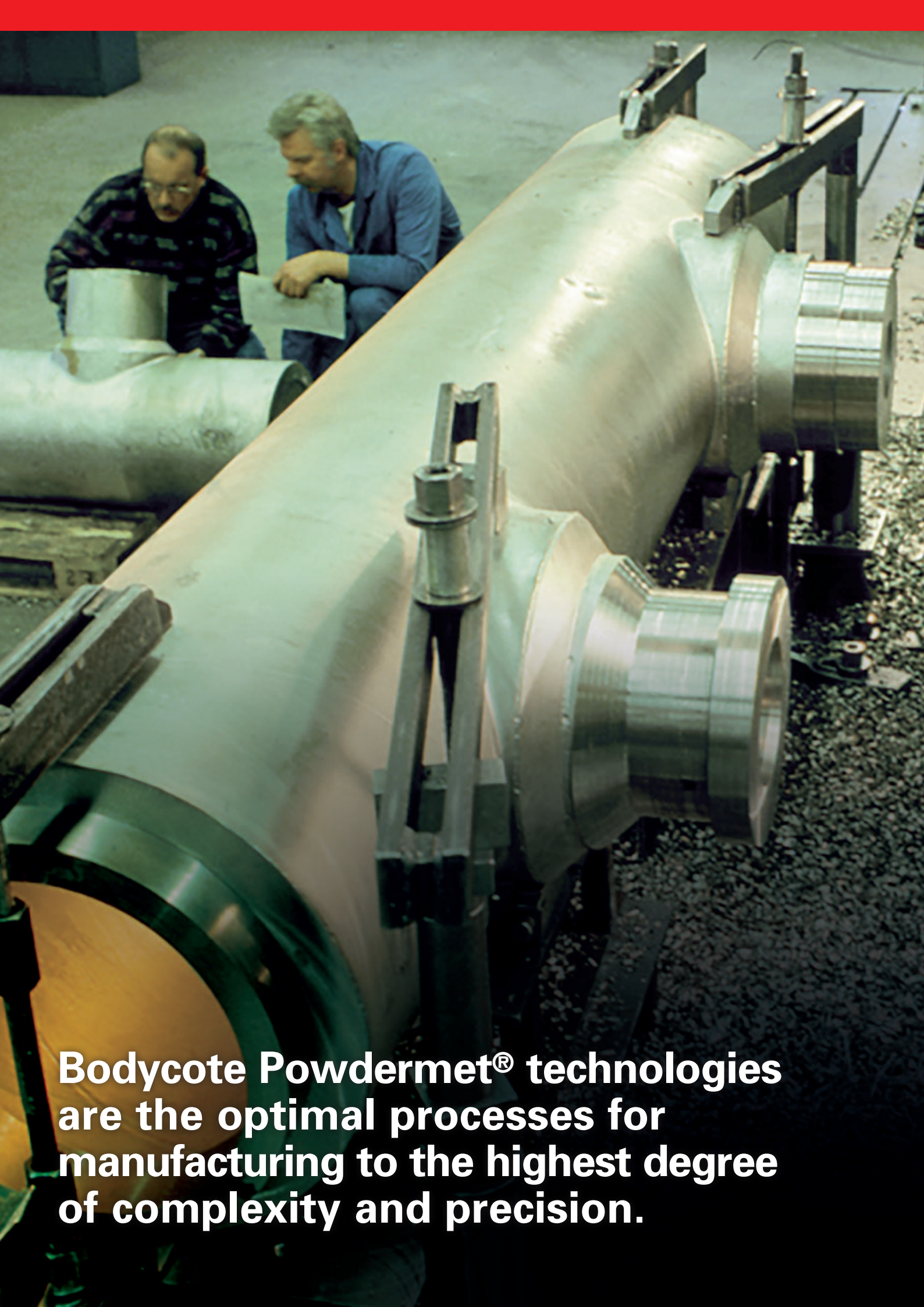


Bodycote Powdermet® technologies





Bodycote Powdermet® technologies are the optimal processes for manufacturing to the highest degree of complexity and precision.

What is Powdermet®?

