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# Effect of Adding Al-Ca Fluoride on Sintering Behavior of Aluminum-Bronze Powder

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**Abstract**

*In order to accelerate the sintering of Al-Bronze powder covered with passive oxide film, we focused on the way to add Al-Ca fluoride consisting of $AlF_3$ and $CaF_2$, examined the effect of the $CaF_2$ mixing rate in Al-Ca fluoride, the amount of the added Al-Ca fluoride and the sintering temperature on sintering properties of Al-Bronze powder and considered the mechanism of the sintering acceleration. Al-Bronze powder was sintered most effectively by adding Al-Ca fluoride with the $CaF_2$ mixing rate of 20mass%. If the amount of added fluoride was over 0.05mass% and the sintering temperature was over 1123K, the sintering acceleration of the Al-Bronze powder appears. Regarding the mechanism of the sintering acceleration, it was presumed that $Al_2O_3$ film on the surface of the Al-Bronze particles was removed in the process of the formation of gaseous AlOF by the reaction with $AlF_3$, and the reaction was accelerated further by the presence of the liquid phase which is formed in Al-Ca fluoride.*

**Keywords : Al-bronze powder, fluoride, sinter, acceleration, mechanism**

## 1. Introduction

The attempts to manufacture Al-Bronze parts by powder metallurgy focusing on the mechanical properties and corrosion resistance of Al-Bronze have been being made, but they haven't been successful yet. The main cause why the sintering of Al-Bronze powder doesn't proceed is estimated because Al-Bronze powder is covered with passive oxide film. With this problem, we had already found and reported that the sintering of Al-Bronze powder proceeded effectively by adding $AlF_3$[1)], which is chemically very stable[2)]. In this study, with the purpose to furthermore accelerate the sintering of Al-Bronze powder, focusing on Al-Ca fluoride consisting of $AlF_3$ and $CaF_2$, we investigated the effect of the addition of Al-Ca fluoride on the sintering of the Al-Bronze powder and the mechanism of sintering.

## 2. Experimental Procedure

We used two kinds of Al-Bronze powders by water-atomization in this experiment, each of which were 7mass%Al and 10mass%Al composition, and both of which were the particle sizes of –150 μm. At first, Al-Ca fluoride of 0～2.0mass% made by mixing $AlF_3$ and $CaF_2$ at certain rates and zinc-stearate of 0.3mass% were added to the above Al-Bronze powders, and these powders were mixed in a mortar. The mixture was compacted into a ring-shape by the metal mold, and sintered with putting in a lidded boat made of stainless steel under $H_2$ atmosphere ( D.P = -30℃ ) at 1073～1273K for 1.8ks.

Of the sintered compacts prepared by this way, we measured the sintered density and the radial crushing strength, and some of them were observed by optical microscope.

With the purpose of examining the mechanism of the sintering acceleration, thermal-analysis and identification on the heat-treated Al-Ca fluoride by X-ray diffraction method were carried out.

## 3. Results and Discussion

### 3.1 The influence of the $CaF_2$ mixing rate in Al-Ca fluoride

Fig.1 shows the influence of the $CaF_2$ mixing rate in Al-Ca fluoride on the sintering density and the radial crushing strength of the sintered compacts of 7mass%Al powder. By adding only $AlF_3$, these values were already higher than those of non-adding specimens, and furthermore by mixing $CaF_2$ with $AlF_3$, these values became still higher. They were maximized at nearly 20mass% of the $CaF_2$ mixing rate in Al-Ca fluoride.

When the rate of $CaF_2$ exceeded 20mass%, these values decreased gradually, and when it went into the composition's area of $CaF_2$ primary crystals in $AlF_3$-$CaF_2$ pseudobinary system, a further decreasing of them proceeded. In the case of adding only $CaF_2$, lower values on both the above properties, rather than those of non-adding specimens, were shown.

