PM Problem Solving Using Metallography

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***Abstract* –** Metallographic investigations have always been useful to find out the reasons for failure. The present paper contains PM industrial examples where the problems have been solved with the help of microstructural analysis. This analyses will help PM customers to become more aware about microstructures and their importance in order to produce better quality products and taking PM to a higher level.

Key words: Powder metallurgy, Powder Metal Component, Failure analysis, Microstructures

INTRODUCTION

Höganäs is the world leader in metal powder industry. Being a leader, there are several value added services Höganäs offers to their customers in order to help them grow and expand their business. Customer Service Investigation (CSI) is one of the value added service, where parts from the customer are investigated for different purposes like failure analysis, quality issues, setting sintering and heat treatment parameters etc. Every year increase in the CSI numbers confirms that it is being appreciated by the customers.
Most of the CSIs are solved using metallography techniques where the microstructure present in the samples are investigated and can tell what have happened to the parts during the processing and the properties of the component can be predicted.
PM microstructure analysis is always different than the conventional steels as it contains pores and heterogeneous structures which comes from mixing of different additives and alloying elements.

MATERIALS AND METHODS

When there is a failure of a component it is very important to investigate the component in the correct way. This to make sure that no information is lost or that you have introduced artifacts to the component during sample preparation which could lead to the wrong interpretation of the failure. The flow diagram in Fig 1 provides the order of the sample preparation and investigation steps carried out for metallography investigation. It also shows what needs to be considered in each step in order to minimize the artifacts caused by sample preparation.

The first step is to select the sample and to cut the component in such a way that you can get out relevant and right information for the investigation. While cutting, the sample will be mechanically deformed. This needs to be considered during the following grinding and polishing operations. While grinding, the metallographic samples will be grounded to the depth of un-deformed region. Polishing is another important step and it is different in PM materials as it contains pores. During cutting and grinding the pores will be smeared together. In order to open up the pores and be able to see the true porosity the samples needs to be polished (Fig. 2). Here it is important that the samples are polished the right time so that the pores are open correctly. If the polishing time is too short the pores will not be opened and if the time is too long the pores will be larger than they are in reality (Fig. 3). Partial or too much opening of pores may mislead to wrong conclusion of density distributions and further mechanical properties predictions. In this cases the

samples were polished in order to get the complete opening of pores present in the samples.

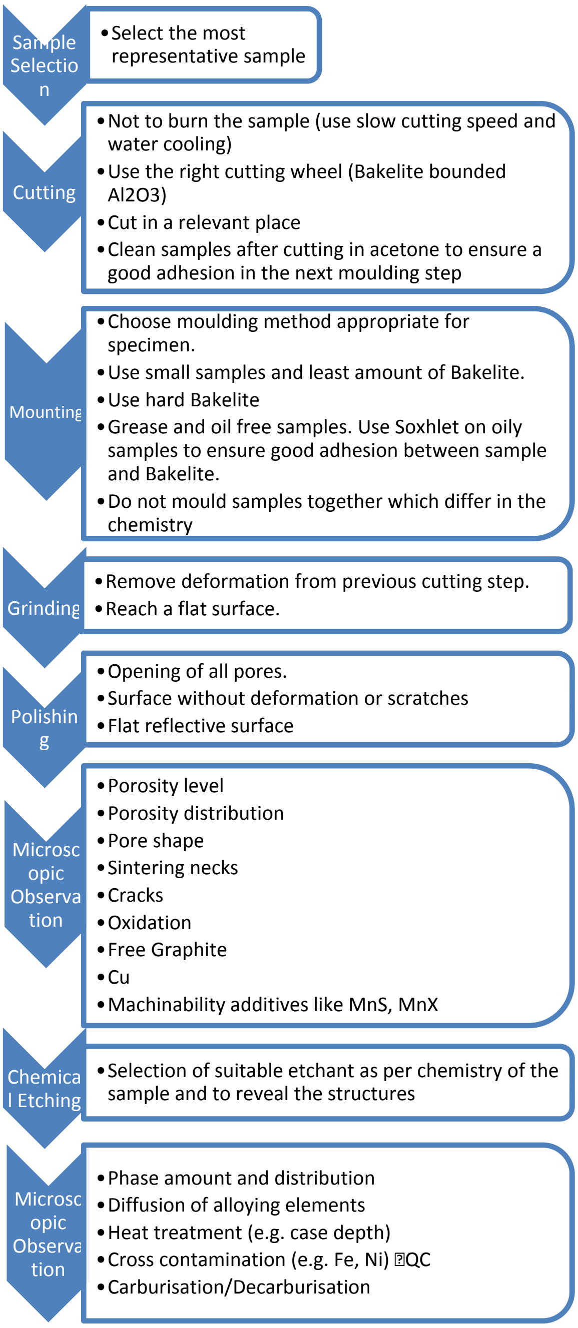


Fig.1: Process flow for metallographic sample preparation and investigation.

