Development of High Strength Sintered Steel by High Pressure Warm Compaction Using Die Wall Lubrication

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Abstract

The high pressure compaction without internal lubricant and the high green density even with the pore free density were achieved by the newly developed die wall lubricant for warm compaction. This developed die wall lubricated warm compaction followed by high temperature sintering resulted in not only the superior mechanical property but also the low dimensional change. In this paper, the effects of increasing the green density on the sintered density, the dimensional change and the mechanical property are mainly discussed

Keywords: **die wall lubrication, warm compaction, high pressure compaction, green density, high temperature sintering, sintered density, dimensional change, mechanical property**

1. Introduction

To expand the use of Powder Metallurgy (P/M) steel parts to new applications, the mechanical performance needs to be improved and cost effective materials need to be used. Since increasing the green density results in the high sintered density and low dimensional change, the cost reduction from the omission of finish machining as well as the improvement of mechanical properties can be expected. Though the conventional warm compaction achieves the high green density of 7.4g/cm^3, the attainable mechanical property is not enough for automotive high performance parts.

Since the developed die wall lubricant for warm compaction realizes the high pressure compaction without internal lubricants and the high green density of 7.6g/cm^3 or higher, the higher mechanical property than in case of the conventional warm compaction process can be expected [1].

The purpose of this paper is to investigate the effects of increasing the green density on the sintered density, the dimensional change and the mechanical property of test pieces prepared by the developed die wall lubricated warm compaction process and followed by the high temperature sintering.

2. Experimental and Results

In this study four kinds of powder mixes based on the low alloyed steel powders (Höganäs AB) were utilized. The compositions are listed in Table 1. All powder mixes did not contain any internal lubricants. Warm compaction was performed at 423K using lithium stearate as the die wall lubricant. All specimens were sintered in the carbon/carbon composite mesh belt furnace (Kanto Yakin Kogyo Co.Ltd., Oxynon) at 1623K for 3.6ks. The furnace atmosphere was pure nitrogen with a dew-point < -70 °C. Sintered specimens were austenized at 1133K in pure nitrogen for 2.7ks. The heated specimens were quenched into oil preheated to 333K and tempered in air at 463K for 3.6ks.

Table 1. Composition of the investigated mixes

Materials	Pre-alloyed Element (wt%)	Diffusion Alloyed Elements (wt%)			Mixed (wt%)
	Mo	Mo	Cu	Ni	C
PA1	1.5	–	–	–	0.5
PA2	1.4	–	–	2.0	0.5
PA3	1.4	–	2.0	4.0	0.5
DA1	–	0.5	1.5	4.0	0.5

In this study, warm compaction was performed up to 1176MPa and there is no galling on the green compaction surface for any of the material. The densification of green specimens continues as the compacting pressure increased in all materials. At 1176MPa, the high green densities of 7.68g/cm^3 in DA1 and 7.60 g/cm^3 in PA1, PA2 and PA3 were attained.

Fig.1 shows the effects of compacting pressure on sintered density. In PA1, PA2 and PA3, the sintered densities are higher than the green densities up to 980MPa.

Eventhough the sintered densities are slightly less than the green densities at 1176MPa, remarkably high sintered densities of 7.55g/cm^3 or higher are observed. In DA1, the sintered density is higher than the green density up to 784MPa and slightly lower than the green density at 980MPa. At 1176MPa, the sintered density is much lower than the green density because of the swelling of the green specimen during high temperature sintering.

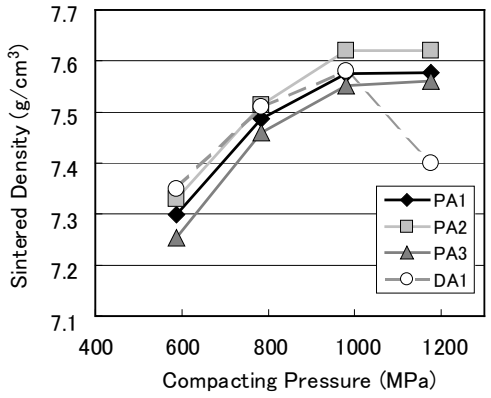

Fig. 1. Effects of compacting pressure on sintered density

Fig.2 shows the effects of compacting pressure on dimensional change. For all the materials, the dimensional change increases as a function of compacting pressure. Almost no dimensional change occurs from 784MPa to 980MPa in DA1 and from 980MPa to 1176MPa in PA1, PA2 and PA3. In DA1, a considerable swelling was observed at 1176MPa.

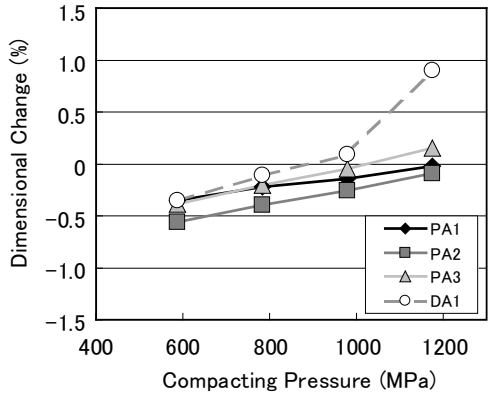

Fig. 2. Effects of compacting pressure on dimensional change

Fig.3 illustrates the relationship of transverse rupture strength (TRS) and tensile strength (TS) in PA1, PA2 and conventional processes. In PA1 and PA2, TRS and TS show high values of 3000MPa and 2000MPa or greater, respectively. These values are much higher than those manufactured by conventional processes, whereas the proportion of TS to TRS in PA1 and PA2 are similar to that in the materials manufactured by conventional processes.

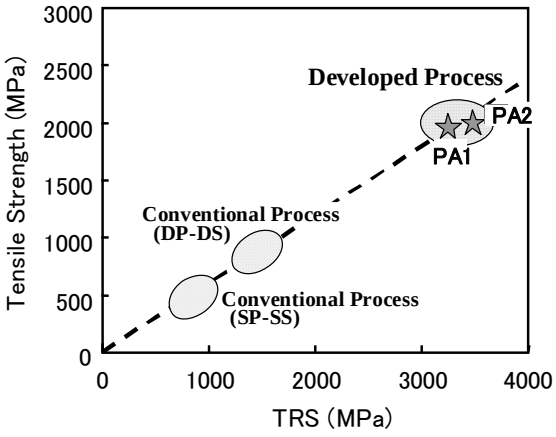

Fig. 3. Relationship of TRS and Tensile Strength(TS)

3. Summary

Based on the above observations, the following conclusions could be made.

1. The developed die wall lubricated warm compaction followed by the high temperature sintering enables remarkably high sintered densities of 7.6g/cm3 or higher.
2. Almost no dimensional change occurs at the compacting pressure from 784MPa to 980MPa in DA1 and at the compacting pressure from 980MPa to 1176MPa in PA1, PA2 and PA3.
3. Remarkable high transverse rupture strength of 3000MPa and tensile strength of 2000MPa or greater are achieved by the developed die wall lubricated warm compaction and, followed by high temperature sintering and heat treatment.

4. References

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