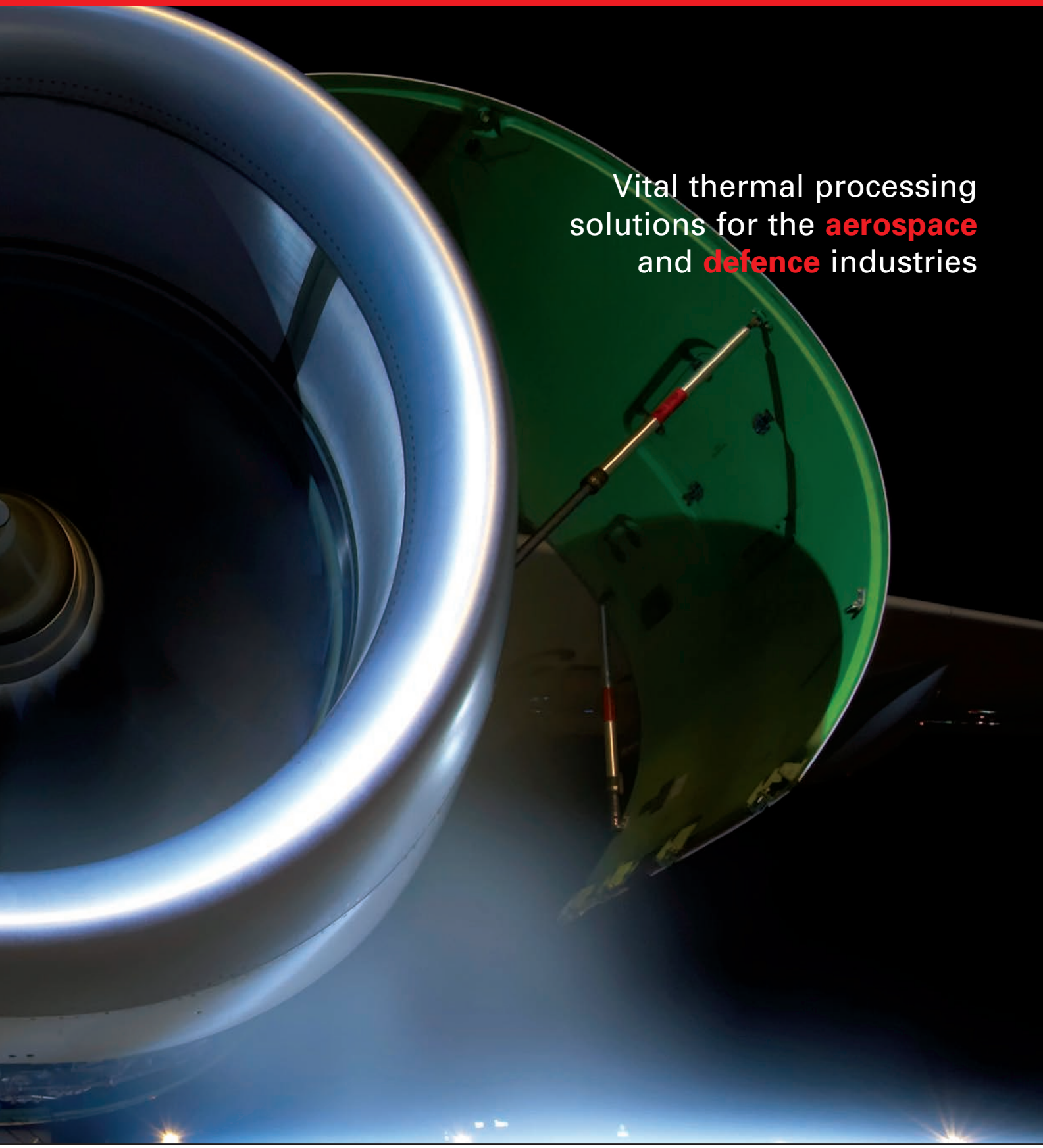


Vital thermal processing solutions for the **aerospace** and **defence** industries

Bodycote

As the world's leading supplier of thermal processing services, Bodycote operates an international network of quality accredited facilities, in support of prime aerospace manufacturers and their supply chains.