Bodycote has decades of experience creating complex, high integrity components from powdered metal. Bodycote Powdermet® technologies are a group of manufacturing processes used in the production of complex components using powder metallurgy.

Bodycote Powdermet® technologies now incorporate new, patent-pending techniques that combine 3D printing with well-established net shape and near net shape techniques. This new technology dramatically reduces the manufacturing time and production cost of a part compared to producing the same part using 3D printing alone.

Powdermet® technologies ensure complete powder consolidation, achieve structural homogeneity, and eliminate internal porosity and unconsolidated powder flaws. The process can produce components with varying surface features and thicknesses, with higher structural integrity than alternative production techniques. The need for brazing or welding parts together to form larger structures is eliminated. Instead, the finished article can be produced as one seamless component and largely avoid the size limitations imposed by the constraints of 3D printing. Different parts of a component can be formed from different alloys presenting the ideal and most cost-efficient solution. Component design can be tailored to the actual requirements for performance and not limited by subsequent machining operations.

Included in Powdermet® technologies are near-net shape (NNS), selective surface net shape (SSNS), 3D printing and hybrid processes with 3D printing*.

*Patents pending

Properties & advantages of Powdermet® technologies

- Single piece construction of highly complex components
- Can combine multiple materials in one component
- One-off or high volume productions
- Substantial elimination of machining operations
- Scalable to large components
- Able to meet exacting tolerances
- Design flexibility and freedom
- Weight optimisation
- Fine and homogeneous grain size
- High cleanliness and no segregation
- Isotropic mechanical properties
- Superior stress corrosion properties
- Reduced welding and machining
- 100% ultrasonic inspectability
- Short delivery times
- Material and total cost savings

Bodycote Powdermet® technologies may use many types and grades of materials, including:

TYPES	GRADES
Stainless steels	304L 316L 316LN
Martensitic stainless steels	17/4PH 13/8PH 15/5PH X4CrNiMo
Ni based alloys	IN625 IN690 IN713 IN718 IN728 IN925 IN939 C22 247LC Supermet 60+ Supermet 60 Supermet 50 Waspalloy
Co based alloys	Stellite 1, 3, 6, 12 and 21
Titanium	CP Ti Ti6Al4V TiAl Ti6Al2Sn4Zr2Mo
Aluminium	Al-Si alloys Al6061 AlSi10Mg
Cobalt Chrome Molybdenum	
Tungsten	

Please contact Bodycote Powdermet® technologies sales team for a full list of materials types, grades and their applications.

CERTIFICATIONS AND APPROVALS

- ISO 9001
- ISO 14001
- AS9100
- ASTM A988/A988M
- ASTM A989/A989M
- ASTM B834
- NORSOK M-630
- DNV-RP-F112

Redefined component manufacturing

Powdermet® technologies ensure complete powder consolidation achieving structural homogeneity and elimination of all internal porosity – characteristics which are not possible to achieve with conventional manufacturing methods. Bodycote's innovative engineering solutions improve customers' product design and system operations while contributing to overall savings.

Powdermet® Hybrid with 3D Printing*

Powdermet® Hybrid technologies* combine NNS or SSNS with 3D printing to produce fully bonded components at greatly reduced cost and production time compared to 3D printing alone. It is also possible to use multi-metallic structures rather than traditional techniques.

*Patents pending

Characteristics of Powdermet® Hybrid with 3D Printing:

- Reduces cost and production time when compared to 3D printing alone
- Transforms internal structures with new dynamic designs
- Accuracy cannot be matched by machined parts
- Wear and corrosion resistance can be enhanced with multi-metallic material combinations
- Net shape inserts ensure critical surfaces meet final drawing requirements

Powdermet® Near Net Shape (NNS)

Powdermet® NNS technology produces components with a high degree of complexity not possible via conventional means.

Powdermet® NNS offers these benefits:

- Provides freedom and flexibility in design
- Designs are not limited by machining processes
- Improves material yield and efficiency
- Reduces material usage compared to conventional forging and machining techniques

These desirable characteristics allow complex components to be manufactured with finished profiles in hard-to-machine, exotic alloys suitable in subsea, oil and gas, aerospace and marine applications.

