PM Steels Approaching the Performance of Wrought Steels

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Abstract

New applications for PM have resulted in a substantial market growth during the last decades. The clue to these components lies in the utilization of new powders and component production processes. In order to reduce development time and increase the probability for success it is essential to work in close cooperation within the whole chain from powder supplier to component supplier and component user.

Keywords : Component, fatigue, mechanical property, design

Introduction

Further inroads of PM components in automotives, home appliance, hand tools etc. will be possible only by providing advantages regarding price, performance and quality as compared to other manufacturing technologies. To fulfill the end user needs, all parties having influence on cost/performance/quality have to work closely together. This paper presents the importance of such collaboration especially between component manufacturer and powder producer.

2. Component design

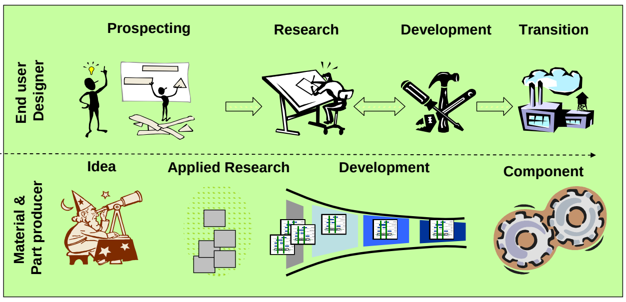

Fig. 1. Early cooperation between designer, part producer and material supplier.

The designers of cars, motors and home appliance equipment have to consider future demands very often five years or more ahead. The requirement for low energy consumption is a major task but also high performance and comfort represent strong market needs. Environmental considerations are also strongly influencing the design and material choice.

The design of an assembly consists of a large number of components which together give the function of the assembly. This can for example be a section of manual transmission, a valve system for a combusting engine or a torque transmission system in a hand tool. In all cases it is essential that the designer is aware of the individual design opportunities for each component. For mechanical devices requiring high strength the obvious material choice is wrought steel machined to the required shape and tolerances. However, design opportunities of PM components should be considered already at this early development stage (fig. 1). At a later stage in the design process the opportunities to influence the design and thus utilize the advantages of the powder metallurgy technology are very limited.

3. The Complexity of Powder Metallurgy

As compared to other manufacturing methods the PM process consists of a few steps to achieve the final design and performance. The prime reason for this is that no or very little machining is needed. The limited number of processing steps also reduces the costs thus being a competitive technology when it comes to large series and complex shapes.

The complexity of PM lies in the interaction between the three “ingredients” necessary to achieve a component. These “ingredients” are powder, compaction and sintering. A high level of knowledge of the relation between powder-compaction, compaction – sintering and sintering – powder is of utmost importance for high strength components in order to fulfill requirements for quality and cost (fig. 2).

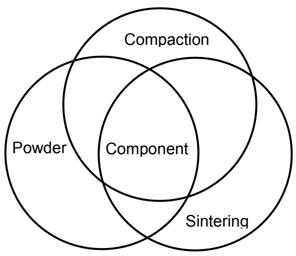

Fig. 2. Interaction between powder, compaction and sintering to fulfill component requirement.

At an early stage of component development the designer needs engineering data to evaluate alternative materials (ref. 1, 2, 3). The availability of material data for PM steels is today very good either through standards (i.e. ISO-material standard), from supplier of components, from powder supplier or from the newly launched "Global PM Property Data Base" which is a cooperation between EPMA, MPIF and JPMA.

Recently developed powder utilized in combination with modern compaction techniques and sintering methods reaches ultimate tensile strength levels of more than 1000 MPa. By heat treating those materials strengths above 1400 MPa can be achieved. Fatigue strength levels of above 350 MPa or even up to 500 MPa are possible to achieve. The latter value after surface modification by shot peening. The highest mechanical performance is achieved for materials with high density. A density of more than 7.5 g/cm^3 can for example be reached after single pressing and single sintering of a pre-alloyed powder with 1.5 % chromium and 0.2 % molybdenum. These material data is at the same level as that for wrought steel such as cast or forged. The obvious conclusion would be that PM steels should be chosen for all components with suitable shape under the condition that production cost is lower than for machined components.

The material data measured on test samples, however, do not always correspond to the actual stress/strain conditions of the final component (ref. 4, 5). There are primarily two reasons for this. One is that the density of the actual component in the stressed location differs from the density of the stressed location of the test specimen. The other reason is that the component or the test species are carburized or decarburized on the surface which strongly influences the mechanical performance. For this reason it is necessary for the designer of end user applications to work closely with the component and powder producer in order to optimize the design and manufacturing process for achieving the right level of quality.

4. Utilizing the Powder Metallurgy for Component Manufacturing

The unique opportunities of powder metallurgy are today utilized for many components both regarding design and material performance. The diffusion alloyed powders for example achieve a microstructure beneficial for preventing crack propagation and are therefore suitable for fatigue loaded parts. Other components can be compacted to high density at local areas with the objective to increase the strength locally at these points. The sinter hardening process has been developed utilizing the sintering furnace not only to sinter the compacted parts, but also to increase strength by rapid cooling and thereby form structural phases similar to those achieved by conventional heat treatment.

In case the "standard" PM processing steps cannot fully meet the component requirements other strength increasing methods are utilized. One of those with a great potential for future applications, especially gears, is surface rolling. This additive process results not only in a fully dense surface but also in very close dimensional tolerances similar to fine machining.

However, adding processing steps or making the manufacturing of components complicated results in higher manufacturing costs. In order to avoid cost increase machining must be limited which is possible if dimensional tolerances can be kept narrow and geometrical design is adjusted to uniaxial compaction and suitable tool design. The most common way to keep close dimensional tolerances is to use segregation free powders such as diffusion alloyed powders or bonded powders such as Starmix. The filling procedures of powder in the tool cavity as well as close control of the sintering process are other crucial processing steps for dimensional accuracy.

By identifying the critical dimensions of the final component it is possible to optimize the manufacturing process to these and still keep the production costs low.

5. Summary

The powder metallurgy manufacturing technology has the potential to grow substantially because it represents a cost efficient process for large series production and high strength levels can be achieved.

The condition for such growth is:

1) Close cooperation between designers, part producers and powder producers.
2) Cooperative development at an early stage.
3) Focusing on specific applications.
4) Establish reliable component design data.

6. References

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