Thermal processing is a vital part of manufacturing processes and includes a variety of techniques and specialised engineering processes which improve the properties of metals and alloys and extend the life of components. Bodycote's services consist of the following core technologies: heat treatment, metal joining, hot isostatic pressing and surface technology.

Our services provide thermal processing solutions across a wide range of applications which include general aviation; commercial, business and military aircraft; and commercial and military helicopters.

SOS – Solution Or Service?

Our customers are all individuals and what they require of us covers many different levels. Whatever is needed, Bodycote is able to adapt to accommodate varying demands and respond to challenges. Our customers may require an adhoc heat treatment service at a facility local to their manufacturing plant, or a global solution incorporating various stages of their supply chain and several of our core technologies. Bodycote has the network, expertise, people and experience to manage both of these options, and everything in between.

Our operations are managed by some of the best engineers, scientists and technicians in the industry, with the experience and expertise to deliver vital support and a real understanding of customer requirements at all levels, from conventional subcontract arrangements to top level strategic partnerships.

Bodycote has a history of working together with customers to assist them with advancing their products through thermal processing related improvements, which can allow materials to operate outside of normal tolerances. Around the globe, Bodycote supports the aerospace industry's R&D process in a number of ways, from new engine design where materials performance research may be required, to verification of joining systems and the development of novel materials made possible by advanced net and near-net-shape production techniques. The development of specific processes and equipment, and application development for new components, may also be included.

Helping to save pilots' lives

As with so many safety critical aerospace parts, the reliable operation of a component can represent the difference between life and death.

For many years Bodycote has provided valuable heat treatment services to manufacturers of ejector seats for military fighter aircraft. The heat treatment of rocket tubes helps to ensure that this vital piece of equipment operates as it should at the precise moment it's needed.

To date, thousands of pilots' lives have been saved due to the efficient deployment of these ejector seats and Bodycote is proud to have played a relatively small yet important part.

Peace of mind for aerospace manufacturers for over 30 years

For over 30 years, the world's leading aerospace companies have entrusted their products to Bodycote's care. We never forget that our customers have invested time, money and resources in all the components we process, which is why quality comes as a standard part of our service.

Bodycote holds all relevant international and national aerospace quality accreditations – such as ISO 9001, AS 9100, ISO 14001 and Nadcap – as well as those of all the major aerospace companies, having 'preferred supplier' status with many major aerospace companies, including Airbus, BAE Systems, Boeing, GE, Honeywell, Messier-Dowty, Pratt & Whitney, Rolls-Royce, Smiths, and Snecma.

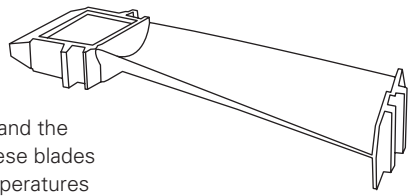
Bodycote's dedicated quality teams are committed to a program of continuous improvement, which includes the active pursuit of internationally recognised quality accreditations such as Nadcap. The quality critical aerospace industry has indicated its preference for suppliers who can specify quality standards to the strict quality requirements needed to achieve Nadcap accreditation. Bodycote has achieved Nadcap accreditation at over 40 of its locations around the world, and this number continues to grow as Nadcap audits are either scheduled, in process or under completion.

With extensive capacity and computerised systems, Bodycote is able to process components of varied shapes and sizes to exacting specifications. Customers can be confident their demands can be met, however stringent, with assured quality, cost-effectiveness and on-time completion every time.

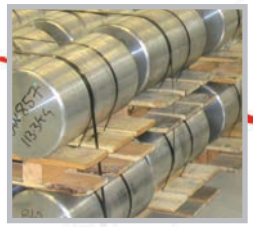
THE POWER TO DELIVER – A COMPONENT JOURNEY

AIRCRAFT TURBINE BLADES AND VANES

Aircraft turbine blades and vanes must withstand extreme temperatures in operation. These materials frequently operate at temperatures approaching their melting point – heat treatment, HIP and the use of surface technology allows these blades to operate reliably at these high temperatures for extended periods of time.



