NEAR NET SHAPE
From Dream to Reality

by: Alain A. HONNART
Managing Director   METALVALUE Ltd
Reducing material loss and energy consumption

- **Reducing the buy to fly ratio** is a top priority
- This is both an *environmental* concern (*energy saving*) and a *cost* issue
- **Powder** processes are clearly the way to achieve it
- **Titanium is not alone in this challenge**, other metals are following the same path: anything which works technically and economically for steel will be very attractive for titanium due to the cost of titanium compared to iron.
Pros and cons of powder

Powder advantages:
- **Homogeneity** → improved properties (corrosion, fatigue, etc.)
- **Process savings** better yield and less material losses, less thermal cycles
- **Easy storage and transportation**

Powder disadvantages:
- **Cost to produce**
- **Surface impurities** or oxides if non-spherical
- Depending on the process final parts **not always 100% dense** (reduced properties)
- **Cost to process** consolidation and shaping can be expensive
The steel powder industry

-Applications driven by lower processing cost:
  -All the so-called pm industry based on water atomized powder, applications for gears, cams, etc.. Large series for the automotive and mechanical industry: around 1,5 million tonnes in the world: but limited properties of the parts due to the 93-94% density.

-Applications driven by powder homogeneity:
  -Hipped products in alloys difficult to forge in conventional metallurgy: many applications for offshore (duplex steel, nickel alloys), nuclear, high speed steel, etc...

-Alloys which cannot be made conventionally
  -High temperature application (furnaces, aerospace, nuclear storage, etc...)  

-Small intricate shapes:
  -All the MIM industry (watches, micromechanics, etc...)  

-Coating applications (Flame spraying, PTA, laser deposition, welding wires, etc..)

Those applications represent much less volume and are mostly made from gas atomized powder.
A parallel with titanium?

- Titanium users want to keep the advantage linked to using an “expensive” material: corrosion resistance, mechanical properties including at high temperatures. Therefore products, even made from powder should have full density and properties of at least a cast part and preferably a forged part.

- The only exception is the use of titanium powder for coating medical implants: porosities linked to irregular shape of the powder are welcome to enhance bio-compatibility.

- Therefore the only 2 industrial processes for parts are
  - HIP for big parts which are then processed like conventional material (little volume because cost advantage limited)
  - MIM for small intricate shape. (watches, small mechanical parts)

- Nothing today to replace medium size forged parts: no process available and lack of availability of powder in big volume.
3-D printing “the new dream”

3D-Printing (additive manufacturing) has emerged as the new concept to solve the problems of the titanium industry:

- makes any shape even complex directly from computer drawings
- compatible with relatively small series encountered in the titanium industry
- has all the advantages of a near net shape process.
... but a disappointing reality

- The process is slow: a few hours for a part
- Powder cost is today too high:
  - because it uses a limited range in grain sizes (20-50μ)
  - because its needs high quality powder (especially for aerospace parts) scarcely available.
Titanium powder production

- **Chemical routes**: almost industrial now, should be competitive, but irregular shape and risk of impurities, need to be treated for use in aerospace

- **Mechanical routes** (hydride de-hydride): relatively low cost but irregular shape (well adapted for medical coating)

- **High quality powder**:
  2 main processes: rotating electrode or gas atomization (in that case with the problem of contamination coming from the nozzle or the furnace). This is the source today for 3-D printing raw material.
Only a fraction of the powder is used
A solution for those problems?

To solve the yield dilemma (buy to fly ratio) and improve the costs of medium size forged parts, the industry needs a « powder process »

This process needs to be supported by low cost powder: why not use the leftover from the Gauss curve once the 3-D printing powder has been extracted: powder cost can in that case be calculated at scrap price (within the limits of 5 to 10 times the 3-D volumes)!

When powder is available there is the need for a cost competitive process for transformation: this process exists and has been developed over the last 15 years: it is today industrially operational:

the MMS-Scanpac process developed in Sweden by Dr C.ASLUND at Metec Technologies AB a subsidiary of Bofors-Brück AB

Alain A. HONNART Managing Director
How was it developed?

- First idea in 1994: an ecological binder able to agglomerate medium size spherical powder
- First patent in 1996: The Scanpac® process
- Years of laboratory, tests, qualification with customers
- Combination in 2006 with adiabatic compaction
- Erection of a pilot plant for a value of 6M$
- New patents from 2007 onward to describe efficient routes to make multilevel parts.
- Globally renamed the MMS-Scanpac® process with 6 patents
- Now accepted for industrial production and produced parts certified for use in pressure vessels.
Once again: benefit from the steel industry!

Because steel and nickel alloy powder is available
Because market size is bigger with already a penetration of powder technology
Because it was cheaper to make tests and tooling
All development was made with steel powder and nickel alloy powder
Shape and tooling problems being basically the same (our process solves the galling problem on tools), to validate with titanium only the metallurgy and part structure had to be studied, which was done for pucks and rings.
Examples of parts already made with the process

![Examples of parts](image-url)
The MMS-Scanpac® process

Production routes Scanpac™/MMS

- Raw powder
  (Spherical powder from supplier)

- Agglomeration
  (Sintering™)

- Conventionell press
- HVC press
  (Hydopulping machines)
- CIP press

- Sintering low temp.
  (All grades)
  - Blue route = MMS

- Sintering high temp.
  (Induction in Press)

- HVC re-annuing
  (Hydopulping machines)

- Sintering high temp.
  (Sintering & Press)

- HIP
  All grades

- Finished part / blank
  (Full density, low tolerances)

- Finished part / blank
  (Full density, high tolerances)
Characteristics of the parts

- Made from gas atomized powder (20-350μ)
- Parts are fully dense (>99% density)
- Properties equal or better than standards for forged parts
- Bimetallic and cermets are possible (already one part in commercial production)
- Component surface tolerances close to machined parts.
Scanpac®-MMS is energy saving

Production route for stainless threaded fittings

Energy saving is 12 kWh/kg!!!!
Equipment necessary
Application for titanium

- All the development (machine, tooling, powder blending and agglomeration, etc…) done for stainless steel and nickel alloys is readily transferable to titanium.
- Extensive laboratory tests have been performed on titanium powder from various origins in cooperation with Chalmers University in Sweden (tests made on pucks and rings to save on tooling costs).
- Powder selection, agglomeration, green strength and properties of finished parts have been tested with excellent results.
A few figures

- **Green strength** starting from 50-250μ spherical powder was in the range of 7-10 N/mm² (when 4 is necessary to handle the products)
- **Density** of finished parts 98 to 100%
- **Properties**: comparable to forged products.
- **Cost saving** estimate: at least 30% compared to conventional.
Competitive range for MMS-Scanpac®

-50 gram

50 gram-5 kg

5 kg-
5 000 kg

Metal Injection Mold (MIM)

Scanpac® MMS

Hot Isostatic Pressing (HIP)
Conclusion

• MMS-Scanpac® makes the Near Net Shape dream a reality which will revolution the forging industry

• What we need now is mass production of high quality Titanium and Titanium alloy powder.