L. KLEIN SA
ACIERS FINS ET MÉTAUX
EDELSTÄHLE UND METALLE
FINE STEEL AND METALS

Powder Metallurgy

Description of the Micro-Melt® process

Frequently Asked Questions Regarding Powder Metallurgy

1 Q: *What is powder metallurgy?*
A: Powder metallurgy is the production of metal products from atomized metal powders.

2 Q: *Who makes the powder metallurgy metals sold by L. Klein SA?*
A: All powder metallurgy steels and alloys sold by L. Klein SA are made by Carpenter Technology Corp., Wyomissing, PA, USA, according to their Micro-Melt® process.

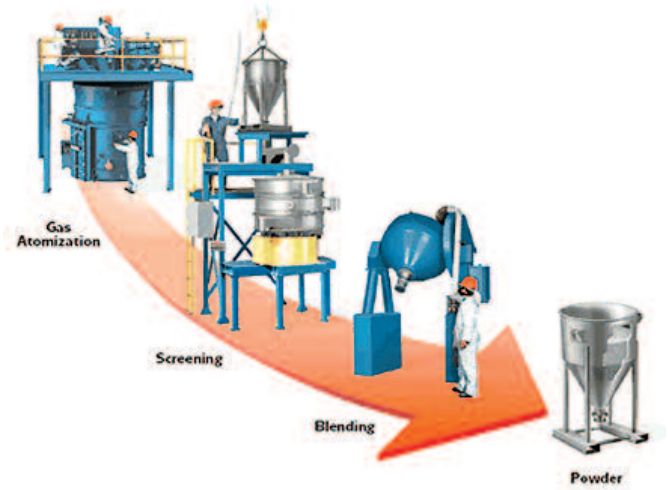
3 Q: *What is the Micro-Melt® process?*
A: The Micro-Melt® process includes 3 pivotal operations:
I. The Vacuum Induction Melting (VIM) steelmaking process of the steel or alloy;
II. The gas atomization;
III. The primary consolidation by Hot Isostatic Pressing (HIP).

4 Q: *What are the advantages of the VIM steelmaking process?*
A: The VIM process allows the melting totally degassed clean steels and alloys, having tightly controlled compositions.

5 Q: *What is gas atomization? (Gas Atomization)*
A: Gas atomization is the pulverization of a liquid metal column by impacting it with a high pressure N2 gas jet. Globular liquid metal droplets form and crystallize as individual particles, without forming any clusters.

6 Q: *Is the composition homogeneity of the atomized particles warranted?*
A: Yes, because each particle is a micro-ingot of the molten metal pool of the heat. All particles have exactly the same composition.

7 Q: *What is the granulometry of the atomized powders? (Screening)*
A: The atomized particles crystallize and cool in the cooling tower of the atomization installation. They are collected into powder hoppers at the bottom, and kept in a protective atmosphere until they are screened at 125 µm (120 mesh).



8 Q: *What is the granulometry spectrum of the screened Micro-Melt® metal powders?*
A: The powder spectrum extends from 0 to 125 µm. The average particle size is 47 µm. It means that 50% of the powder volume or weight is made of particles other than 47 µm smaller or larger .

9 Q: *How is the reproducibility of the composition ensured? (Blending)*
A: The screened powders of several VIM heats are blended to obtain a final composition within closely controlled and reproducible limits. The composition scatter of blended powders is typically 2 to 3 times smaller than with other metal-making processes.

10 Q: *How is the homogeneity of the powder granulometry warranted? (Blending)*
A: The blending operation warrants a uniform and homogeneous distribution of the various particle sizes of the blend.

11 Q: *How are the powders protected?*
A: The powders are kept in a controlled atmosphere.

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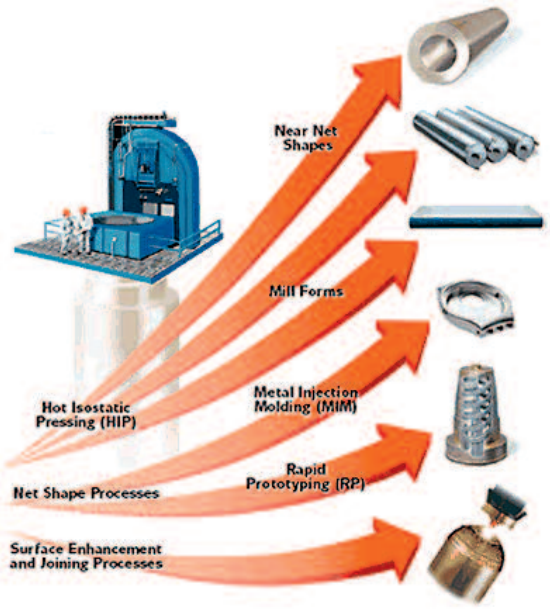
12 Q: *What is a HIP canister? (Hot Isostatic Pressing)*
A: A HIP canister is a welded metal box made of steel having a composition compatible to the metal which is to be pressed it is filled with the selected powder blends of the metals to be hot pressed.

13 Q: *How is the filling of the HIP canisters done?*
A: The filling of the canisters is done on a vibrating table. The tap density of the filled canisters reaches 70–72%, thence it is very near the theoretical density of 74%. The powders are slightly warmed to avoid any contamination or condensation during the filling operation. The HIP canisters are permanently kept under vacuum during filling and are finally, hermetically welded under vacuum.



14 Q: *What is HIP (Hot Isostatic Pressing)?*
A: HIP is when HIP canisters are placed in an autoclave and pressurized with an inert gas up to the working pressure. This pressure is higher than the yield strength of the material at the pressing temperature. Then, the canisters are heated to the pressing temperature and hold long enough to ensure the total closure of all pores by pressing, and diffusion bonding. In all cases, the final density is 100%.

This operation is the last of the Micro-Melt® process itself.

15 Q: *How different is the HIP process from other powder metallurgy processes? (Near Net Shape)*
A: The HIP process is the only primary consolidation process having the capability to achieve a 100% density by itself. All the other processes end up with a residual porosity of typically 0.2 to 2%, as in the case of the MIM (Metal Injection Molding) process, or up to 5% or more in the case of the classical sintering process, or other Net Shape Processes like RP (Rapid Prototyping), Printing processes and Non-Fusion assisted Additive Manufacturing.

16 Q: *Is it possible, with the help of secondary warm or cold deformation processes, to further reduce the residual porosities of the sintered products?*
A: Yes, in principle. Warm or cold deformation processes, like forging, allow it, although these processes rarely allow for the total elimination of residual porosities.

17 Q: *What are the following warm transformations made on the HIP ingots? (Mill Forms)*
A: The primary hot rolling is made to shape the billets necessary for the production of rod materials, which are subsequently warm rolled into the desired rod dimensions. In the case of 5.5 mm rod material, the total warm reduction from HIP to rod is approximately 1'900.

18 Q: *How is the production of wires and bars for automatic Swiss lathes done? (Mill Forms)*
A: By cold wire drawing and intermediate anneals, if required. In the case of 2.5 mm wires, the total cold reduction, after any surface conditioning of the rod materials or drawn wires, is approximately 4.

19 Q: *What are the total cumulated reductions of the wires and bars in their final delivery condition? (Mill Forms)*
A: The cumulative reduction ratios of the warm and cold deformations amount to approximately 7'000 in the case of wires or bars 2.5 mm diameter, and 60'000 with 1 mm wires.

20 Q: *Is the Micro-Melt® process also used for products other than wires and bars? (Mill Forms)*
A: Yes, for the production of steel or alloy strips, like the martensitic stainless steel CHRONIFER® M-15X, for example.

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