The turbine blades begin life as nickel-based superalloy ingots or billets. This superalloy gives superior strength at high working temperatures



The billets are investment cast to form the blade shape and then fettled to remove casting material

The cast blades are HIPed to remove porosity and increase their creep and fatigue resistant properties

Honeycomb for abradable seals is vacuum brazed onto the vanes' main sections

The blades are precipitation hardened to increase their strength at high temperatures

A thermally sprayed coating is applied to improve temperature resistance

Finally, the blades are machined prior to their assembly as part of an engine

End application – aircraft engine

BODYCOTE COMPONENT JOURNEYS

This is just one example of how Bodycote brings together the huge wealth of knowledge and expertise from across the Group to provide the vital engineering services you need...

For more component journeys visit **www.bodycote.com**

Denotes the parts of the component journey undertaken by Bodycote

Heat Treatments & Metal Joining

HEAT TREATMENTS

Bodycote is the market leader in the vacuum heat treatment of aerospace components such as precision cast turbine blades, with experience in every generation of material including the latest single crystal alloys. Investment in the latest technology furnaces and control systems has ensured that Bodycote is able to meet the requirement for ever tighter control of temperature uniformity and provide critical heating and cooling rates necessary for optimum blade performance. Validated furnaces are situated at key locations, together with trained personnel, to meet the industry's need for this specialised heat treatment support.

Controlled atmosphere heat treatment, case hardening or through hardening and tempering of components such as flap tracks, landing gear parts, flight control items and similar airframe and structural components, represent a significant proportion of the heat treatments carried out by Bodycote for aerospace manufacturers.

The nitriding of critical engine components, such as engine bolts and gears, is a long established Bodycote speciality, having developed computerised process controls and cycles to suit specific aerospace steels and components.

METAL JOINING

Bodycote has extensive expertise in the field of critical metal joining techniques for aerospace applications, including vacuum brazing, honeycomb brazing and electron beam welding.

Electron beam welding (EBW) is a cost-effective means of producing complex aerospace engine components with varying section thickness which require ultimate joint strength and integrity. The precision and cleanliness with which joints can be produced enables EBW to be used for items such as engine flame tubes without adversely affecting prior heat treatment or fine details such as air-cooling holes.

Honeycomb brazing is used to join critical honeycomb seals in jet engines, which are essential to the efficiency of gas flow through the engine. Bodycote's skilled workforce has many years of experience in the complex process of honeycomb brazing.

Bodycote can also diffusion bond similar and dissimilar materials via hot isostatic pressing - see page 7 for further information.

KEY AEROSPACE SERVICES

Heat Treatment:

Vacuum Heat Treatment:

- Ageing
- Annealing
- Homogenising
- Low Pressure Carburising (LPC)
- Plasma Nitriding
- Single crystal vacuum heat treatment
- Solution treatment

Controlled Atmosphere Treatment:

- Carbonitriding
- Carburising
- Case hardening
- Corr-I-Dur® (a proprietary form of Ferritic Nitrocarburising)
- Gas nitriding
- Hardening & Tempering
- Nitrocarburising

Metal Joining:

- Braze repair/Wide gap brazing
- Electron Beam Welding (EBW)
- Felt metal brazing
- Honeycomb brazing
- Vacuum brazing

Hot Isostatic Pressing

HIP SERVICES

Component failure at 30,000ft is not an option. Closed porosity and voids in cast aerospace engine components are potential initiators of failure. These defects are effectively eliminated using Hot Isostatic Pressing (HIP).

Turbine blades and vanes from the high-temperature section of jet engines are routinely HIPed to ensure freedom from residual microporosity. HIP is used to optimise the properties of the latest generations of single crystal and directionally solidified investment cast blades. For parts that are subjected to high in-service stresses, the removal of porosity is essential to maximise the properties and working life of the component.

