Sustainable solutions for Aerospace high integrity components

Enhancing your performance
Aubert & Duval integrated from nose to tail

Process flow

Selected raw materials

- Remelting
- Melting
- Forging and/or rolling
  - Forging
  - Forging and/or closed-die forging
  - Heat treatment
  - Premachining
  - Non destructive testing
  - Machining to net shape

Conversion

- HPS
- NISA
- Ti

HPS
High-Performance Steels:
A range of alloyed steels with tightly controlled characteristics offering optimum value for customers.

NISA
Nickel-based Superalloys:
A range of alloyed materials with specific resistance to very high temperatures and corrosion, the majority component being nickel.

Ti
Titanium:
Pure or alloyed titanium, combining mechanical properties and corrosion-resistance with light weight.

AL
Aluminum:
Slightly alloyed aluminum, widely used in aircraft structural parts.

PM
Powder metallurgy:
HIP Net Shape parts & Metal Powders (steels, superalloys or titanium) for additive manufacturing.

Bars & sheets
Net shape parts
Powders
Founded in 1907, shortly after the first manned flight, Aubert & Duval has continuously participated in the development of the most challenging programs. Today, we partner with OEMs for the development of their newest programs: A350 XWB, A400M, A320neo, Boeing 787, 737 MAX, C 919, Superjet 100, CSeries…

Aubert & Duval, the global solution

While earlier aircraft were based on a wooden frame, both aluminum and steel have been extensively used for fuselage and wings, further complemented by composites and titanium.

In the same time, engines have also evolved, to withstand higher and higher combustion temperatures, now reaching 800°C / 1,475°F. Hence the development of Nickel-based alloys to meet these stringent requirements. In modern aircraft, Aubert & Duval offering encompasses 90% of potential metallic applications. This is achieved since we process in-house the 4 most critical materials: High-Performance Steels, Nickel, Aluminum and Titanium.

We also master the full range of melting and remelting processes: EAF, VIM, ESR, VAR and gas atomization. We use the most sophisticated open-die and closed-die forging techniques. We forge and roll bars and sheets in all kinds of alloyed steels, Nickel-alloys and Titanium-alloys.

Average split of metallic materials in civil aircraft

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>40%</td>
</tr>
<tr>
<td>Steel</td>
<td>30%</td>
</tr>
<tr>
<td>Titanium</td>
<td>20%</td>
</tr>
<tr>
<td>Others</td>
<td>10%</td>
</tr>
</tbody>
</table>

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For information on the space industry please refer to the dedicated brochure. You can download it on our website.
At Aubert & Duval, we manufacture most of the parts for engine pylons such as spars and beams.
A bird is not only made of feathers! It is built on a relatively resistant, albeit supple assembly of bones and articulations which altogether connect and animate the whole body. A similar role is played by our critical parts, providing maximum safety with minimum surcharge. So, when the ‘bird’ is 80 m / 262 ft long and weighs 600 t, Aubert & Duval is the metallurgy specialist to partner with.
Utmost confidence for repeated landings

Main landing gear

Arms
- Al forgings
- HPS forgings
- Ti forgings

Bogie beams
- HPS forgings
- Ti forgings

Brake rods
- HPS bars

Large and smaller round bars used in landing

We provide various types of semi-finished products for hydraulic and electric actuators, braking pads and related fittings. Namely for landing gear locking, retraction and steering, or braking torque systems.
Always trying to land as softly as birds, aircraft are built to withstand exceptional situations such as wind gusts where the impact pressure can be compared to a car crashing at 160 km/h - 100 mph, this without getting damaged, and still with only 2 main landing gear. The largest part now reaches 3.5 m / 118 in, twice the size of a human being. Material choice and quality are therefore of utmost importance to meet these requirements. With the understanding that, every second, a large passenger aircraft lands somewhere in the world.

Main materials

Titanium Alloys
- TA6V
- Ti662
- Ti10.2.3

Aluminium Alloys
- 7010
- 7175

High performance steels
- 300M
- E35NCD16H
- 35NCD16
- 16NiCrMo13
- AMS 6481
- AMS 5937
- AMS 5955
- PH13-8Mo
- 4330
- 15-5PH

Closed-die forging parts:
- From 50 kgs / 110 lbs to 20 t
- Up to 8 m / 314 in
Meeting the most arduous requirements

LPC/IPC disks
- Ti forgings

HPC disks
- NISA forgings
- PM HIP parts
- Ti forgings

Compressor shafts
- HPS forgings
- Ti forgings

Spinners
- Al forgings

Fan disks
- Ti forgings

Turbine shafts
- HPS forgings
- NISA forgings
No parts in the engine face as many stress challenges as rotating parts: temperatures close to 800°C / 1,475°F, corrosion from gas and humidity, resistance to shock and crack propagation, to name a few. And this for hours and hours… with minimized fuel consumption. Hence the necessity for the most advanced materials such as Nickel-based Superalloys and Titanium, and for the most demanding techniques such as open and closed-die forging.