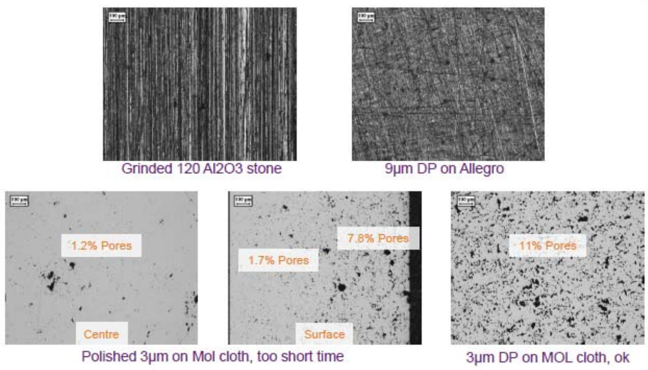


Fig.2: Porosity after grinding and polishing

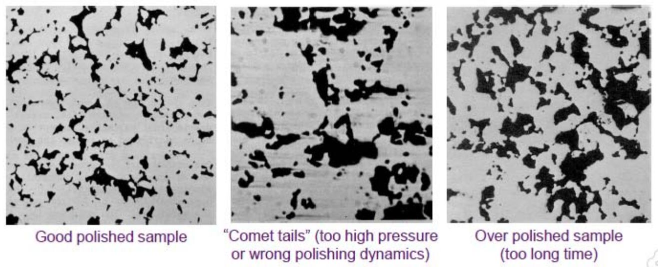


Fig.3: Example microscopic images showing difference between good and bad polished samples

When the sample have been polished it needs to be investigated in un-etched condition. In un-etched condition the porosity can be evaluated regarding density levels and quality of the sintering it will also give information regarding the compaction process and if there are cracks in the component. After the investigation of the component in un-etched condition it is time to etch the sample in order to investigate the phases and structures present in the component. This will give information about diffusion of alloying element, carburization/decarburization during sintering, heat treatment. It is important to choose the right etching agent in order to be able to reveal the phases and structures in the correct way. By combining the information found in the un-etched condition with the information that can be found in the etched condition it is possible to know the history of a component. All from what material has been used as well as how it has been processed like compaction, sintering and heat treatment. In the same way as

the history of a component are revealed the future can be predicted with what properties the component will have.

RESULTS AND DISCUSSION

As explained in the introduction parts, that this paper deals with the customer activities and the related investigations to solve the problems using metallography, the Results and Discussion parts is explained with the help of some cases.

1. Low Strength in a component

The customer noticed lower strength in the component inspite of using a high performance material Distaloy® HP. When the microstructure was investigated, cracks were found in the tooth. This was found to be the reason for the lower strength of the component (Fig. 4).

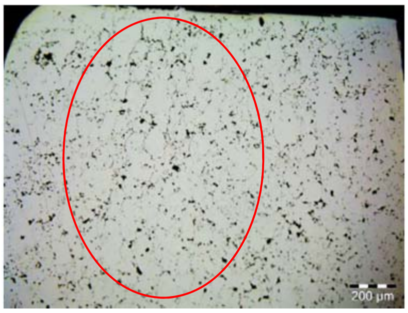


Fig.4: Encircled cracks present in the tooth of the component.

2. Poor Machinability

Component was made using Fe + 2% Cu + 0.3% MnS + 0.8% Lubricant. The Sintering was carried out at 1120°C for 30 min in 90/10 N_2/H_2 atmosphere. The component had machinability problem and experienced high tool wear.
The microstructure present in the part contained ferritic grains with brown Cu rich areas (Fig. 5) Ferrite is a soft phase compared to other phases and structure like pearlite. Here the ferrite created problems as it sticks to the tool. A solution here could be either to use another type of tool or have a small carburization of the surface during sintering which could improve the machinability of the material.