In the aerospace component market, there is a constant demand for lighter and stronger materials. Working together with customers, Bodycote can provide cost-effective development of exotic and novel materials using HIP technology. New classes of raw materials, such as metal matrix composite (MMC) materials, were developed using the HIP process. For example, an aluminium alloy matrix with a high proportion of silicon carbide ceramic particles may be compacted to full density by the HIP process to give a very light and stiff material. Bodycote is involved in continuing research and development of the use of HIP for new types of MMCs and compound materials for future aerospace applications.

For airframe and structural components HIP is an established part of the production route. Many high integrity, precision airframe castings from alloys such as titanium, aluminium and steel are HIPed to ensure integrity, optimise mechanical properties and improve fatigue life. Another typical structural component, treated using Bodycote's Densal® process, is the aluminium steward seat which is subject to high stresses during take-off and landing.

HIP PRODUCT FABRICATION

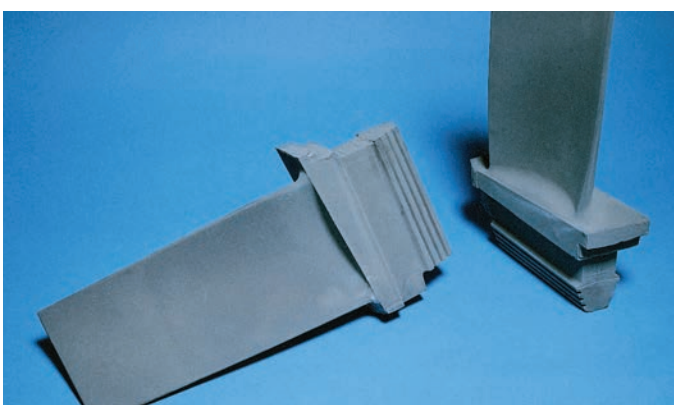
In addition to the densification of castings and bulk powders, HIP provides a different means to produce components which would be unobtainable using traditional methods (such as casting and forging) or the ability to consolidate multiple components into one. Using Bodycote's Powdermet® process, net and near-net-shape techniques allow the design engineer additional options as they produce value-added, fully dense components with isotropic material properties. The ability to diffusion bond dissimilar materials, each having specific properties, expands the manufacturing possibilities, enabling the protection of aerospace components to be addressed. For example, diffusion bonding and superplastic forming are used to make titanium airfoils in the fan section of large jet engines. Additionally, a thick cladding of wear and corrosion resistant material, such as the cobalt chrome Stellite® alloys, may be applied by HIP to enhance the performance of actuators and other aircraft components.

The benefits of HIP to the aerospace industry are clear. HIP of castings increases fatigue strength, ductility, toughness and resistance to stress rupture, whilst improving machinability and surface finish. Significant cost savings may be achieved with an investment cast and HIP route in comparison to machining from solid, whilst HIP product fabrication techniques can be used to manufacture unique parts and novel materials. Designers and manufacturers alike can make better products by introducing HIP to their production route.

KEY AEROSPACE SERVICES

- Densal® - aluminium densification
- Densification of superalloy and titanium castings
- Powdermet® manufacture of complex net and NNS* powder metallurgy components and novel materials
- Diffusion bonding of complex geometries
- HIP brazing
- HIP cladding

*Near-net-shape



Surface Technology

As one of the first industries to fully adopt thermally sprayed treatments into the design of precision engineered components, aerospace applications have been a focus of Bodycote's thermal spray activities. With over 100 key thermally sprayed applications within aerospace turbine engines, Bodycote can provide surface technology solutions for a range of properties including wear control, corrosion resistance, thermal efficiency and conductiveness to protect against lightning strikes. Without these surface treatments, today's aircraft components would not operate to the required standards.

Thermal spraying allows coatings of high performance materials such as metals, alloys, ceramics, cermets or carbides to be applied to relatively easy-to-work and more economical base materials. The various processes can offer excellent improvements in component performance and lifetime.

Thermal spray refers mainly to two robotically-controlled surface treatment techniques: plasma and HVOF. Plasma spraying offers versatility in deposition of materials starting from pure metals and alloys, through abradables to carbides and ceramics. This unique feature allows use of this technology in various applications improving surface characteristics such as wear resistance, thermal and electrical conductivity or insulation, coefficient of friction, corrosion resistance, high temperature oxidation resistance and biocompatibility.