**Cone shafts**

- The 40 KT closed-die forging press is the center piece of our fully-automated EDPL (Engine Disk Production Line).
- Lean workshop integrating all steps from the preparation of our own billets to final ultrasonic tests.

**Main materials**

### High performance steels

<table>
<thead>
<tr>
<th>A&amp;D grade</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td>GH4W</td>
<td>40CrMoV12</td>
</tr>
<tr>
<td>MARVAL 18</td>
<td>Maraging 250</td>
</tr>
<tr>
<td>ML1014</td>
<td>GE1014</td>
</tr>
<tr>
<td>ML340 New</td>
<td>X23NiCoCrMoAl13-6-3</td>
</tr>
<tr>
<td>X17U4</td>
<td>17-4PH</td>
</tr>
<tr>
<td>X13VDW</td>
<td>X12CrNiMoV12</td>
</tr>
<tr>
<td>XN26TW</td>
<td>A286</td>
</tr>
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</table>

### Superalloys

<table>
<thead>
<tr>
<th>A&amp;D grade</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PER718</td>
<td>INCO 718</td>
</tr>
<tr>
<td>PER72</td>
<td>Udiment720</td>
</tr>
<tr>
<td>PER3</td>
<td>Waspaloy</td>
</tr>
<tr>
<td>PER901</td>
<td>Gatorized Waspaloy</td>
</tr>
<tr>
<td>AD730 New</td>
<td>INCO 901</td>
</tr>
</tbody>
</table>

### Aluminum Alloys

<table>
<thead>
<tr>
<th>Al</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2618</td>
<td></td>
</tr>
<tr>
<td>7050</td>
<td></td>
</tr>
</tbody>
</table>

### Titanium Alloys

<table>
<thead>
<tr>
<th>Ti</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TA6V</td>
<td></td>
</tr>
<tr>
<td>Ti6.2.4.6</td>
<td></td>
</tr>
<tr>
<td>Ti17</td>
<td></td>
</tr>
<tr>
<td>Ti6.2.4.2</td>
<td></td>
</tr>
</tbody>
</table>

**Powder metallurgy:**

Gas-atomized alloyed steels, superalloys, or titanium powders, further hipped into semi-finished or near net-shaped products.

**Closed-die forging parts:**

- From 20 kgs / 44 lbs to 20 t
- Max diameter for disks: 1,400 mm / 55 in
- Max length for shafts: 4 m / 157 in
Safety, flexibility and speed

When incompatible becomes feasible
Helicopters must endure a very high torque effect in the main gear box, as well as many vibrations. At the same time, to avoid fatigue, the same parts must offer very high hardness characteristics. This is made possible with Aubert & Duval nitriding or carburizing proprietary grades such as GKP, FND and FDG which allow to combine flexible core and hard surface.
Over the decades, helicopters have become an irreplaceable transportation means. Not only for traditional military, offshore or business requirements, but more and more for police, anti-terrorism, border protection, health care and other emergency issues. For the next decade, it is predicted that approximately 16,000 turbine helicopters will be needed, the vast majority consisting of new rotorcraft for fast growing countries such as China.
Setting the bars at their highest

Our customers transform our bars

Rods, rod-ends and struts
These are generally fabricated out of round bars, and potentially used all across the aircraft or helicopter.

Structural fasteners and assembly components
Round bars or wire for bolts, nuts, studs, pins, clamps, hinges, all kinds of fittings, and other safety parts.

Gears and shafts
While shafts are essential parts of aircraft engines, 42- and 90-degree transmissions are key to helicopters integrity. Other gears and shafts can be found in several other devices: APU, wing flaps, landing gear, pumps, etc.

Bearings and ball screws
Ball bearings, roller bearings, flange bearings are used in numerous areas, such as engines and hydraulic or electric actuators.

Titanium bars
Through its UKAD 4,500-ton forging press, Aubert & Duval has made the first step towards the manufacturing and sales of bars made of commercially pure and alloyed titanium.