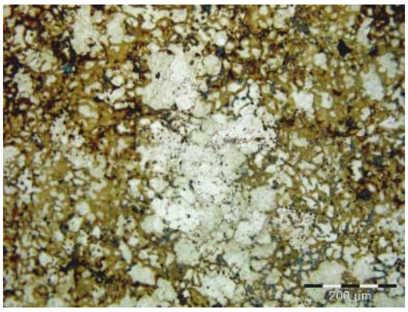


Fig. 5: Ferritic microstructure present in the component

3. Cracks in the component

A component got cracks after induction hardening. The carbon content was 0.35% which is low for a material that is Induction hardened. The microstructure in the sample was martensite with few areas of ferrite, white spots in (Fig. 6), in the induction hardened area. The ferrite areas in the martensite means that the part was not fully austenitized during the induction hardening[2]. Since ferrite and martensite have different tendency to grow it can result in the crack formation. It was suggested to revise the induction hardening parameters so that the part is fully austenitized another alternative could be to increase the carbon content in order to fully austenitize the material at lower temperatures.

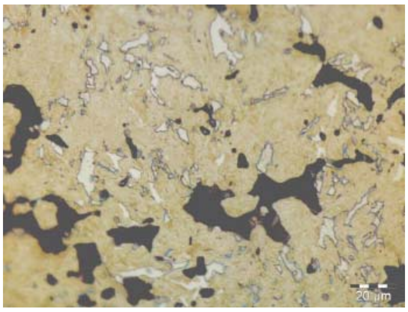
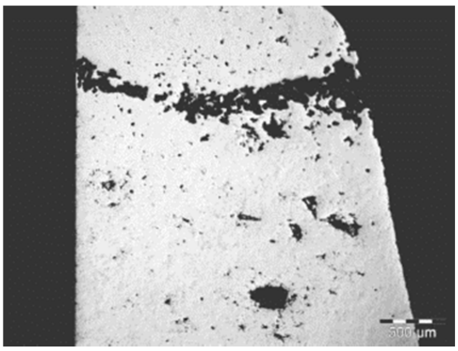


Fig.6: The microstructure in the induction hardened area of the component

4. Blow holes in a component

The customer was getting blow holes on the surface of the components. These defects were noticed during face machining at the time of assembly at OEM place. The un-etched microstructure revealed that there were large pores and voids in the component (Fig. 7). In the etched structure near the defect the microstructure was martensite with large amount of retained austenite and cementite while the normal area contained martensite. This means that the defect was caused by something that had high carbon content. In this case it was caused by agglomeration of graphite. This component generally contain high content of graphite in the mix which often leads to agglomeration and results in blow holes. Höganäs´s bonded mixes will help to avoid agglomeration hence, it was suggested to use a bonded mix instead of a premix.



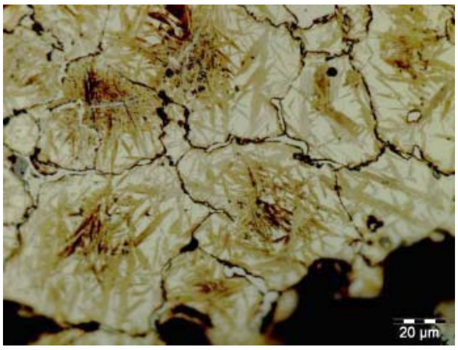


Fig. 7: The microstructure present in the component near the defect.

5. Poor heat treatment of Gears

The heat treatment parameters for PM parts is often different than conventional as it contained pores.

Due to the pores, the penetration rate of carbon increases for these parts. It is generally observed that in PM gears, tooth and tooth root shows different microstructure probably due to difference in cooling rate. In this case a small amount of bainite-soft areas were present in the tooth root of the gear, which will decrease the strength in the tooth root (Fig. 8). Here the heat treatment parameters needs to be adjusted in order to have a fully martensitic structure at the surface of the tooth root.

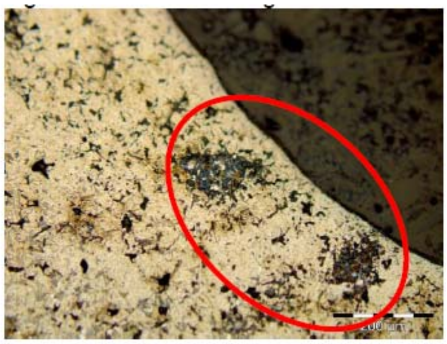


Fig. 8: Heat treated gear contained bainitic areas in the tooth root

CONCLUSION

All these examples of metallographic investigations of real cases shows that by investigating the microstructure both in un-etched as well as in etched condition will give you a lot of information on how the components have been processed. With this information it is possible to find the root cause of defected components.

REFERENCES

[1] Höganäs Handbook, Metallography
[2] G Krauss "Principals of Heat Treatment" 1993