The 19th Conference of Mechanical Engineering Network of Thailand
19-21 October 2005, Phuket, Thailand

Mechanical Properties of Sintered Dual Phase Stainless Steel Prepared from 304L and 410L Powders

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Abstract
Properties of sintered dual phase stainless steels, prepared from mixtures of different mass ratios of 304L and 410L powders, were investigated and compared to those of sintered 304L and 410L steels. The 100% 304L, 75% 304L-25% 410L, 50% 304L-50 % 410L, 25 % 304L-75% 410L and 100% 410L powders were processed using a 'press and sinter' technology. In order to examine physical and mechanical properties of sintered materials, the powders were compacted into tensile test bars, which were later debinded and sintered at 1280 °C for 45 minutes in pure hydrogen. It was found that dimensional change, particularly shrinkage after sintering, of the sintered dual phase stainless steels was lower than that of the sintered 304L or 410L alloys. Because of lower shrinkage, sintered density of the dual phase materials were lower than that of the sintered 304L or 410L alloys. The dual phase materials exhibited increase of ultimate tensile strength, yield strength and hardness with scarified elongation, when the 410L content was increased. The materials prepared from 25 % 304L-75% 410L showed the most significant increase of strength and hardness.

Keywords: Dual phase stainless steels, 310L, 410L, Stainless steel powders

1. Introduction

Development of a dual phase stainless steel (known as duplex stainless steel (DSS)) is one of many examples of alloy mechanical property improvement. The DSS refers to a stainless steel, whose microstructure contains both austenitic and ferritic phases [1]. This alloy exhibits better mechanical properties and corrosion resistance, compared to those of typical stainless steels (austenitic, ferritic, and matensitic). The outstanding properties of the dual phase stainless steel arise from combination of phase advantages. Because of their excellent properties, DSS are applied in a wide range of industries, especially in corrosive environment such as off-shore construction, heat-exchanger and gas/oil pipeline [2].

Wrought DSS is common for metallurgical world. However, to obtain this type of alloy usually faces fabrication difficulty. To obtain a dual phase microstructure, high accuracy temperature control furnace and high metallurgist experience are needed for manufacturing of the alloy.

Due to the manufacturing difficulties, powder metallurgy (P/M) process has been noticed and chosen as alternative production route of the dual phase stainless steel. The P/M process offers simple processing steps, powder mixing, compacting, delubricating and sintering. Although the P/M process is simple, processing of a mixture of austenitic and ferritic powders to produce an excellent dual phase material is tricky. Systematic and careful research and development has to be conducted for design and manufacturing of a P/M dual phase material.

In this research, dual phase material samples have been prepared from mixtures of varied 304L and 410L powder contents. In previous investigation, it was found that the dual phase material, prepared from 50 wt.% 304L and 50 wt.% 434L powders, exhibited interesting mechanical properties [3]. Further investigation of the combined 304L + 434L material on the effect of 310L/410L ratio has been carried out. The output is presented and discussed in this article.

2. Experimental Procedure

Raw materials, employed for experimental works, were 304L and 410L stainless steel powders (Coldstream, Belgium).

Dual phase powders were prepared from mixtures of different mass ratios of 304L and 410L powders, as shown in Table 1. The 304L and 410L powders were weighted and mixed. Mixing time was 8 hour in order to obtain a homogeneous distribution of different phases. Zinc strearate (1.0 wt.%) was added to the mixed powders. Mixed powders were press into tensile test bars (ASTM E8-96) at 650 MPa with a uniaxial press. Pressed parts (known as "green parts") were then sintered at 1280^{o}C for 45 minutes in pure hydrogen atmosphere.

Dimensions of green and sintered test bars were measured for calculating of dimensional changes from the die size. Densities of green and sintered samples were determined using the Archimedes method. A universal testing machine (Instron model 8801) was employed to test mechanical properties of the sintered samples. Microstructures of the sintered parts were observed using optical microscopy.

