Improvement of Machinability of PM Steels by Addition of $CaCO_3$ Based Compound

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Abstract

We investigated that the effect of $CaCO_3$ based compound on machinability of two types of PM steels. One is a copper steel which is selected as a general PM steel, and the other is a diffusion alloyed steel selected as a high strength PM steel. It is found that $CaCO_3$ based compound addition improves machinability in drilling of both of the PM steels. Although the compound addition degrades the mechanical properties of PM steels, it is considered that decrease of the properties can be compensated by increasing density.

Keywords: machinability, PM steels, $CaCO_3$ based compound

1. Introduction

Many PM components require machining operation to obtain final shape, because they need geometry or higher tolerance which compaction and sintering process can not achieve. Because demand for complicated geometry on PM component is increasing year by year, improving machinability of PM steels, especially high strength steels, is becoming more important.

In order to improve machinability of PM steels, an additive is occasionally mixed into raw powder. MnS and CaF_2 are well known as additives to improve machinability, and are often used for PM copper steels. However, the effect of these additives are insufficient for high strength steel, such as diffusion alloyed steels, it is desired to develope a new additive which improves machinability of high strength steels.

In this report, it is investigated that the effect of $CaCO_3$ based compound addition on machinability of two types of PM steels. One is a copper steel which is selected as a general PM steel, and the other is a diffusion alloyed steel selected as a high strength PM steel. It is also investigated that influence of $CaCO_3$ based compound addition on mechanical properties of the PM steels and machinability of a current product.

2. Experimental and Results

2.1 Experimental

2.1.1 Drilling test

Each powder mix shown in Table1 was pressed into a disk-shaped specimen of 30mm diameter and 10mm height. The green density of copper steels, A to C in Table1, was $6.7Mg/m^3$, and that of diffusion alloyed steels, D to F in the table, was $7.0Mg/m^3$. Sintering was conducted in an endo-gas atomosphere with a temperature of 1140 degree C for 20 minutes. The disk-shaped specimen was drilled with a diameter of 1.2mm high-speed steel drill under a drill revolution speed of 10,000r.p.m and a feed per revolution of 0.012mm/rev. The number of holes drilled by one drill was evaluated.

Table1. Chemical compositions.

Material	Powder (mass%)					
	Fe	Diffusion bonded	Cu	C	CaF_2	$CaCO_3$ based
A	bal.	—	2	0.7	—	—
B	bal.	—	2	0.7	1	—
C	bal.	—	2	0.7	—	1
D	—	bal.	—	0.5	—	—
E	—	bal.	—	0.5	1	—
F	—	bal.	—	0.5	—	1

Chemical composition of diffusion bonded powder is Fe-4mass%Ni-1.5mass%Cu-0.5mass%Mo.

2.1.2 Mechanical properties

Each powder mix of A, C, D and F was pressed into a bar of 55mm X 10mm X 10mm. The green density and sintering conditions were the same with those mentioned in 2.1.1. Tensile specimen was machined out from the bar. Hardness and tensile strength were evaluated.

2.1.3 Improving machinability of a current product

A current product shown in Fig.1 is made of material F, and its center part indicated by an arrow in the figure is machined out from a sinter by endmilling. Samples made of material F were prepared in the same manner with the current product. For this product, machining speed is much more important than tool life. Therefore, it was determined that the maximum machining speed at which vibration of the endmill does not occur. Hardness and crushing strength of the current product were compared with those of the sample.

Fig. 1. Appearance of the current product.

2.2 Results

2.2.1 Drilling test

The result of the drilling test is shown in Table2. From Table2, it is found that $CaCO_3$ based compound addition improves machinability of both types of the steels comparing with CaF_2 powder addition and non-addition.

Table2 The result of the drilling test.

Type of steel	Copper steels			Diffusion alloyed steels		
Material	A	B	C	D	E	F
Number of holes	82	309	1105	1	0	22

2.2.2 Mechanical properties

Table3 shows the mechanical properties of A, C, D and F materials. From Table3, it is found that hardness of PM steels is independ of the compound addition. On the other hand, tensile strength is decreased by the compound addition. It is considered that decrease of tensile strength can be compensated by optimization of the amount of the compound addition and increasing density. It was confirmed that decrease of tensile strength by addition of 1mass% of the compound, approximately 40 MPa for both materials, was compensated by raising up the density level of $0.1Mg/m^3$.

Table3 The influence of $CaCO_3$ based compound addition on hardness and tensile strength.

Type of steel	Copper steels		Diffusion alloyed steels	
Material	A	C	D	F
Hardness (HRB)	66	67	94	92
Tensile strength (MPa)	405	367	709	660

2.2.3 Improving machinability of a current product

The sample made of material F can be machined four times faster than the current product made of material D. It was also confirmed that tool life to machine the sample was longer than that to machine the current product. These facts shows that $CaCO_3$ based compound addition improves machinability in drilling of a diffusion alloyed steel component.

Table4 shows hardness and crushing strength of the current product and the sample. In Table4, hardness and crushing strength are expressed as ratio comparing with the specification. Although hardness of the sample is the same with that of the current product, crushing strength of the sample is inferior to that of the current product. However, crushing strength of the sample satisfies the specification, and also it is expected that crushing strength can be improved by increasing density.

Table4 Hardness and crushing strength of the current product and the sample expressed as ratio comparing with the specification.

	Current product	Sample	Specification
Hardness	1.1	1.1	1
Crushing strength	1.3	1.2	1

3. Summary

It is found that $CaCO_3$ based compound addition improves machinability in drilling of the PM steels. Although optimization of the amount of the compound addition and increasing density of components may be required, it is expected that $CaCO_3$ based compound improves machinability of a wide range of PM components, including high strength ones.