Powdermet® 3D Printing

Powdermet® 3D Printing technology combines building of three-dimensional parts layer-by-layer based on digital models with Bodycote post-build processes of heat treatment and hot isostatic pressing. This additive manufacturing technique allows the flexibility of creating complex components with unique material properties quickly and less costly compared to traditional subtractive methods.

Advantages of Powdermet® 3D Printing:

- Enhances uniform mechanical properties
- Achieves 100% powder consolidation
- Eliminates porosity
- Reduces possible risks from premature failure
- Imparts isotropic properties

Powdermet® Selective Surface Net Shape (SSNS)

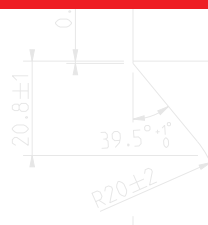
Powdermet® SSNS technology produces components which require minimal post-process machining and retain their finished machined tolerances. Powdermet® SSNS can be used to produce components that would be cost-prohibitive if manufactured by other means.

Benefits of Powdermet® SSNS:

- Freedom in design
- Reduces material usage significantly compared to forged components
- Eliminates costly machining operations
- Shortens delivery lead times
- Minimises finishing processes to mating or critical design surfaces only

Certain environments or applications benefit from the use of very high strength alloys. These alloys are easily incorporated into SSNS technology unlike competing casting processes. Selective surface net shape parts made from optimal alloy composition offer higher performance, extended life and repeatability in volume manufacturing. Powdermet® SSNS technology has been flight tested on aerospace applications and is well suited for oil and gas applications.

R6-R50 (TYP.)
BETWEEN MACHINED AND
NONE MACHINED SURFACES



Creating value for industries

Aerospace & Defence

For parts that are subjected to high in-service stresses, it is essential to maximise the properties and working life of the component. The design flexibility inherent in Bodycote's Powdermet® solutions means that it is possible to produce components from metallic compositions that are difficult or impossible to forge or cast by conventional means.

Each generation of aeronautical engines continues to improve performance and efficiency; whilst reducing emissions and weight. Critical high pressure, high temperature aerospace components can be manufactured entirely using SSNS or hybrid SSNS with 3D printed segments. Welding operations are eliminated or minimised and the 'as built' structure design takes advantage of Powdermet® technologies.

Oil & Gas

Oil & gas operations require specialised equipment that must be reliable, cost-effective and safe to the environment. Powdermet® components provide integrated, highly complex parts with shorter lead times. Unlike conventionally forged billets and preforms, machining and welding are minimal. In subsea manifold systems, subcontract welding has been reduced by up to 80%.

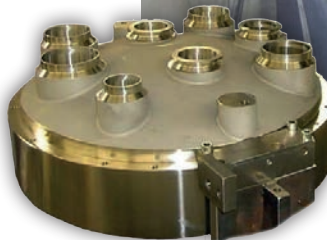
Powdermet® 3D printing technology, particularly in high pressure, high temperature sour environments, reduces the cost of expensive materials and extends component service life. The homogeneous microstructure in Powdermet® hybrid technology increases wear and corrosion resistance in components required to meet the increasingly stringent demands of the offshore industry. Multiple large and complex components can be combined and produced as a single piece in one-off or full production operation - a cost-effective manufacturing route.

Net shape features at key locations within a component eliminate the need for machining in difficult-to-access areas, enhancing performance and component life through material optimisation in critical areas.



Nuclear

SSNS and NNS parts require minimal machining; so in comparison to conventional wrought components, the design can be tailored to the actual requirements for part performance, rather than limited by subsequent machining operations. In many instances, large complex components can be produced in one piece, reducing post-weld examinations and offering a cost effective manufacturing route.