Table 1 List of studied materials

wt-% of 304 L	wt-% of 410 L	Code
100	0	100 A
75	25	75 A
50	50	50 A
25	75	25 A
0	0	0 A

3. Results and Discussion

Dimensions of green and sintered parts were measured for calculating of the dimensional change from die size. For each samples, three positions, designated as grip (P1), gauge (P2) and length (P3), were measured. The calculated dimensional changes of different dimensions for the studied samples are shown in Fig 1.

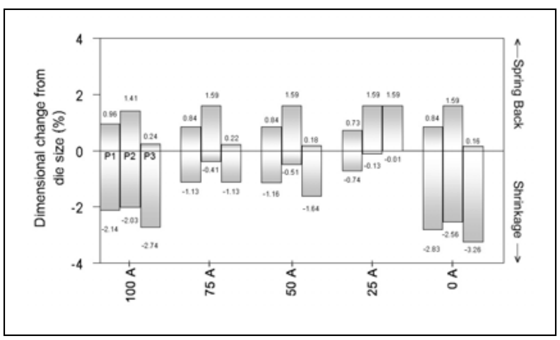


Figure 1. Dimensional change from the die size of green and sintered samples.

Spring back (expansion of pressed part dimensions after being ejected from die, illustrated in the upper part of Fig. 1 with positive value) of each studied samples showed the highest value at the P2 position, which has the smallest die wall to die wall distance. Due to the shortest distance, stress generated during compaction is expected to be highest. The highest stress causes highest spring back.

After sintering process, some sintered materials exhibit dimensional shrinkage. Shrinkage of the studied is shown in the lower part of Fig. 1 with negative value. Comparison shrinkage of the sintered 304L and 410L samples with the sintered dual phase samples showed that shrinkage of the sintered dual phase samples was lower. Note that shrinkage of the 25A sample exhibited the lowest value.

Sintered densities of the studied samples showed no significant difference (Fig. 2). The 25A sample exhibited the lowest sintered density. The sintered density values conform to the shrinkage data as mentioned above.

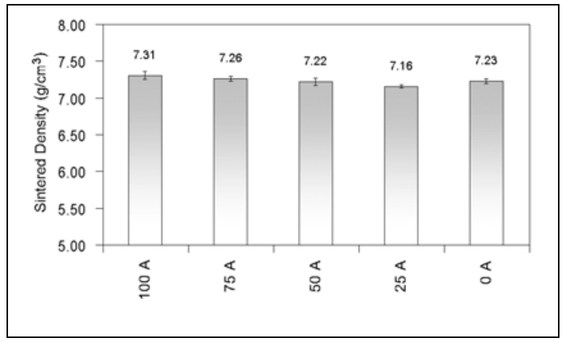


Figure 2. Sintered density of the studied samples.

Mechanical properties of the sintered dual phase samples are illustrated in Figs. 3-6. Yield strength, ultimate tensile strength and hardness of the sintered dual phase materials exhibited the same trend, in which strengths and hardness increased with increasing 410L content. It was noticed that the 25A sample showed significant improved yield strength, almost 2 times of yield strength of the sintered 304L material and significant higher than that of the sintered 410L material. Improvement of strength is very impressive.

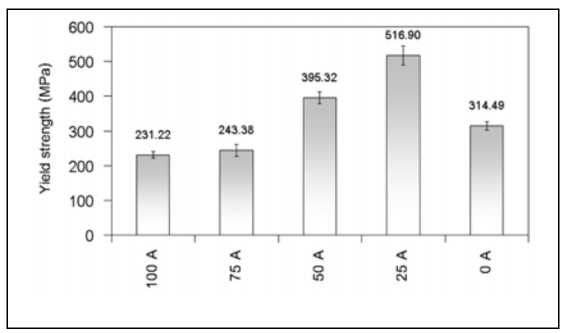


Figure 3. Yield strength of the sintered dual phase samples.