### Main Sizes

<table>
<thead>
<tr>
<th></th>
<th>mm</th>
<th>inches</th>
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<tbody>
<tr>
<td>Round Bars</td>
<td>Ø 7.5-500</td>
<td>Ø 0.30-20</td>
</tr>
<tr>
<td>Flat &amp; Square Bars</td>
<td>T ≤ 310</td>
<td>T ≤ 12</td>
</tr>
<tr>
<td>Sheets</td>
<td>0.6 ≤ T ≤ 150</td>
<td>0.2 ≤ T ≤ 6</td>
</tr>
</tbody>
</table>

### Surface Conditions
- Black
- Peeled
- Ground
- Others

### Heat Treatment Conditions
- Annealed
- Hyperquenched
- Normalized
- Heat solution treated
- Heat treated
- Aged

www.aubertduval.com
Whether used in transmission, in engines or as fittings, the millions of small parts play a role as important as that of larger parts. They are generally machined from bars which can be forged, rolled or drawn. The initial quality of the selected materials is therefore key to the overall performance and safety of the aircraft. This is why our bars – round or flat – billets and sheets are designed, manufactured and tested with the same rigorous care as larger parts.

For more information on bars, please refer to our dedicated brochures. You can download them on our website.

Certifications and specifications

In addition to general certifications (ISO 9001, ISO 14001, ISO 18001), our Lyon Service Center is certified to the most stringent industry specific standards: ISO 9100 (aero design and manufacturing), ISO 9120 (aero distribution) and AQAP 2110 (NATO). Also, our products are AMS, ABS and ASNA specified.
Optimize your buy-to-fly ratio with powder metallurgy

Net Shape parts by Hot Isostatic Pressing [HIP]

Aubert & Duval has a unique capability in the design and manufacturing of medium to large metal parts, from simple to complex design, thanks to Hot Isostatic Pressing technology. Hot Isostatic Pressing (HIP) is a process to densify powders in a HIP furnace:
- at high pressure (usually 100, up to 200 MPa)
- and high temperature (usually from 900 to 1250°C).
The gas pressure acts uniformly in all directions to provide isostatic properties and 100% densification.

HIP process steps

Net Shape container assembly & welding
Container filling with metal powder
Powder densification by Hot Isostatic Pressing
Fully dense finished part

HIP semi-products

Net Shape impeller
For space rocket

HIP Net Shape Casings
For aircraft and helicopter engines

Courtesy of Safran Aero Engines
Aubert & Duval and its sister company Erasteel, offer a unique portfolio of technologies in the field of powder metallurgy (PM).

Hot Isostatic Pressing (HIP) and additive manufacturing are innovative technologies to produce complex metal Net Shape parts in small to medium series with key benefits:

- material savings, thanks to the net shape design possibilities
- less machining and fewer welding & assembly operations
- shorter manufacturing leadtime vs conventional metallurgy

**Powders for additive manufacturing**

Aubert & Duval and Erasteel is the world leading producer of spherical gas-atomized powders for Hot Isostatic Pressing, Additive Manufacturing and MIM. Available in tailor made compositions, particle size distribution and small batches, Pearl Micro powders are recommended for various additive manufacturing technologies (SLM, EBM, 3D printing, laser metal deposition). Aubert & Duval state-of-the-art VIM gas atomization process is recommended for alloys with reactive elements and to ensure low gas content.

**Additive manufacturing process steps**

- A thin layer of powder is applied on the powderbed
- A laser beam selectively the powder layer
- The operation is repeated until the part is built
- Finished net shape part

**HIP parts and Additive Manufacturing**

<table>
<thead>
<tr>
<th>Ni-Base</th>
<th>Ni 625, Ni 718, 247LC, 738LC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Base</td>
<td>CoCr</td>
</tr>
<tr>
<td>Ti-Base</td>
<td>Ti6Al4V, Ti6Al4V ELI</td>
</tr>
<tr>
<td>Steels</td>
<td>316L, 17-4PH, ASP®, etc…</td>
</tr>
</tbody>
</table>
Meeting our customers ever more demanding requirements

We make sure we deliver the best product

Components and parts we produce at Aubert & Duval are critical and have to comply with the most stringent specifications. Therefore, our products go through advanced non-destructive tests:

- Magnetic particle inspection
- Fluorescent penetrant testing
- Red dye penetrant testing
- Eddy current testing
- Ultrasonic testing (including phased array)
- Radiographic testing

Many NDT are performed at different steps in the metallurgical process, from melting to the delivered parts. Aubert & Duval is accredited by COFREND to perform certification examination for level 1 and 2 in accordance with COSAC (EN 4179) and CCPA (EN473).
ubert & Duval contributes to the global sustainability challenge. We work exclusively on fully and easily recyclable materials. By developing enhanced materials solutions, we allow our customers to build ever more fuel-saving aircraft. In addition, our production and warehousing sites are ISO 14001 certified.

