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Fabrication process of anisotropic NdFeB magnet by single stroke hot deformation

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1. Introduction

The single stroke hot deformation is the new and simple method for fabricating anisotropic NdFeB magnet that was first introduced by our laboratory. In order to get the optimum conditions, Taguchi method[6] of experimental design was used in this work. The optimum condition obtained on the basis of coercivity in Taguchi analysis was a little different from those of remanence and maximum energy product. The contribution of each factor to magnet properties is calculated in detail. From the results we can know which is the main factor and control it carefully.

2. Experimenta

The isotropic ribbon powder used was MQ powder (MQPA). The ribbon powder was first filled into the copper tube with the diameter of 13.1 mm and different heights by hand pressing at the room temperature with the pressure of 3000 psi in order to get dense compacts, then the copper tube was pressed in an Ar atmosphere at the temperature range from 600 to 750℃. The magnetic properties were measured by a hysteresisgraph system with the maximum field of 20 kOe after premagnetization at 90 kOe.

The Taguchi method of experimental design used in this study was the standard L9 array, which consisted of nine runs and allowed up to four factors to be varied at three levels.

3. Results and discussion

3.1 Coercivity

Taguchi analysis was carried out using coercivity as the response variable. And the results are shown in Fig. 1. As can be seen, for the coercivity of the magnet, the optimum fabrication conditions are the press temperature of 700 ℃, height of 15.1 mm, deformation percentage of 60 %, press time of 5 s.

Table 2 gives the contribution of each factor to coercivity. The order of significance to the coercivity from large to small is factor C > A > B > D, and the difference among factor A, B, C is small. So it may be concluded that those three factors (deformation percentage, temperature, height of copper tube) play the same important roles in the contribution to coercivity.

3.2 Remanence and Maximum Energy Product

Taguchi analyses were carried out with remanence and maximum energy product as the response variable respectively. The results are shown in Fig. 2 and Fig. 3. They show that the optimum conditions of the fabricating in this work are temperature of 650℃, sample height of 15.1 mm, deformation percentage of 60 %, and instant press.

Further calculations similar to section 3.1 are shown in Table 3 and Table 4. It shows that the factor A (temperature) is the most significant factor, its contribution being more than 70 %, followed by the factor C, B, D in the order from large to small.

4. Conclusion

According to Taguchi experimental design and ANOVA calculation, we know that those four factors of the single stroke hot deformation as mentioned above have different effect to hard magnetic properties, such as coercivity, remanence, and maximum energy product. The factor of temperature, height of copper tube, and deformation percentage has approximately one-third contribution to the coercivity, respectively. However, the aspect is quite different for the remanence and maximum energy product. The key parameter for remanence and maximum energy product is the temperature with the contribution of more than 70 %, next is deformation percentage with the contribution about 17 %.

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Table 1 Taguchi L9 array developed for detailed investigation of the anisotropic NdFeB magnet fabrication

Run No.	Temp. (℃) Factor A	Height (mm) Factor B	Def. Pct. (%) Factor C	Press time(s) Factor D	iHc (kOe)	Br (kG)	(BH)max (MG.Oe)
1	650	7.9	70	5	7.9	10.3	22.8
2	700	7.9	50	0	11.5	9.4	18.3
3	750	7.9	60	10	9.2	7.7	10.4
4	650	9.9	60	0	11.9	10.5	24.5
5	700	9.9	70	10	6.8	8.2	11.0
6	750	9.9	50	5	3.8	5.0	0
7	650	15.1	50	10	14.8	8.6	16.0
8	700	15.1	60	5	24.2	9.7	22.4
9	750	15.1	70	0	5.7	6.9	5.7

Table 2 ANOVA table for coercivity as response variable

Column	Factor	f	S	V	P
1	A	2	97.962	48.981	32.8
2	B	2	87.695	43.848	29.3
3	C	2	105.015	52.508	35.1
4	D	2	8.349	4.174	2.8
Total			299.022		100.0

Table 3. ANOVA table for remanence as response variable

Column	Factor	f	S	V	P
1	A	2	17.749	8.875	70.9
2	B	2	2.309	1.155	9.2
3	C	2	4.003	2.002	16.0
4	D	2	0.976	0.488	3.9
Total			25.036		100.0

Table 4. ANOVA table for maximum energy product as response variable

Column	Factors	f	S	V	P
1	A	2	403.307	201.653	71.4
2	B	2	42.747	21.373	7.6
3	C	2	96.987	48.493	17.2
4	D	2	21.660	10.830	3.8
Total			564.764		100.0

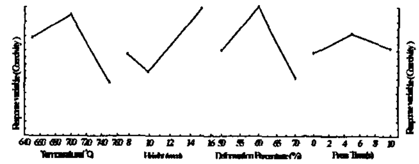

Fig. 1 Taguchi analysis of L9 array using coercivity as the response variable

Fig. 2 Taguchi analysis of L9 array using remanence as the response variable

Fig. 3 Taguchi analysis of L9 array using maximum energy product as the response variable