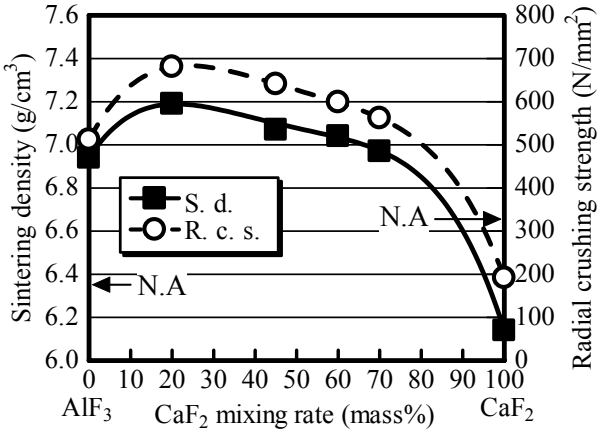


**Fig. 1. Influence of the $CaF_2$ mixing rate in Al-Ca fluoride on the sintering density and the radial crushing strength of 7mass%Al sintered compacts.**

**・Amount of added Al-Ca fluoride：0.1mass%**

**・N.A：Non-adding specimen**

### 3.2 The influence of the amount of added Al-Ca fluoride

Regarding the amount of added Al-Ca fluoride, it was found that the addition of only 0.05mass% of Al-Ca fluoride with the optimum mixing rate to Al-Bronze powder remarkably accelerated the sintering of Al-Bronze powder. And when the amount of added Al-Ca fluoride exceeded about 1.0mass%, the effect of the sintering acceleration began to decrease gradually.

### 3.3 The influence of the sintering temperature

Regarding the sintering temperature, the sintering acceleration caused by adding Al-Ca fluoride with the optimum mixing rate was recognized at 1073K. And when the sintering temperature exceeded 1123K, at which the liquid phase in Al-Ca fluoride would be formed, the sintered density and the radial crushing strength had a tendency to increase rapidly with increasing the sintering temperature, and these values were saturated at about 1223K.

Fig. 2 shows the optical microstructures of the sintered compacts by sintering at 1223K with 0.1mass% of Al-Ca fluoride. The structures were fine and the sintering of the powder particles proceeded so well that the original shapes of the powder particles were indistinguishable and the pores were round.

### 3.4 The mechanism of the sintering acceleration

Regarding the mechanism of the sintering acceleration of Al-Bronze powder with adding Al-Ca fluoride, it is estimated that the gaseous AlOF was formed by the reaction

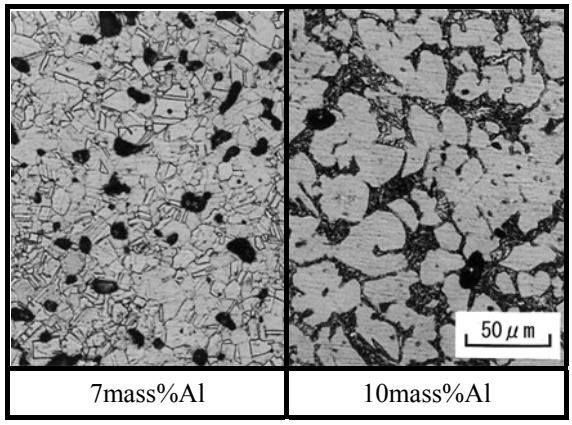


**Fig. 2.The optical microstructures of the sintered compacts**

between $AlF_3$ and $Al_2O_3$ film on the surface of Al-Bronze powder, and the above reaction was accelerated by the formation of $AlF_3$ vapor over a wide area with a phenomenon that the liquid phase in Al-Ca fluoride by the addition of $CaF_2$ into $AlF_3$ was formed and wetted the surface of the Al-Bronze powder.

## 4. Summary

We examined the effect on the sintering acceleration of Al-Bronze powder by adding Al-Ca fluoride, and it led to the following conclusions:

1) By adding Al-Ca fluoride consisting of $AlF_3$ and $CaF_2$, the sintering properties of the Al-Bronze powder were improved remarkably, and the sintered density and the radial crushing strength were maximized at nearly 20mass% of the $CaF_2$ mixing rate in Al-Ca fluoride.
2) Even if the amount of added fluoride is as small as 0.05mass%, the radial crushing strength of the sintered compact is higher than that of the non-adding specimen, and when over 1.0mass%, it began to decrease gradually.
3) When the sintering temperature exceeds 1123K that the formation of the liquid phase of Al-Ca fluoride begins, the sintered density and the radial crushing strength increased rapidly and these values were saturated at nearly 1223K.

## 5. Reference

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