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# Production of hollow spheres (HS) and hollow sphere structures (HSS)

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ABSTRACT

In our paper we focus on component materials, production and prospective applications of metallic hollow spheres. We give an insight into technology, production, and the hollow spheres' diversity. It is our aim to provide an overview of the technology and enable the reader to evaluate whether the hollow spheres technology meets their specific needs.



## 1. Technology platform

Glatt GmbH, in cooperation with its subsidiary company hollomet GmbH is pleased to introduce a wide spectrum of hollow spheres. We produce metallic and ceramic hollow spheres based on our hollomet-Process and market them under our brand names “golobomet” and “globocer”. In the first part of this paper we will describe the materials required for the production of hollow spheres. In the second part we give an insight into the industrial manufacturing process. In the third part we highlight possibilities of mechanical treatment.

## 2. Materials used for production

*Polystyrene core.* A core is used in the production of the hollow sphere. For both metallic and ceramic hollow spheres a solid un-foamed polystyrene ball is usually used. Prior to the coating process the un-foamed polystyrene spheres are placed into a foamer and expanded (EPS = *e*xpanded *p*olystyrene). Grain sizes may vary during the expansion process. Sieving the polystyrene spheres is necessary for a narrow size distribution of the final product.

*Coating.* Various metal powders can be applied, their ability to be sintered being the only requirement. The grain size of the metal powder determines the minimum coat thickness possible. However in this case with a wall thickness equal to the grain size of the powder the mechanical integrity will be low. In order to achieve a solid integral hollow sphere after sintering, the coat should approximately be five times larger than the grain size of the metal powder being used. Initial preparation of the metal powder (e.g. water and gas atomization) considerably effects production costs, as well as technical specifications of the end-product. So far various materials such as iron, stainless steel, titanium and molybdenum have been well proven. Alloys of hollow spheres can also be produced in situ. Therefore different metal powders are simultaneously sprayed on the core, the formation of the alloy takes place during sintering. The approach of combining different metal powders to spheres is not only a more cost effective means of production, but also enables an amalgamation of low and high-cost powders. Using this technique one may improve the technical specification and could reduce the costs of production in comparison to spraying an alloy-powder.

*Binder.* Prior to coating the metal powders are suspended in a binder–water mixture. Selecting the appropriate binder system depends on certain criteria such its pyrolysis, its gluing ability and its rheological properties. The binding forces glue the metal particles onto the core and interconnect the particles. The binder agent is generally kept at a minimum in the suspension.

## 3. Manufacturing process

### 3.1. Coating

The suspension recipe of metal powder, water and a certain amount of binding agent is weighed and poured into a suspension-container, where the ingredients are stirred, forming a consistent suspension, avoiding any sedimentation. A certain amount of polystyrene spheres, according to the recipe are placed into the spray chamber of the coating apparatus (as described in Patent DE 197 50 042 C2 [1]), where they are fluidized and rotated. The pump releases an exact amount of suspension through a nozzle onto the rotating and fluidized polystyrene spheres. The following picture (Fig. 1) shows the manufacturing process.

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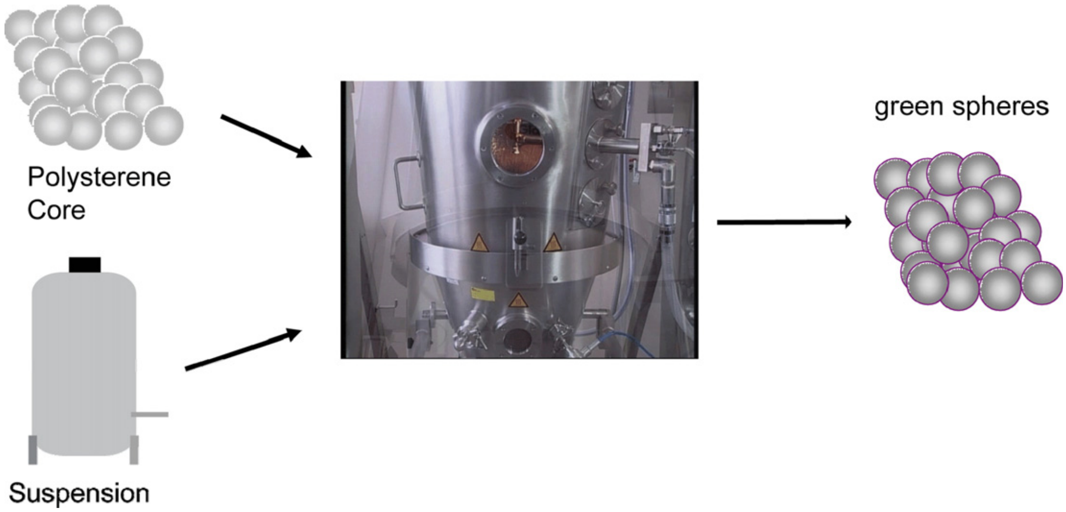