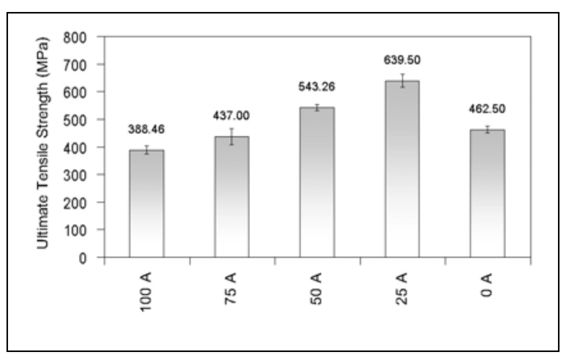


Figure 4. Ultimate tensile strength of the sintered dual phase samples.

In contrast, it was found that elongation of the sintered dual phase samples was dramatically decreased when the percentage of 410L was increased. Loss of the material ductility is needed to be improved in further investigation. Otherwise, the sintered dual phase materials will be considered as poor candidates for engineering parts applications.

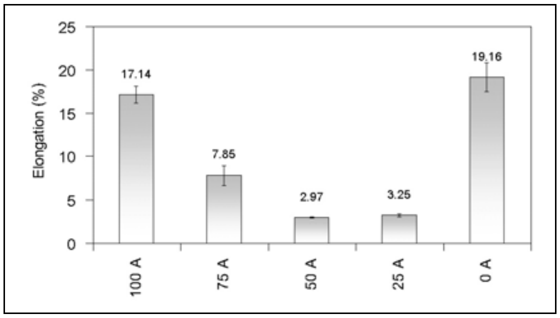


Figure 5. Elongation of the sintered dual phase samples.

Hardness values of the sintered dual phase materials were higher than those of the sintered 304L and 410L materials. The 25A sample showed the highest hardness. Hardness of the sintered dual phase samples was directly resulted from microstructural characters, shown in Fig. 7. It was observed that new phases were formed in the sintered dual phase materials.

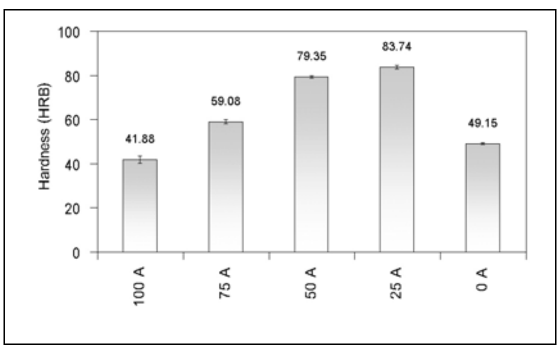


Figure 6. Hardness of the sintered dual phase samples.

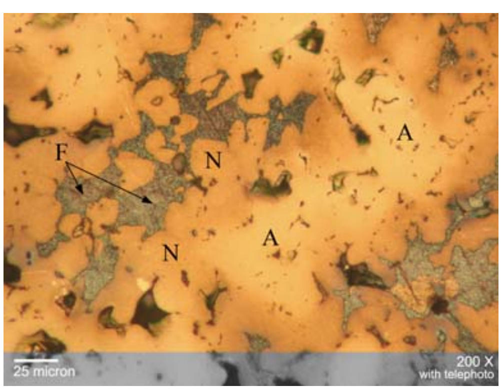
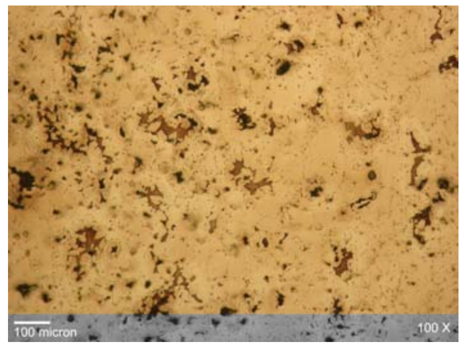
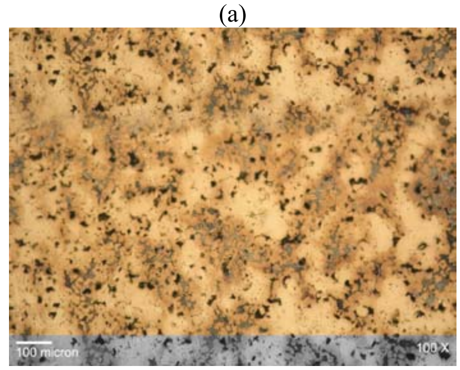


Figure 7. Microstructure of the 50A sample.

