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Determinants of the quality of sintered steel for the automotive industry

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Abstract The increasing demand on components obtained using powder metallurgy is driven by economic changes that have turned product quality into the most basic criterion which affects the interest in a component and its successful use. The improvement in quality should be expected in the beginning of the planning of the technological process and selection of adequate raw materials. High requirements concerning product quality management and production improvement stimulates the development of the current automotive industry where sintered steels represent the highest percentage of products. The multiphase sinters investigated in the study were prepared from two types of water–atomized steel powders: 316L and 409L. Optical microscopy, X–ray phase analysis and examinations of microhardness were performed in order to determine the microstructure and basic properties of sintered steels. The main assumption for this study was to analyse the microstructure and mechanical properties of sintered steels used for manufacturing of various car parts.

Key words – powder metallurgy, ISO/TS 16949, automotive industry

1. Introduction

Powder metallurgy (PM) is a technology used for manufacturing of structural materials from metallic powders with addition or without addition of non-metallic powders as a result of processes of forming and sintering. An interesting aspect of using the PM technology is a small number of process steps, which offer opportunities for bulk production of components with complex shapes while maintaining the dimensional precision and surface quality. Furthermore, a significant factor that makes the PM technology unrivalled is the degree of the consumption of raw materials of around 97%, which is considered as a chipless manufacturing of sinters (SHEPPARD L. 2007, WROŃSKA A., DUDEK A. 2014, LIPIŃSKI T. 2015).

Powder metallurgy of stainless steel components represents an important and dynamically growing sector of the PM industry. At present, the biggest consumer of sintered products is the automotive industry (ca. 73% of all sinters – see Figure 1). These products are mainly used for replacement of the components obtained using standard casting or forging methodologies. The most characteristic products of powder metallurgy for the automotive sector are parts of engines, bearings, gears, filters, pumps, rings in anti–lock ABS systems or flanges for exhaust systems (CIAŚ A., FRYDRYCH H., PIECZONKA T. 1992, ULEWICZ R., NOVY F., MAZUR M., SZATANIAK P. 2014, DUDEK A., WROŃSKA A., ADAMCZYK L. 2014).

The concept of quality has a long history and numerous definitions. One of them was created by Deming, who argued that quality is a *predictable degree of product homogeneity and reliability while keeping* *costs as low as possible and meeting market expectations* (PUENTE J., PINO R., PRIORE P., FUENTE D. 2002).

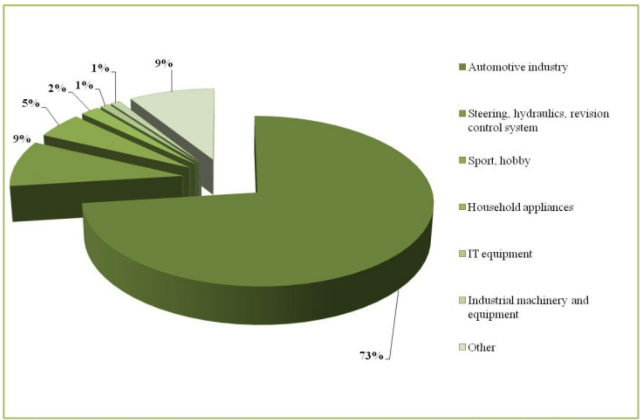


Fig. 1. Main customers for sintered products

Source: Author's own elaboration based on (CIAŚ A., FRYDRYCH H., PIECZONKA T., 1992)

The highest quality of products is expected in the automotive industry, leading to the necessity of certification for quality management standards (ISO/TS 16949) by suppliers of all components. ISO/TS 16949 defines the basic requirements concerning the quality at the initial stages of the research and development, material production, installation and service in the automotive sectors. The use of this specification is required over the whole supply chain, from producers of raw materials (steel, paint, polymers, composites) to companies that assemble bigger products (cockpit, gearbox etc.) (TORUŃSKI J. 2012, SPECYFIKACJA TECHNICZNA ISO/TS 16969:2002, SELEJDAK J. 2013, ULEWICZ R., MAZUR M. 2013).

2. Material and Methods

Sintered steels were made of water-atomized commercial powders 316L and 409L manufactured by Höganäs (Sweden). Table 1. presents chemical composition of the powders. The three different mixtures of ferritic and austenitic steel powders were prepared with the following composition: 80% 316L+20% 409L, 50% 316L+50% 409L, 20% 316L+80% 409L, which was subjected to uniaxial compaction at 720 MPa. The molded pieces were heated at the temperature of 1250°C for 30 minutes and then cooled at the rate of 0.5°C/s. The whole process was carried out in the reducing atmosphere using hydrogen which helps significantly limit oxidation of the batch and protects from reduction of the chromium content.

