A NEW PROCESS TO MANUFACTURE TITANIUM NEAR-NET SHAPES

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ABSTRACT

Reducing the buy-to-fly ratio is a major concern for the aerospace industry. A number of development programs are aiming at reducing this ratio.

-METEC Powder Metal AB has developed a technology which allows to manufacture near-net shape parts of up to 6lbs (limitation only linked to the present equipment, the process could allow bigger parts).

-METEC is currently making parts in stainless steel or tool steel from powder in its Swedish facility in Karlskoga. The process is proprietary and protected by 5 patents. It can start from any kind of powder.

-A Research & Development program has been going on for one year to apply the process to the manufacturing of titanium parts. Parts with 98% density and forged products properties have already been made, full density and complete forged product properties should be reached by year end.

-The process allows to make multilevel shaped products with an extremely economical process due to the reduced number of heat cycles and absence of material loss.

1. INTRODUCTION

Reducing the buy-to-fly ratio is the obsession of the titanium aerospace industry. Present ratios of up to 10 create a huge cost handicap to the usage of titanium. Starting from powder is one of the ways to reduce this ratio. The difficulty comes with the consolidation of this powder to make solid parts. The most developed process is laser-deposition of powder: successive layers are added to create a near net shape product. However this process is slow and expensive and maintains the need for a final machining. For very small parts (like watch cases) injection molding is already widely used but it needs expensive ultrafine powder and can only be applied to very small parts.

A new process was needed gto ba able to consolidate various titanium powder and consolidate them into shapes at low cost. This is being developed by METEC PowderMetal AB.

2. METEC POWDERMETAL AB

2.1 METEC’s development

METEC PowderMetal AB has been created in 2006 by a group of engineers putting together several Swedish based proprietary technologies to be able to manufacture powder based parts. The underlying idea was that there was no un-expensive way to make parts from clean powder: the traditional P.M. industry widely dedicated to manufacture automotive parts is using vertical presses to compact water atomized powder. But this powder cannot reach the high purity and cleanliness of spherical gas atomized powder and cannot reach 100% density for the parts.

METEC original idea is to start from clean spherical powder, to agglomerate this powder with a patented process allowing to use even big grain size powder (cheaper). This agglomerated powder is then compacted using high velocity presses. The kinetic energy and adiabatic effect inherent to this process allows to reach much higher green densities (85% is easy to achieve). Combined in multistage process (also patented) parts of over 95% density can be made.

Using this process allows to mix powders of different densities and also to mix metallic powders with ceramic fibers. The mixture is homogeneous due to the proprietary agglomeration process.

The process allows production in series with reasonable tooling costs. The parts being finished with a high-velocity re-striking do not need any
final machining and reach machined parts tolerances.

Metallurgical properties of the products are equal or better than forged products due to full density and to the isotropy of powder made parts.

METEC’s plant is located in Karlskoga Sweden, which is famous for being the birth place of Alfred Nobel. All machines have now been installed and production has started in 2009 after several years of R&D. The first parts to be manufactured are gears for the transport industry (tools steel), stainless steel parts for the automotive industry, and other mechanical parts. METEC is now backed by CALVI HOLDING an Italian company specialized in special profiles which brings to METEC its agents network worldwide and its wide knowledge in near-net shapes.

2.2 METEC process and equipment

a) Agglomeration (the SCANPAC ® process)

Powder is mixed with an hydrocolloid in small quantities

b) High Velocity Compaction

Agglomerated powder is then filled into the mold of a vertical high velocity press

The press can make several parts per minute with prismatic complex shapes.

To manufacture multistage parts, a pre-shaping is performed (different technologies are used for that purpose) and high velocity is used only at final stage for obtaining the tight tolerances.

c) Sintering

Debinding is performed either at this stage or after the perform mentioned above, removing any trace of the binder.

Parts which are then with densities varying from 92% to 98% (depending of the process used before) are then sintered to quasi full density.

Sintering is performed in controlled atmosphere or vacuum furnaces depending on the alloy. A final containerless HIPping can be done to cope with the most stringent specifications.

Properties are better than forged products properties due to isotropy of powder base material.

