REPLACING THE CONVENTIONAL/FORGED ROUTE TO MANUFACTURE STAINLESS STEEL FITTINGS

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Abstract: The conventional way to manufacture stainless steel fittings is heavily energy consuming due to the different manufacturing steps (forging, rolling, sometimes cold drawing, followed by machining) and generates a high percentage of scrap during the machining of the inner hole and outside features. Using the MMS-Scanpac® process (agglomeration, pre-compaction, low-temperature sintering, high velocity adiabatic re-striking and final sintering) allows to make the same products with a better yield (76% instead of 33%) and a shorter supply chain. This eco-friendly route has been used to make products with properties equal or better than forged products which are approved for pressure vessel usage.

1. **The MMS-Scanpac (MMS = Metec Multi Step)**
route is defined with the following steps.
   - Raw material is spherical gas atomized powder.
   - The powder is agglomerated-> together with a non plastic organic binder creating clusters of the spherical powders which can be pressed with good green strength
   - The first pressing to a preform can be made by Cold Isostatic Pressing CIP, conventional hydraulic or HVC pressing (only one level parts!). Typical density is 80-85 % of theoretical density.
   - A first heat treatment operation consisting of a combined de-binding /sintering step making a pre-form with a density of between approx. 85-90 % of density
   - Subjecting the part to High Velocity Compaction HVC, driving the density to between 95-97 % of full density.
   - Consolidating the part to a density over 99 % of TD by final sintering or container-less Hot Isostatic Pressing HIP.

   As said the first compaction step can be made by conventional pressing, Cold Isostatic Pressing CIP or HVC. The most important (and compulsory) step is the second compaction step HVC, which can be considered as a heavy cold forging step.
   As will be mentioned later, this allows also to utilize coarser powder than normally used.

   Contrary to, for example, water atomized stainless steel powder, which, after atomization, contains about 3500 ppm oxygen, the gas atomized powder has an oxygen content of 50-100 ppm. Due to the amount of oxygen and irregular shape which mechanically close in the oxides at compaction such water atomized powders can never be used when aiming for full density.

2. **The standard material for stainless steel fittings is 316 L** (normally EN 1.4404).

   In order to be used for example in pressure vessel applications the material must fulfill certain criteria regarding mechanical properties

Condition	Yield strength Rp0.2 MPa	Yield strength Rp1.0 MPa	Rm MPa	Elongation A5 %	Impact properties Charpy-V J	
EN 1.4404	Min. 200	Min. 235	500-700	Min. 40 %	Min. 60	
MMS-Scanpac	225	275	600	55	125	Typical
Forged	250	275	600	55	80 – 150 (lower transverse)	“

Table 1
The table shows that the SCANPAC material fulfills all min. values required for acceptance to the European norm for forged products EN 10222-5.

We say that the material is AS GOOD OR BETTER than corresponding wrought steel.

In which aspects is it better?

- **Weldability**: The oxygen in the steel is bound to fine or ultrafine (<1 µ) oxide particles. These oxides serve as a grain size controller especially in the weld zone but also in the heat affected zone HAZ. Especially dramatic is the improvement on steels prone to grain growth at high temperatures like the ferritic stainless steels. This phenomena is named the Zener Brake phenomena.

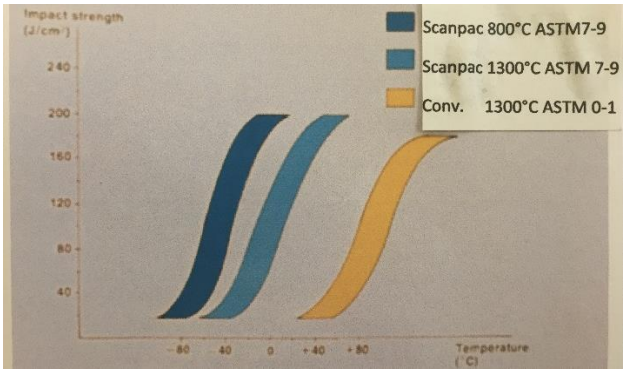


Fig. 1
Observe the dramatic difference between the Scanpac mtrl. (blue curves) and standard material (yellow curve) after simulated welding.

- **Creep properties**. In the creep range Scanpac mtrl. shows better properties than conventional in the lower creep range. With controlled additions of oxides, the creep properties at higher temperatures can also be improved vs. forged dito.

- **Better homogeneity**. The Scanpac material shows same properties in all directions. This property combined with the low segregation due to the fast cooling at atomization give overall a better control of the designed part in its specific function. This is clearly pronounced with respect of impact properties. For a stainless steel it also means better pitting corrosion resistance.

