by-atom to the glass to operate the individual pixels and protect the display circuit elements. Molybdenum contributes to increased system performance and reliability in the cockpit. Thus it helps provide the pilot, the most important part of the control system, with the information needed to make critical flight decisions.