2.3 Examples of METEC parts

Gears for transmission in the transport industry, valve seats for diesel engines, cutting tools, dies for extrusion machines, components for safety locks, fittings, etc...
3. APPLICATION TO TITANIUM

The process allows to handle any kind of powder. It is compatible with the pyrophoric properties of titanium powder. Therefore the idea came to use the process for titanium parts.

Once the process is established from the metallurgical view-point, there will be no difficulty to replicate for titanium the type of shapes which are currently made with stainless steel, tools steel or other alloys.

We therefore concentrated our energy to develop a route giving full density for the parts and to compare different type of powders.

We tested chemically-obtained powder, hydride-de-hydrided powder and gas atomized powder.

Good results were obtained from the 3 different routes. The main difference in the structure which we obtained were mostly linked to the size of the powder: chemically obtained powder was extremely fine and gave a finer structure than the hydride-dehydrided powder for which we started from 850 micron powder. The better compromise appeared to be the gas atomized powder which we supplied from Japan. We obtained a 98% density on the pucks which have been sintered this spring and we expect, with the process improvement decided this summer to reach close to 100% in September. This improvement will be covered by a new patent.

You can see below some of the structures obtained during the tests.

![Example of 98% density Gr2 part](image)

This research has been performed with the help of Chalmers University in Goteborg (Professor Lars Nyborg). We continue to work with them to optimize the debinding process and the sintering process.

4. SIZE CONSTRAINTS AND ECONOMICAL ADVANTAGES

METEC is equipped with HVC presses up to the equivalent of 2000 tonnes which allows to make parts of several kilograms.

There is no theoretical difficulty to make bigger parts, which are already feasible if the customers accepts to do a final surface machining.

The process involves only 2 or 3 heat cycles which is a big advantage compared to conventional forging and implies no material loss.

Parts in Grade 2 and Grade 5 have been done. Provided the powder is available any grade of titanium can be done.

It is clear however that the path to full industrial operation will require a more important R&D program which we intend to perform in connection with main customers. Availability and cost of titanium powder will also be an issue when significant volumes will be ordered. Some inquiries we have received refer to 50 tonnes per year for one part (non-aerospace application) and it is clear that aerospace will require much bigger volumes.

CONCLUSION

METEC’s new process brings the shortest way from melting to finish parts. Final consolidation through hipping allows immediate qualification for aerospace purposes. However one or two years of intensive R&D are still necessary to optimize the process and to make it fully industrial.

ACKNOWLEDGEMENTS

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I also want to thank CHALMERS University and Professor NYBORG for their scientific help.

I finally want to thank GFE for supplying Hydride-dehydrided powder and Osaka Titanium which supplied all the gas atomized powder used for our tests.
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Reducing material loss and energy consumption

• Reducing the buy-to-fly ratio: a top priority for the aerospace industry!

• METEC developed a new process:
  – Starting from powder
  – Involving a maximum of 3 heat cycles
  – Producing parts at high speed
  – Extremely cost effective
  – Allowing to reach machined parts tolerances
  – With full properties of a forged product.
METEC POWDER METAL AB

- A new company, created in 2006
- Proprietary process protected by 5 patents
- Located in Karlskoga (Sweden): Alfred Nobel birthplace!
- Combining:
  - A proprietary powder agglomeration technology
  - HVC presses (adding kinetic energy and adiabatic effect to the compaction)
  - Sintering furnaces
  - An access to CIP and HIP facilities
Scanpac agglomeration process

Spherical powder

Agglomeration process

Scanpac™ agglomerated powder
Our compaction equipment

**Powder compaction machines**

HYP35-7 HVC Compaction (Equal to 350 ton)
HYP35-18 HVC Compaction (Equal to 900 ton)
HYP35-40 HVC Compaction (Equal to 2000 ton)

**Re-strike machine**

HYP35-7R (Equal to 350 ton)
Our equipment
SINTERING FURNACES

• CREMER CONTINUOUS FURNACE (1450° C)
• EISENMANN CONTINUOUS FURNACE (1280° C)
• CM HIGH TEMP. BATCH FURNACE (1450° C)
• Access to High Temperature Vacuum Furnace
New process to make multilevel parts with full density

New CIP forming

HYP35-7 HVC Press  HYP35-18 HVC Press  HYP35-40 HVC Press

Furnace  HYP35-7R HVR Re-strike Press

Containerless HIP process
• Example of a 98% density Ti part
• We can do complex parts!!!