3. The MMS-Scanpac® route compared to the conventional way to manufacture fittings:

For the purpose of this presentation we shall describe the production of a 3 parts threaded union in 316L. (tube diameter 26,9mm)

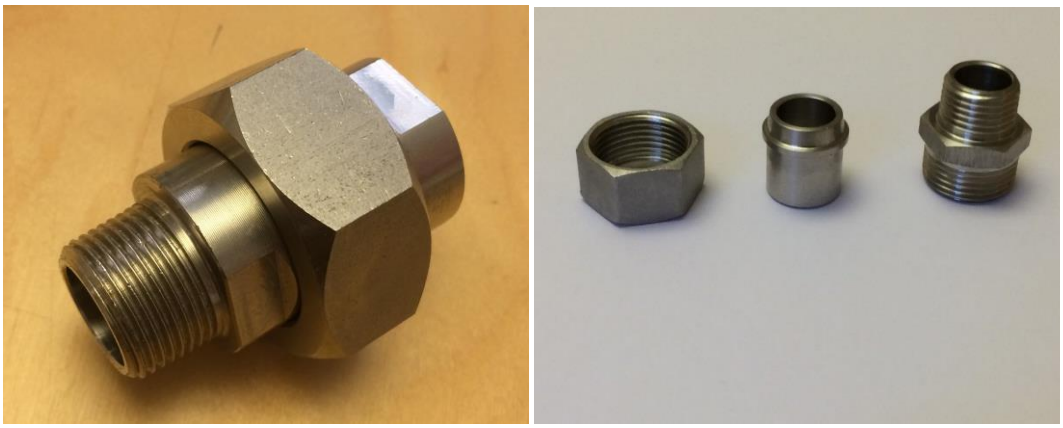


Fig.2 Union produced by MMS Scanpac route

The conventional way to make such a fitting is to start from a bar, which has been forged from a cast billet,
This bar is very often cold drawn and then finally machined. Those operations are done in different locations generating transport costs and intermediate inventories. Typically 3,2 kg of liquid metal are necessary to produce 1kg of final product.

In above case you have three components whereby 2 is multilevel and one is single level (nut). In the picture below is shown the dramatic step, where the nut is shown in its four steps from first pressing, sintering, HVC and finally the last sintering. You can clearly see the substantial reduction in height in the third step where the phenomena adiabatic softening occurs in the HVC step. Such a big reduction in a material is of course only possible when you have a material, which has a high ductility.
If you replace the HVC pressing with conventional pressing you only reach as best 90-92 % of T.D. which result in a non dense finished product even at very high tool pressures up to 1000 N/mm2.

Fig. 3 The four steps in the Scanpac process. Observe the big reduction from step 2 to step 3 Densities from left to right is 84 %, 89%, 97% and finally 99.8% of T.D.

In the case of the Scanpac process the final conditioning, which in principle consists of threading can be integrated and follow directly after the final sintering process on line.

The powder route allows to limit the quantity of liquid metal to 1,4 kg for 1kg of final product. Due to the reduction of recycling, concentration in one location and reduction of the number of heat cycles the process allows a saving of several kWh/kg of finished fitting, compared to the conventional forged route. The absolute savings depends of course of the exact size and shape of product.

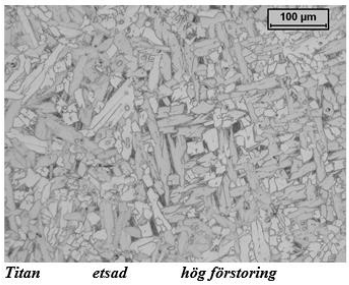
The powder route appears, as usual, as eco-friendly and energy conserving.

It shall also be noticed that the allowance of the usage of Scanpac components is valid for the highest pressure classes in contrast to cast parts which sometimes is used in production of low pressure class unions..

4. SUMMARY; The MMS Scanpac route offers strong advantages compared with the conventional route to produce threaded fittings
   - The process is energy efficient compared to the standard route due to a “compact” process route from the received powder to finished part.
   - The material savings are substantial.
   - The inventories can be reduced compared to conventional production
   - The new process route for fittings can also be applied to duplex and high alloyed stainless steels, titanium and its alloys but also nickel alloys and even brass.

In figure 4 and 5 below is shown example of microstructures for Titanium 6-4 and Duplex steel

2205 produced with the Scanpac route.



