THE INCREASING OF TECHNOLOGICAL PERFORMANCES FOR ALUMINUM CASTINGS BY APPLYING HOT ISOSTATIC PROCESSING

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***Abstract**: Hot isostatic processing (HIP), involves the simultaneous application of pressure and elevated temperature to materials. Under these conditions of heat and pressure, internal pores or defects within a solid body or a powder compact collapse and weld up. HIP is today used for a lot of applications, like upgrading castings (removing shrinkage pores in interdendritic space), densifying pre-sintered components, consolidation of powders and interfacial bonding. The paper presents some theoretical data for Densal applications and also, some experimental data about CastCon process applied to ATSi5Cu1 alloy.*

***Keywords**: HIP processing, diffusion bonding, Densal.*

1. INTRODUCTION

HIP is able to remove internal voids from all types of material and promotes diffusion bonding across the surfaces of the void.

The replacement of the void by continuous material is the basis for the improvements in mechanical properties that HIP provides.

HIP is normally the first thermal process after casting and results in homogenization of the cast microstructure.

HIP is not effective when the porosity breaks out at the surface of the casting.

In this situation the pressurizing gas enters the pore and there is no pressure differential to drive pore closure.

For this reason large steel sand castings and cast copper alloys do not normally respond well to HIP.

It is possible to enclose the casting in a welded capsule with ceramic grain surrounding the casting to act as a pressure transmitting medium.

An alternative is to identify and weld over the surface breaking porosity.

However, these procedures are usually cost-effective only with the highest-value products

2. INDUSTRIAL APPLICATIONS

2.1. Aluminum Alloys

Aluminum alloys respond particularly well to HIP. Typical improvements in mechanical properties are a doubling of elongation and an order of magnitude increase in fatigue life.

HIP is widely used on sand, low pressure die and investment castings for aerospace, automotive and general engineering applications.

Turbocharger compressor rotors are increasingly being HIPped as in order to meet demands for higher duties that require improves fatigue performance.

HIP can also improve the pressure tightness of pump housings by eliminating porosity that would otherwise be exposed during machining.

Aerospace aluminum castings are HIPped to achieve better X-radiographic standards as well as improved mechanical properties.

The HIP process parameters used by TTI Group ~ 500 ºC and (50 – 100) MPa (argon gas) for 1 hour - are suitable for the majority of commonly used alloy specifications. Heat treatment of aluminum alloys is also carried out at Letchworth, offering the possibility of a "one-stop shop" for HIP and heat treatment of aluminum castings.

2.2. New Prospectives with Densal

Densal = DENSe ALuminum and was developed by Bodycote HIP Ltd.

Aluminum alloys are a very important material group in modern automobiles. The alloys' low density ~2.8 g/cm^3 combined with their proven mechanical properties offers automobile manufacturers new possibilities in lightweight construction.

Aluminum casting offers an attractive possibility of economically producing complicated net-shape components. However, regardless of the casting techniques or the alloy composition used, gas- and shrinkage-porosity can exist in the castings that negatively influence the mechanical properties of the component.

Densal is an innovative, post-casting, hot isostatic pressing, or HIP, densification process that remedies porosity problems. Using Densal in combination with proper foundry techniques results in a significant improvement in the mechanical properties of cast parts over parts without Densal.

The use of Densal ensures the economical and resource friendly production of high quality, defect-free cast aluminum components with mechanical properties that approach those of forged aluminum parts.

A prerequisite for successful Densal processing is that the porosity should not be surface connected, or contain high internal gas pressure.

The best results are attained with unmachined, sand- or permanent mould castings with undamaged casting surface (Fig. 1).

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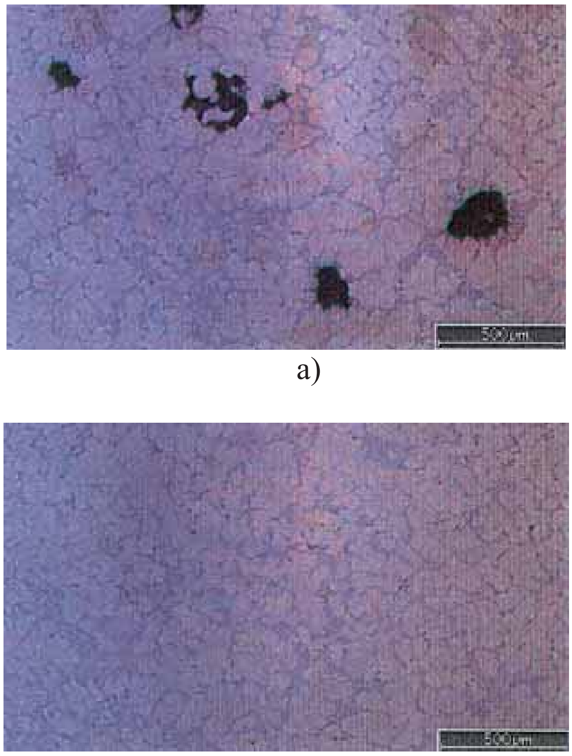
Densal delivers:

■ higher mechanical strength;
■ higher fracture toughness;
■ up to an order of magnitude longer fatigue life;
■ uniform mechanical properties;
■ pore-free surface after machining;
■ uniform properties throughout a production run;
■ full x-ray inspection acceptance;
■ better property adherence to attainable values.



a)

b)

Fig. 1 Aluminum component without Densal (a) and with Densal (b) for ATSi5Cu1 casting alloy

The best densification results from Densal are seen with unmachined, sand- or permanent mould castings with an intact casting skin. Porosity should not be surface connected and should not contain high pressure gas.