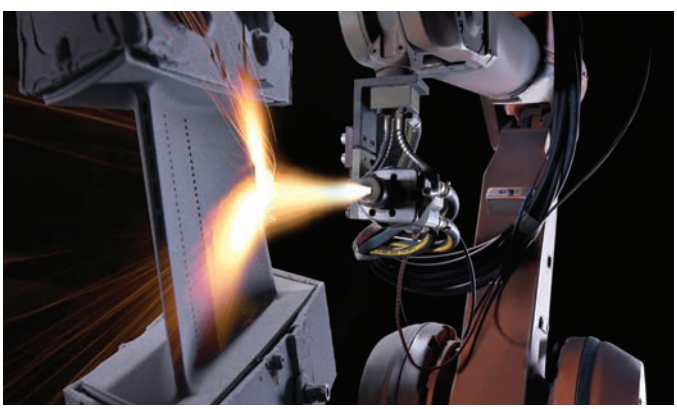
HVOF has an exceptionally high coefficient of adhesion, commonly exceeding bond strengths of 12,000 psi between coating and substrate. This allows HVOF coatings to maintain nearly 100% of their wear resistant qualities in high temperature environments, an especially useful attribute for components that must function in the absence of proper lubrication for extended periods of time.

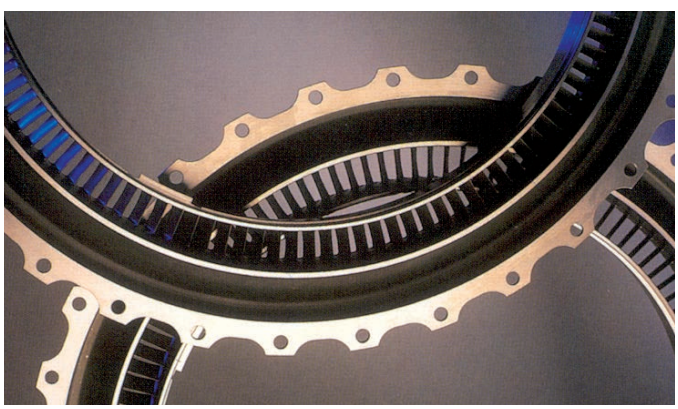
Thermal spraying is an attractive treatment technique as it offers a wide choice of materials and processes with reduced impact on the environment when compared to conventional plating processes. Almost any metallic or ceramic can be applied to a huge range of materials with excellent bond strength and without distortion of the substrate.

Bodycote can also offer a range of specialised ceramic surface treatments. Bodycote's thermochemically-formed ceramic treatment range provides extreme hardness and corrosion resistance without any detriment to the mechanical properties of the component. This ceramic surface is designed to fill microporosity and cracks and produces a chemical bond between the ceramic coating and the substrate.

KEY AEROSPACE SERVICES

- HVOF (High Velocity Oxy Fuel)
- Plasma spray
- Thermochemically-formed ceramics
- Ceramic densification
- Polymer and hybrid coatings





Repair & Rejuvenation

In addition to thermal processing services for newly manufactured components, Bodycote can provide part repair and rejuvenation.

HIP is used in the field of turbine blade rejuvenation for improvement of material integrity, porosity removal, improved bonding and for the removal of creep porosity developed during previous service.

Brazing is a cost effective restorative process that eliminates the risks associated with traditional repair techniques such as standard welding. Bodycote uses brazing to repair surfaces that are susceptible to corrosion, cracking and erosion. The repair process comprises three distinct stages: substrate cleaning, alloy application and vacuum heat treatment. Turbine components are typically manufactured from complex alloys that form tenacious oxides during service. The oxides prevent braze alloy diffusion and must be removed prior to alloy application. Bodycote has developed a gaseous cleaning technique that reduces oxides deep within cracks and at the component surface. After cleaning, the designated surface is inspected and prepared for alloy application. The constituent parts are then vacuum brazed and diffused to produce a homogenous microstructure. Each stage of the heat treatment cycle is closely controlled to produce a dimensionally stable repair that meets the customer's requirements.