Titan etsad hög förstoring

Fig. 4 Titanium 6-4

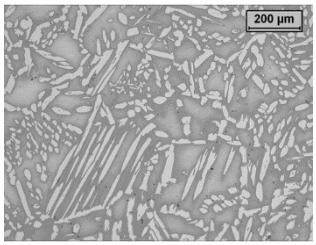


Fig.5 Duplex

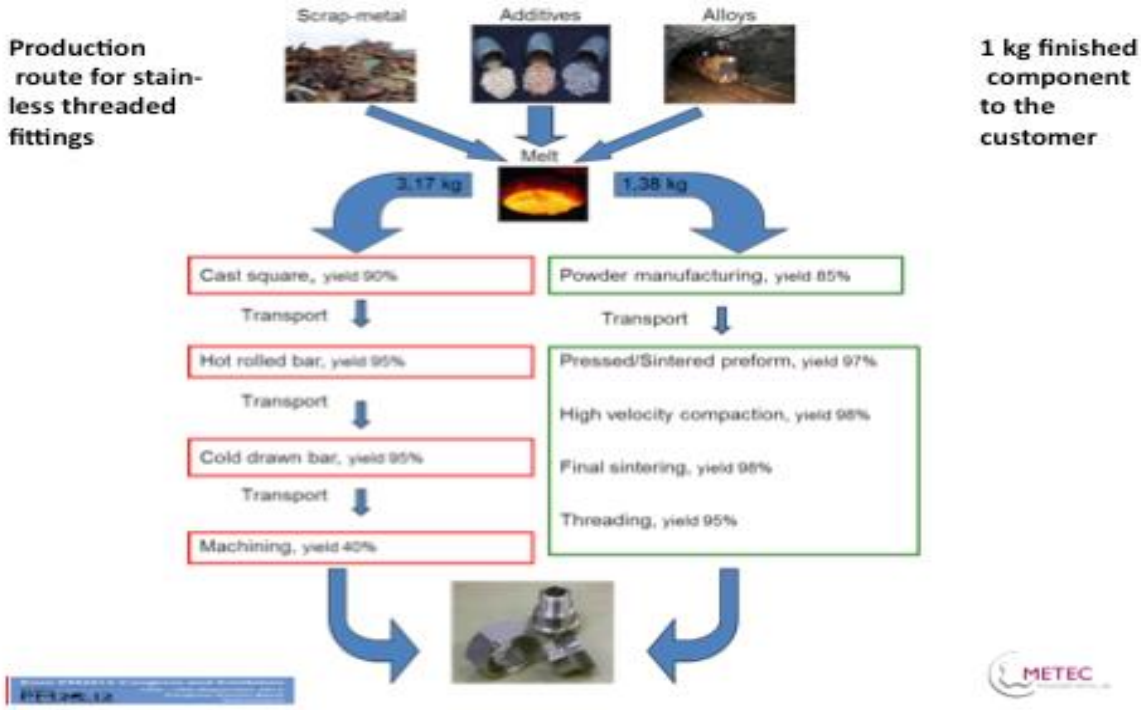


Fig.6 Comparison between the forged route and Scanpac route for production of fittings

WHAT ABOUT THE FUTURE?

5. The MMS Scanpac process is limited to component weights of around 5 kg. In principle due to limitation of size of existing HVC presses. However, for stainless steel fittings in commercial standard sizes, this weight range cover a main part of tonnage produced today.

   In the production cost for a 250 gram 316 L fitting in the SCANPAC process, the major cost is the ingoing raw material i.e. the cost of gas atomized powder.

   Depending of size range etc., the powder cost stands for, with present market prices, about 65-75 % of the variable costs. In practice it means that the powder cost is about twice the cost of said rolled bar in same grade.

   These price levels reflect the scale of present gas atomizing units. In a new planned atomizing plant, which has a capacity of around 45000 tons gas atomized powder, the production cost is

roughly half of today for the above stainless steels, which means that the market price is roughly same as the rolled bar in same steel grade.

This is a dramatic improvement, which will result in a very attractive cost structure for production of stainless steel fittings with the MMS Scanpac process.

On top of that the powder route offers also other interesting features:

- Easy shipment of bulk powder
- Easy storage
- Small lots, customization

6. There is also another interesting aspect referring to the MMS Scanpac process. Contrary to many other processes like MIM, AM (Additive Manufacturing), PTA etc. this process can accept also rather coarse powder up to 250 µ or removal of the finer parts in the bulk powder. For example, the fine particles < 22 µ or < 50 µ can be removed to be used in any of the other above mentioned processes. In fact, it can be considered as a quality improvement for example to remove the fines as they contribute to an oxygen increase in the finished component. This will add further competiveness to the Scanpac process against the forged route due to better utilization of the produced powder..

CONCLUSION:
With those break-through technologies:

-a process to consolidate powder to make mass production parts in the range 50g to 5kg with forged products properties
- a drastic reduction in the cost of gas atomized powder

Will result in that

The powder route will progressively become the normal way for the metallurgy of the future for more and more applications competing with the forged route.

Only the potential market of stainless and high alloyed fittings represents a market in Europe of approx. 500000 tons.

Thank you for your attention.

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