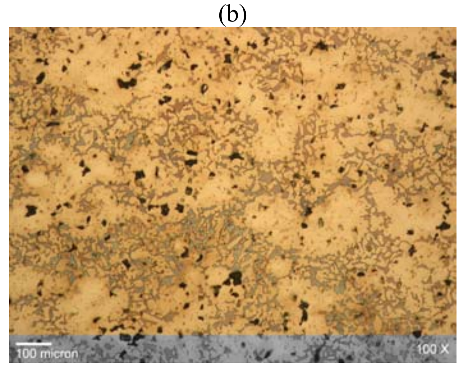
In order to observe microstructures, the sintered dual phase samples were polished and chemically etched using Behara reagent. Optical micrograph (Fig. 7) showed three phases with different morphologies. According to previous study by Puscas et al. [4], microstructure in Fig. 7 could be identified. The dark grey zone with irregular shape and rough texture was identified as a ferritic phase, designated as ‘F’. The lightest grey zone in a microstructure was an austenitic phase, designated as ‘A’. The pale grey zone between ferrite and austenite phases was a new phase, designated as ‘N’.



(a)



(b)



(c)

Figure 8. Microstructure of the sintered dual phase samples (a) 75A (b) 50A and (c) 25A.

The new phase is the mixture of ferritic, austenitic and matensitic phases. This phase is formed by diffusion of Ni from austenite into ferrite during sintering [4]. Micro-hardness tests performed on each phases showed that the new phase exhibited the highest micro-hardness. Hardness of the new phase was 30% higher than that of the austenitic phase.

The number of the new phase increased with increasing 410L powder content (Fig. 8). Diffusion of Ni to 410 powder particles causes formation of the new phase. When the Ni receivers are increased, probability for new phase formation is also increased. Volume fraction of the new phase seems to affect mechanical properties of the sintered dual phase materials. Increase of the new phase volume fraction (Fig. 8) results in improved strengths and hardness (Fig. 3,4 and 6).

4. Conclusions

Sintered samples, prepared from mixtures of 304L and 410L powders, exhibited microstructure consisting of ferritic, austenitic and new phases. The new phase is formed by diffusion of Ni from 304L to 410L. The new phase is the combination between austennetic, ferritic and matensitic structures. The new phase, whose volume fraction is increased with 410L content, enhances the mechanical properties of the sintered samples. Yield strength, ultimate tensile strength and hardness of the sintered dual phase materials are higher than those of the sintered 304L and 410L materials. Loss of ductility may lead the sintered dual phase materials to be poor candidate for engineering applications. Ductility improvement is recommended for further investigation.

Acknowledgment

The authors would like to express their sincere gratitude to Metal and Materials technology Center (MTEC) for financial support for this investigation.

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References

[1] ASM, Practical Handbook of Stainless steel & Nickel Alloys, CASTI Publishing Inc., Canada, 1999, pp. 181-183

[2] P. Datta and G.S. Upadhyaya, “Sintered duplex stainless steels from premixes of 316L and 434L powders”, *Mater. Chem. Phys.*, Vol. 67, 2001, pp. 234-242

[3] N. Kuljittipipat, N. Tosangthum, O. Coovattanachai, R. Krataitong, S. Mata, A. Daraphan, B. Vetayanugul, N. Poolthong and R. Tongsri, “Mechanical Properties of Austenitic + Ferritic Stainless Steels Prepared by Powder Metallurgy”, NSTDA Annual Conference, Phatumthani, Thailand, 28-30 March 2005, pp. 56.

[4] T. M. Puscas, A. Molinari, J. Kazior, T. Pieczonka, and M. Nykeil, “Sintering transformation in mixtures of austenitic and ferritic stainless steel powders”, *Powder Metall.*, Vol. 44, 2001, pp. 48-52