Thermal spray technology is also widely used in the reclamation of damaged or worn components, offering a cost-effective alternative to the purchase of new replacement parts. Treated parts often last up to twenty times longer than the original. The high bond strength and ability to build a smooth, dimensionally consistent coating to thicknesses up to 1/2" enables the effective refurbishment of worn components, with the resulting surface restoring conformity to dimensional tolerances without additional machining.

A greener, cleaner environment

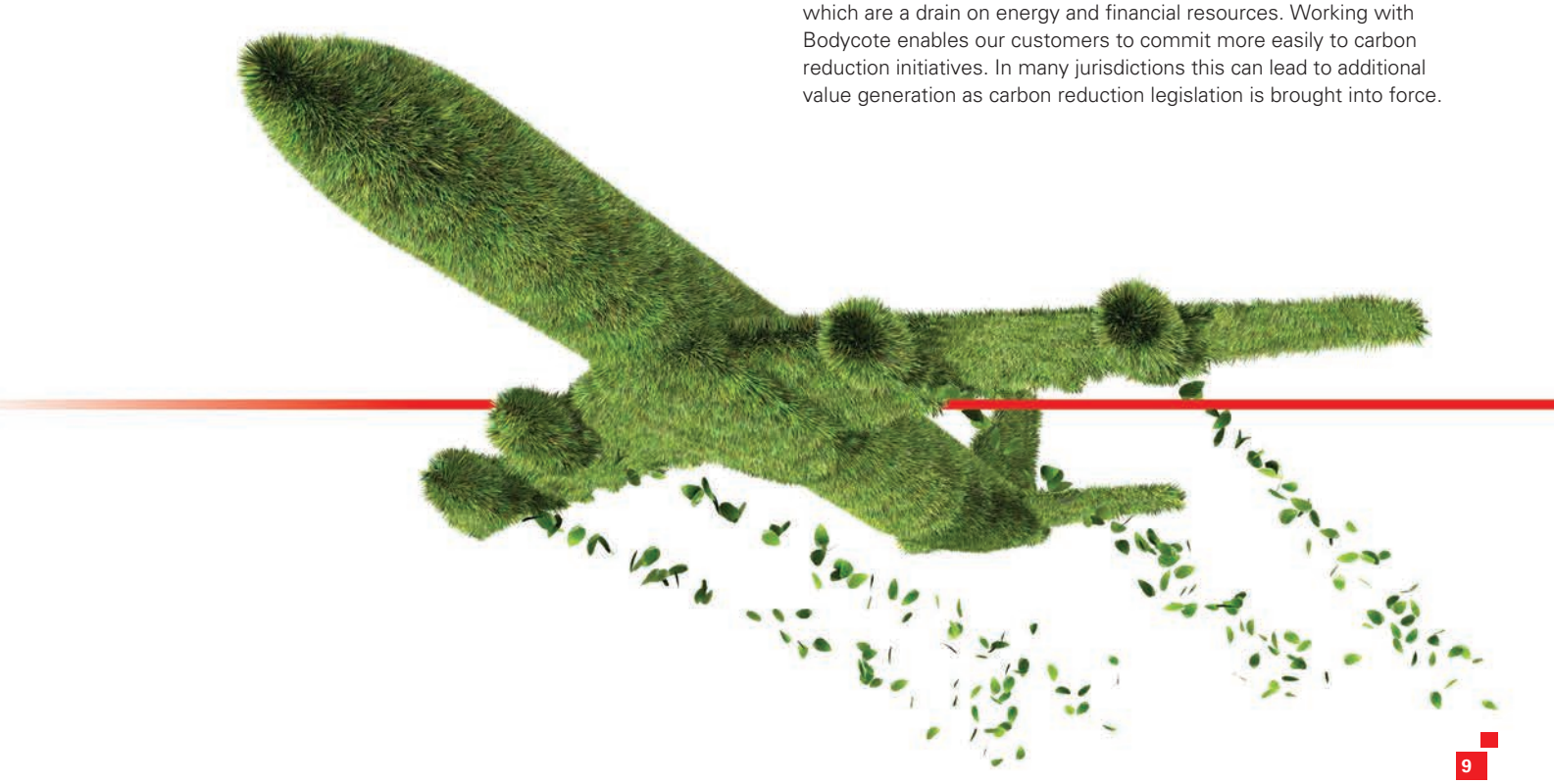
Reducing any detrimental impact on the environment has become a growing focus of the worldwide aerospace industry and Bodycote can assist in the drive towards carbon reduction and environmentally friendly approaches in a number of ways.