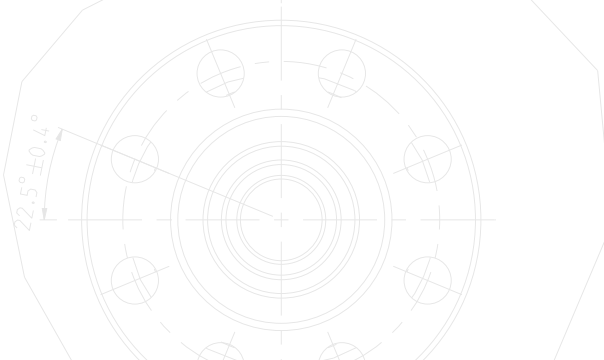
For the Large Hadron Collider, the world's largest energy subatomic particle accelerator, Bodycote successfully manufactured over 1,000 superconducting dipole cryomagnetic end covers using Powdermet® technology.

Power Generation

The power generation industry is constantly working to improve the efficiency of turbines and looking at new ways to manufacture components. For example, Powdermet® technology has successfully been used to produce steam chest parts in steam turbines, which have intricate internal cavities. It is the only manufacturing technique available to achieve complex internal profiles. Other application examples include rotors, turbine discs, diaphragms, valve bodies and steam generator components.



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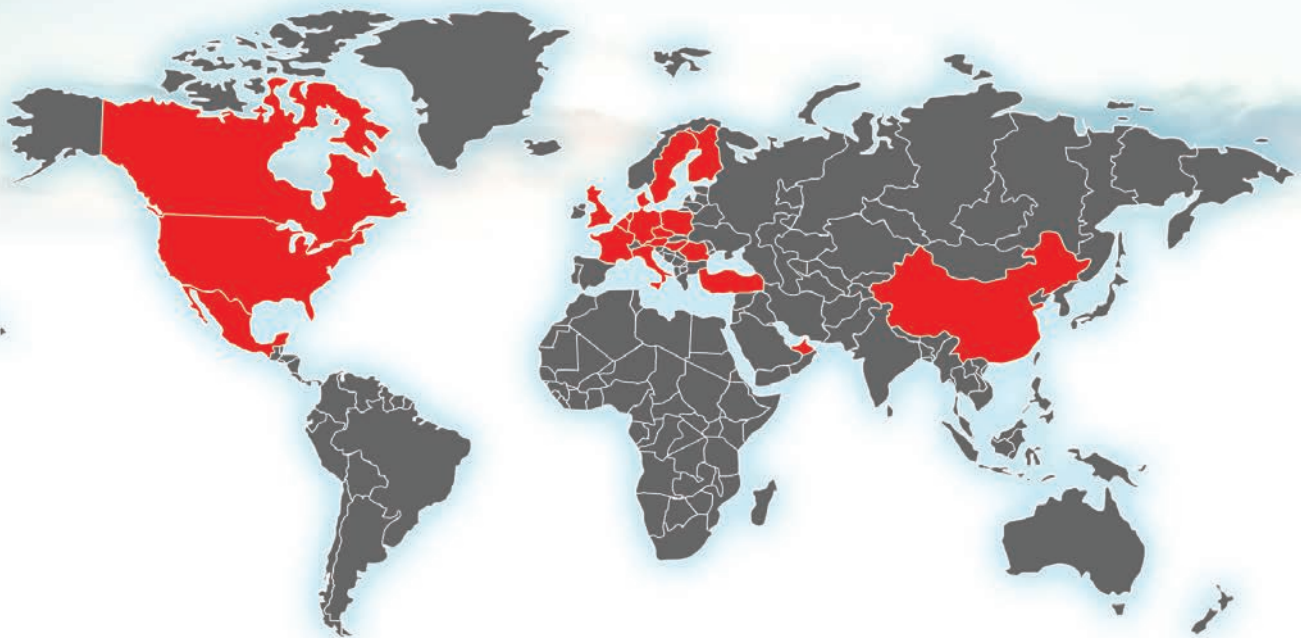


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As the global leader in heat treatment and specialist thermal processing services, Bodycote has been at the forefront of hot isostatic pressing (HIP) technologies for decades with the largest equipment network in the world and continues to invest in greater capacity in recognition of growing demand.

Bodycote Powdermet® technologies* are a group of processing services. These services include near-net shape, selective surface net shape, 3D printing and hybrid processes with 3D printing.

*Patents pending



www.bodycote.com

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: powdermet@bodycote.com

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www.interactivedimension.com