Table 1. Chemical composition of steel powders (%wt.)

Element	Powder grade	
	316L	409L
Cr	16.8	11.86
Ni	12.0	0.14
Mo	2.0	0.02
Si	0.9	0.82
Mn	0.1	0.14
C	0.022	0.02
S	0.005	0.01
Fe	Balance	Balance

Source: Author's own elaboration

The analysis of the microstructure was carried out using Axiovert 25 optical microscope. Vickers methodology (with load of 980.7 mN) was used to measure microhardness of the sintered stainless steel.

Identification of phase composition was carried out using the X–ray diffractometer (Seifert 3003 T–T) with a cobalt lamp with characteristic radiation wavelength of λ_{coka} = 0.17902 nm (Table 2. presents others parameters).

Table 2. X–ray diffractometer parameters

Parameters	Ranges
Supply voltage (U_r)	30÷40 [kV]
Current intensity (I_r)	30÷40 [mA]
Angle range (2θ)	10÷120°
Measurement step	0.1°
Pulse integration time (t_r)	10 [s]

Source: Author's own elaboration

3. Results and Discussion

The microstructures were observed using the metallographical sections etched with Nital. Figure 2 presents the microstructures obtained for sintered stainless steels by the optical microscope Axiovert 25.

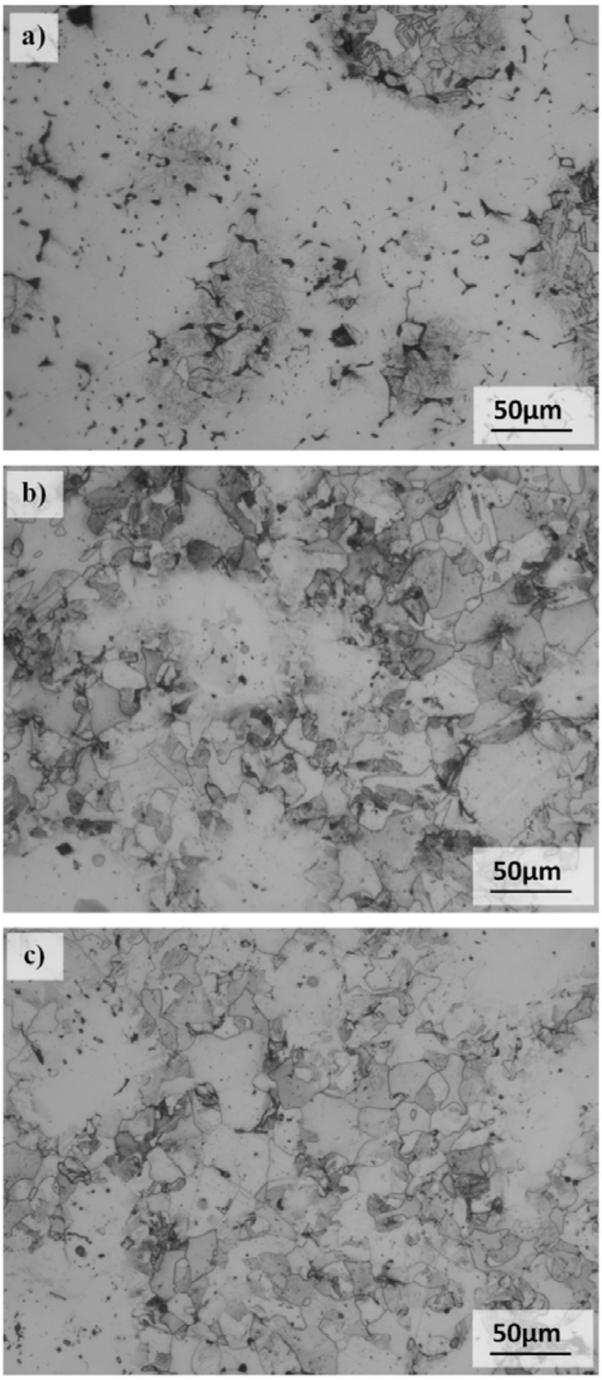


Fig. 2. Microstructure of sintered steels:
a) 80%316L+20%409L, b) 50%316L+50%409L,
c) 20%316L+80%409L

Source: Author's own elaboration

Hardness measurements were used to evaluate mechanical properties. The results represent the mean from four measurements (Figure 3).