Certain processes, such as thermal spray surface treatments, are leading the way in the replacement of older, less environmentally friendly processes. Thermal spray is replacing many applications of hard plating applications, such as the hard chrome plating of landing gear, and is increasingly being specified by companies that are environmentally aware. Future restrictions that will be placed on chrome plating due to health and safety and environmental issues have led to major aerospace companies embarking on initiatives to replace it. These companies have highlighted thermal spray coatings as the preferred replacement for chrome plating. Bodycote has been involved in a number of initiatives to replace chrome plate and results have shown that, in addition to the environmental benefits, thermally sprayed tungsten carbide based coatings outperform hard chrome plate for both wear and corrosion protection.

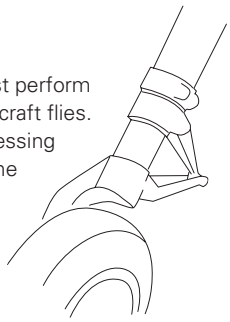
Modern thermal processing techniques have allowed design engineers and manufacturers to use much lighter materials, such as aluminium and titanium, and have significantly prolonged component lifetimes. Through the effective use of thermal processing, parts can now be lighter and overall component weight reduced, leading to improved efficiency and reduced fuel consumption.

At every stage where Bodycote is involved in the manufacturing cycle, our operational aim is to lessen the overall impact on the environment, not just in our own operations, but also those of our customers. The key to Bodycote's positive contribution lies in efficiency; as an aggregator of specialised engineering services, Bodycote reduces the carbon footprint of its customers' activities by increasing the lifespan of their products and using modern, energy efficient equipment.

Without Bodycote, many companies would be using older technology in-house and running their equipment at reduced capacity, both of which are a drain on energy and financial resources. Working with Bodycote enables our customers to commit more easily to carbon reduction initiatives. In many jurisdictions this can lead to additional value generation as carbon reduction legislation is brought into force.



TOUCH DOWN – A COMPONENT JOURNEY



AIRCRAFT LANDING GEAR
Safety critical landing gear must perform without fault every time the aircraft flies. A combination of thermal processing techniques is used to ensure the steel's material properties are optimised and to protect it during its working life. Traditionally, landing gear has been surface treated using hard chrome plate, but this is now being superseded by more environmentally friendly thermal spray processes, which provide extreme wear and corrosion resistance.

Alloy steel billet is forged to shape

B The part is heat treated to harden and temper the steel

B A thermally sprayed surface treatment is applied to replace hard chrome plate for improved wear and corrosion resistance

B The component is surface machined using diamond tools due to the extreme hardness of the surface finish

End application – aircraft undercarriage

BODYCOTE COMPONENT JOURNEYS

This is just one example of how Bodycote brings together the huge wealth of knowledge and expertise from across the Group to provide the vital engineering services you need...

For more component journeys visit **www.bodycote.com**

B Denotes the parts of the component journey undertaken by Bodycote

www.bodycote.com

Operating an international network of facilities and serving a wide range of industries, Bodycote is the world's largest and most respected provider of thermal processing services – a vital link in the manufacturing supply chain.

Bodycote operates in two major areas: the Aerospace, Defence & Energy business serves the aerospace, defence, power generation and oil & gas industries, whilst the Automotive & General Industrial business serves sectors including automotive, construction, tooling, medical and transportation.

Bodycote plc
Springwood Court
Springwood Close
Tytherington Business Park
Macclesfield
Cheshire
United Kingdom
SK10 2XF

Tel: +44 (0)1625 505300
Fax: +44 (0)1625 505313
Email: info@bodycote.com

Ref: ID4846
Designed and produced by ID
www.interactivedimension.com