**Fig. 1.** Manufacturing process of green spheres.

The following factors should be considered:

- The spherical shape is affected by the precise moisture content of the spray. An overly moist process will cause agglomeration, whereas a process that is too dry will cause the spheres' surface to become uneven and fixation on the core is poor.
- Consistency and density can be controlled by the rotational speed of the coating apparatus.
- Droplet size discharged from the spray nozzle also contributes to consistent application of the suspension. An over accelerated spray process of smaller droplets will cause an increased amount of dust particles in the spray chamber, whereas agglomeration will occur if the droplets are too large.

The outer diameter of the hollow sphere is affected by the material being sprayed and the geometry of the equipment. For cost reasons, large-volume production metal hollow spheres are generally produced by this method are in a range of 1 and 15 mm in diameter. Shell thickness can be varied, depending on the grain size and grain spectrum of the metal powder. Stronger, thicker shells with further increased solidity and robustness are always possible.

Outer shell characteristics such as porosity, density and grading are influenced by the coating and sintering process. The following microscopic shell dissections (cf. Fig. 2) highlight the hollow spheres' wide technological spectrum.

The hollomet technology furthermore enables a consistent and reproducible shell structure as well as an invariable constant hollow sphere size; advantageous compared to other cellular materials in both mass-produced articles made of hollow spheres and for simulating these materials.

The constant airflow during the manufacturing process enables the polystyrene spheres (green-spheres) to dry and sufficiently harden after the coating process. Once sufficiently hardened they are pneumatically ejected from the spray chamber. Now the green hollow spheres are prepared for the final heat treatment, i.e. debinding and sintering.

### 3.2. Heat treatment

A further important stage in the production of metal hollow spheres is the heat treatment, where the green-spheres are transformed into solid hollow sphere shells by sintering. The basic concept of heat treating hollow spheres is very similar to that of metal injection moulding (MIM). Heat treatment is carried out in two phases. During the first stage the polystyrene core and the binding agent are removed by pyrolysis. In the second phase the aggregation of the metal powders to a solid metal takes place, i.e. the end product is sintered and hardened.

#### 3.2.1. Debinding

During the de-binding process all organic parts within the green-spheres, i.e. the EPS core and the binder are pyrolised. For metallic systems this step is usually carried out under inert gas like hydrogen or endo-gas or in vacuum enabling an optimized temperature control and a reduced risk of oxides building up within the shell. Furnace temperatures and heating rates depend on the amount and kind of binder material and EPS used in the green-spheres. Once the de-binding process has been completed the previous green-spheres turn a brownish colour, which is the result of small metal powder particles having been bound together, hence the spheres are now called brown spheres. These brown spheres are fragile structures out of loose interconnected metal particles.

#### 3.2.2. Sintering

Sintering follows the debinding process, where single powder particles amalgamate to form the outer hollow sphere's shell. Sintering occurs when powder particles are heated up to about 80% of their melting temperature. This process step is carried out in vacuum or inert gas to avoid surface reactions of the metal powder. Such surface reactions

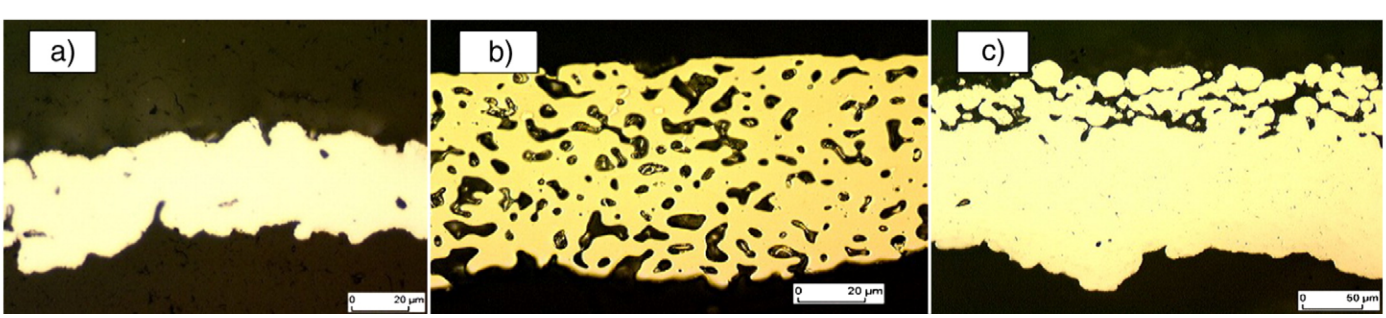


**Fig. 2.** Shell dissections: a) thin dense shell, b) porous shell, c) graded shell.