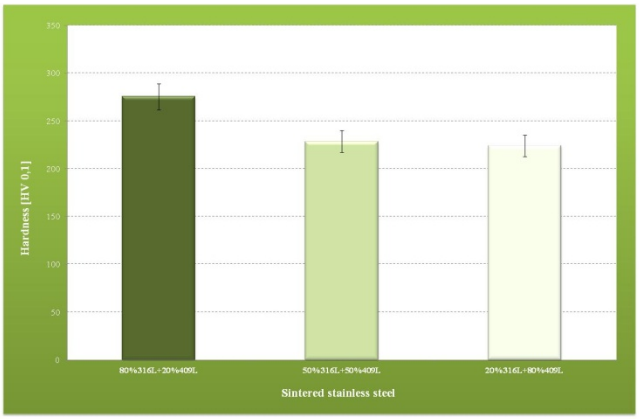
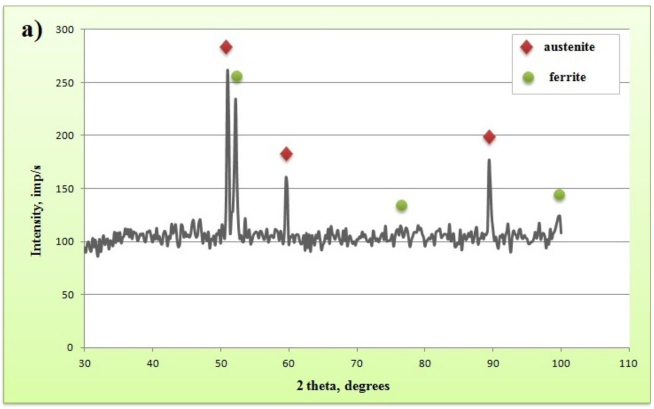


Fig. 3. Microhardness of sintered steel

Source: Author's own elaboration

Identification of the phase composition of the surface layers in sintered steels was carried out based on X–ray phase analysis. The results are presented in Figure 4. The phase analysis for individual specimens revealed presence of the austenitic and ferritic phases with the content proportional to the powders used, which was confirmed by microscopic observations.



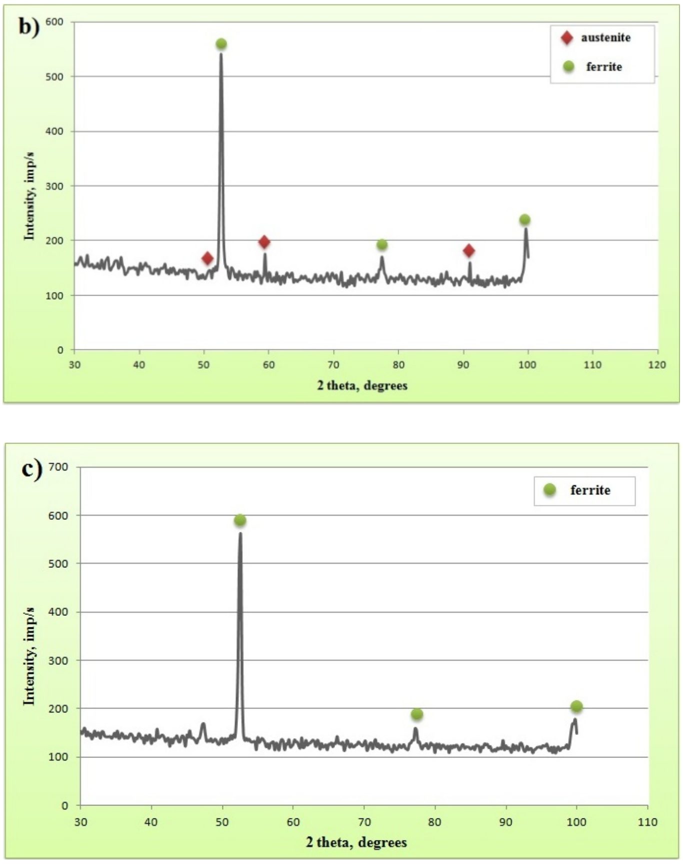


Fig. 4. Sinter diffractograms: a) 80%316L+20%409L, b) 50%316L+50%409L, c) 20%316L+80%409L

Source: Author's own elaboration

4. Conclusions

In an ever increasing climate of business competition, quality is expected in all types of services and commerce. It has a substantial effect on manufacturers, for whom quality should become a priority and on consumers, who have opportunities for finding the sources of supply they appreciate. A key decision is to properly choose materials for the components used in the automotive industry since this translates into the quality of the final product. Strength properties of the finished product depend directly on e.g. the structure, chemical composition and phase composition of the material. The sinters are selected depending on the expected application of the structural components of car parts.

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