The Densal process allows for the economical production of high quality defect-free aluminium casting - which are comparable with forged components.

Applications for Densal use, are:

■ highly dynamically loaded aluminum castings;
■ safety critical parts made from aluminum alloys;
■ defect-free sealing components and cosmetic parts.

Examples of Densal Usage

Aluminum casting are used significantly in modern,high-performance engines. Constantly increasing performance requirements for these engines increasingly bring these components, for example crankcases and cylinder heads, to their stress limits.Densal also offers further cosmetic advantages in manufacturing: after the process, when all sub-surface pores has been closed, and during machining, no unwanted porosity in the machined surface will appear. Without Densal porosity exposed through machining usually results in scrapped parts.

Fatigue Life Improvement with Densal

Rotating beam fatigue test of samples taken from the bearing support area of the crankcases mentioned previously prove that Densal increases fatigue life by the factor 10 for material: ATSi5Cu1.

3. THE CastCon PROCESS

The European automotive industry is known worldwide as the technically most advanced and innovative. Based on economical and political pressure to reduce fuel consumption and CO_2 emission the efforts for light weighting in automobile design and constructions have increased significantly and specific solutions based on the intensive use of aluminum as modified or new alloys have been developed in the last decades [6].

The European automotive industry has more than doubled the average amount of aluminum used in passenger cars during the last decade and will do even more so in the coming years. In the year 2000 an average of 102 kg aluminum was used in automotive parts in Western Europe, with 59 kg in engine parts, 11 kg in structural parts, 6 kg chassis applications and 5 kg for body-in-white (21 kg others). Based on current developments in new model generations with innovative aluminum concepts it can be estimated that the use of this material in European passenger cars will more than double in the next decade.

One of the main advances of aluminum is its availability in a large variety of semi-finished forms, such as shape castings, extrusions and sheet. Such semis are very suitable for mass production and innovative solutions in the form of compact and highly integrated parts that meet the high demands for performance, quality and cost efficient manufacturability.

As part of these advantages are given by CastCon technology. Table 1 outlines its general capabilities.

Table 1 CastCon Prototyping Capabilities

Parameters	Capabilities
Shape	Simple to very complex;
Size	From less than one ounce to over a hundred pounds;
Dimension Accuracy	1% or greater without post-machining (would depend on material, size and shape);
Materials	Various Steels, Cu, Co, Ni, Ti alloys as well as metal matrix composites;
Structure	Most any geometric shapes including holes, internal channels and bonding;
Mechanical Properties	Equivalent to forged parts;
Surface Roughness	N11 or better without post-machining;
Quantity	From prototype up to production runs;
Cost	From less than 1 USD for large quantities - to a few thousand USD for large complicated parts

CastCon begins with a sand mold formed with a pattern and made from a selected sand and binder mixture. A powdered material is fed into the cavity of the sand mold either dry or wet. The powdered material is then heated and isostatically pressed with a high pressure source. The sand mold acts as a pressure transmitting medium, uniformly consolidating the powdered material within the mold [5].

The major advantages of the CastCon process include:

- excellent shape forming capability inherited from the vast usage of sand molding techniques in the metal casting industry;
- good mechanical properties equivalent to forged parts. The CastCon process is rapidly approaching commercialization. Opportunities currently exist to implement this advanced manufacturing process in a production

application. Product flexibility, superior properties, and a reduced total cost makes the CastCon process enticing to members of the rapidly advancing manufacturing community, as given advantages:

- due to zero porosity and fine microstructure;
- great flexibility of producing a wide variety of metallic, intermetallic, ceramic and composite components facilitated by using various powdered materials and their mixtures;
- capability of producing macro composites by bonding different powders, or a powder to a solid, or a solid to a solid;
- an unique powder coating method for improving abrasive and corrosion resistances.

3.1. Experimental data

Experimetal tests were applied to casted samples from ATSi5Cu1 alloy [5]. Isostatically, the samples were tested CIP at 100 MPa for 120 min. The pressed structure was obtained after rapid cooling in water from 510 ^{O}C in so called "incubation period".

Table 2 Mechanical properties of ATSi5Cu1 alloy

Lot Samble No.	Tensile strength [N/mm2]		Compression strenght [N/mm2]		Elongation [%]	
	Classic test	Cast Contest	Classic test	Cast Contest	Classic test	Cast Contest
1	129.2	136.0	291.9	335.2	6.92	10.45
2	118.2	136.2	290.4	329.7	6.74	10.70
3	109.5	129.2	280.1	327.9	6.23	11.40
4	115.4	125.0	267.6	328.3	6.19	9.90
5	123.8	125.3	271.7	321.6	6.72	11.12

Mechanical properties are given in Table 2 and are obtained after natural ageing for a period of 7 days. The CastCon process is rapidly approaching commercialization. Opportunities currently exist to implement this advanced manufacturing process in a production application.

Product flexibility, superior properties, and a reduced total cost make the CastCon process enticing to members of the rapidly advancing manufacturing community.

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