Fully integrated tier 1 supplier

In fine metallurgy, each process step strongly depends on how the upstream ones have been carried out. In the past, a single person would master the whole chain from raw material selection to end-testing, thus ensuring the customer with an optimized flow. Today, thanks to its integration scheme, Aubert & Duval can provide the same kind of benefits, with the volumes, speed and quality corresponding to most modern requirements. We are today able to manage the full chain from raw materials to machining.

Improved performance

Sustainability

All our handled materials are systematically recycled. This is particularly necessary while only a part of the weight bought will actually fly. We contribute directly to environmental protection through the development of ever more effective materials. These combine several of the following features:

- Resistance to high-temperature, allowing the highest-yield engines.
- Lower density, to lighten the aircraft weight, hence also decrease fuel consumption.
- High intrinsic mechanical resistance, in order to use less materials.
- Surface immediately resistant to corrosion, to avoid hazardous chemical coatings.
We invest in new solutions

New materials

HPS ML340
This duplex hardening grade is specifically adapted for turbine shafts operating at high temperature (450°C/840°F), and requiring 2230 MPa/323 Ksi resistance. This allows savings in weight, together with engine efficiency improvement, hence lower gas consumption.

HPS MLX®17 & MLX®19
These new precipitation hardening steels show a strength of 1700/1900 MPa (247/276 Ksi), and simultaneously keep an excellent resistance to stress-corrosion cracking. Eliminating the need for cadmium plating, it is a most environmentally friendly solution.

NISA AD730®
Designed to improve engine efficiency and save fuel, AD730 is a fully-innovative nickel-based superalloy. It withstands higher temperatures (700°C/1,350°F) while preserving strength, creep and fatigue resistance at a competitive cost.

Al Aluminum-lithium alloys
Aluminum lithium grades (such as Airware® 2050) allow weight gain up to 4%. Their static properties are equivalent or higher than 7075/7050 and fatigue and rigidity properties improved more than 10%.

Our R&D expenditure represents 4% of our added economic value
Based on its own proprietary work as well as on cooperation with customers or other partners, Aubert & Duval continuously develops new processes and new products, able to face technical and economical challenges. In investment, priority has been recently given to capacity extension, so as to be fully ready for the rapid development of the aerospace industry.

**A unique range of facilities**

**Integrated solution for titanium**
With its fully integrated solution for titanium, Aubert & Duval is a leading global supplier and manufacturer of aviation grade titanium and titanium alloy products. From melting to finished parts, Aubert & Duval produces high strength titanium alloy products in ingots, billets, closed die-forging and machined parts.

**Powder metallurgy**
Aubert & Duval, and its sister company Erasteel, are key players in innovative and promising technologies such as Hot Isostatic Pressing and Additive Manufacturing. The whole group operates atomization units, and in particular facilities:
- In Irun (Spain), on Aubert & Duval site, which operates in particular a state-of-the-art VIM gas atomizer, for additive manufacturing, MIM and R&D.
- In Söderfors (Sweden), with the new Durin large capacity gas atomization tower, in operation since 2011: dedicated to the production of high quality steels.

With these facilities and a unique know-how in metallurgy and metal powders, Eramet Alloys can help its aerospace partners to develop new solutions based on net shape technologies.

**VIM furnace for larger ingots**
Aubert & Duval has recently extended its vacuum melting capacity by investing in a VIDP (Vacuum Induction Degassing & Pouring) furnace. This cutting-edge facility allows the casting of ingots up to 20 t.

**Precision forging integrated solution in India**
SQuAD Forging Private Ltd. (JV with Aequs) is dedicated to the production of small to medium-size closed-die forging components for demanding applications (Aerospace, Space, Defense…). Strong of its forging capacity up to 10,000 t hydraulic press together with heat treatment dedicated lines, SQuAD is the preferred partner to provide vertically integrated solutions from forging to finished parts.
“Our ambition is to be, for our customers, a worldwide metallurgy reference, innovative, agile and aware of our responsibilities.”