Optimization of Die Press Model

(TEAM Workshop Problem 25)[1]

1. General Description

Fig.1 shows a model of die press with electromagnet for orientation of magnetic powder [1]. This is used for producing anisotropic permanent magnet. The die press and electromagnet are made of steel. The die molds are set to form the radial flux distribution. The magnetic powder is inserted in the cavity. The model can be assumed as two-dimensional.

The aim of this problem is to obtain the shape of the die molds by using the optimization method. The effect of optimization method on number of iterations, accuracy etc. should also be investigated.

2. Definition of Problem

The B-H curve of the steel shown in Fig.2 is to be used. The typical values of B (T) and H (A/m) are shown in Table 1.

2.1 Specified values and unknown variables

The ampere-turns (dc) of each coil are chosen as 4253AT and 17500AT respectively.

(a) Small Ampere-Turns (4253AT)

x- and y- components Bx and By of flux density at the points along the line e-f in the cavity are specified as follows:

$$\left.\begin{aligned} Bx &= 0.35\cos\theta\,(T) \\ By &= 0.35\sin\theta\,(T) \end{aligned}\right\} \qquad (1)$$

where θ is the angle measured from the x-axis.

By the preliminary analysis, it is clarified that the specified flux distribution can be nearly obtained by assuming the shape of die press by the combination of straight

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line, circle and ellipse. The shape of the inner die mold is assumed as a circle. The inside shape of the outer die mold is represented by the ellipse and a line parallel to the x-axis as shown in Fig.1. Then, the radius R_1 of the inner die and the long and short axes L_2 and L_3 of ellipse and the dimension L_4 are chosen as design variables.

The shape g-h of the inner die mold and the inside shape i-j-k-m of the outer die mold can also be represented by free curves.

(b) large ampere-turns (17500AT)

Bx and By along the line e-f are specified as follows:

$$\left.\begin{aligned} Bx &= 1.5\cos\theta\,(T) \\ By &= 1.5\sin\theta\,(T) \end{aligned}\right\} \quad (2)$$

In this case, the shape of the inner die mold and the inside shape of the outer die mold cannot be represented by a circle and an ellipse like the case of small ampere-turns. The shapes g-h and i-j-k-m can be represented by free curves.

2.2 Objective function

The objective function W is given by

$$W = \sum_{i=1}^{n} \left\{ \left(B_{xip} - B_{xio}\right)^2 + \left(B_{yip} - B_{yio}\right)^2 \right\} \quad (3)$$

where n is the number of specified points (=10). The subscripts p and o mean the calculated and specified values respectively.

2.3 Constraints

The constraints of R_1, L_2, L_3 and L_4 can be, for example, represented as follows:

$5 < R_1 < 9.4$
$12.6 < L_2 < 18$
$14 < L_3 < 45$
$4 < L_4 < 19$

3. Items to Compare

3.1 Final shape (Optimal Shape)

The final shape of die molds which is obtained using the optimization method should be shown.

3.2 Flux densities

The amplitude |**B**| and angle θ_B of flux density vector along the line e-f (R=11.75) in the cavity are to be compared. |**B**| and θ_B of the final shape of die molds which are obtained using the optimization method should be written in Table 2.

3.3 Solution form

To compare optimization methods, obtained final shapes, etc., please complete Table 3. The maximum error $\varepsilon_{\theta max}$ of the amplitude and the maximum error $\varepsilon_{\theta max}$ of the angle of flux density vector are defined as follows:

$$\left.\begin{aligned} \varepsilon_{B\,max} &= \max\left|\frac{B_p - B_o}{B_o}\right| \times 100\% \\ \varepsilon_{\theta\,max} &= \max\left|\theta_{Bp} - \theta_{Bo}\right| \end{aligned}\right\} \qquad (4)$$

where the subscripts p and o mean the calculated and specified values respectively.

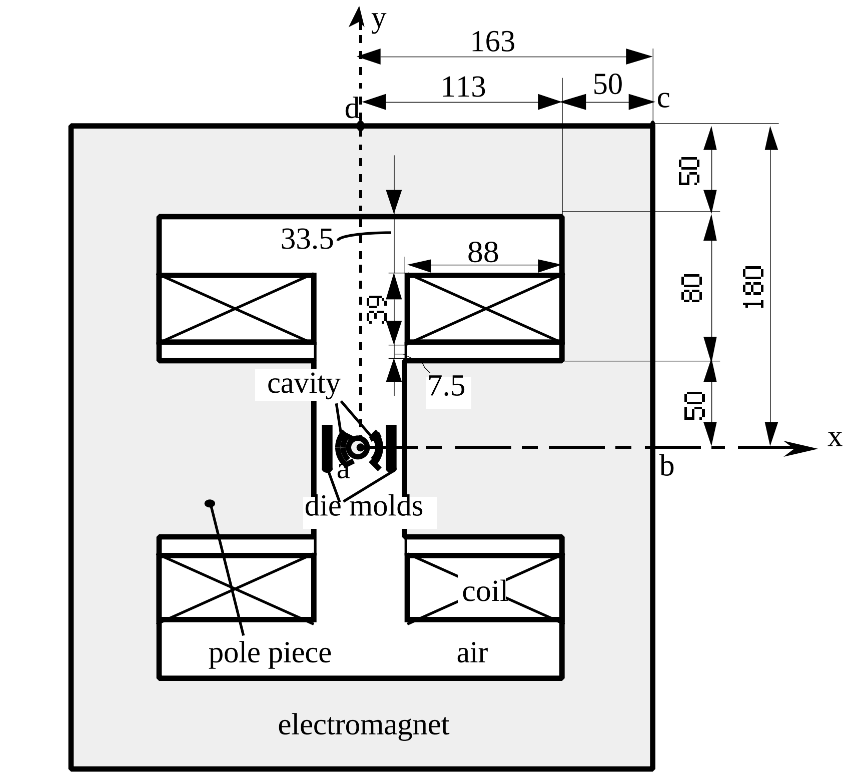
4. Measurement

The die molds of initial and final shapes are produced and the flux distribution in the cavity is measured. The number of turns of each coil is 243. The thickness of the electromagnet and die molds is 100mm(2-D model).

The x- component of flux density is measured using a Hall probe at 0^o, and the y-component is measured by rotating a Hall probe at 90^o using a goniometer. The comparison of measurement and calculation is reported in reference [1].

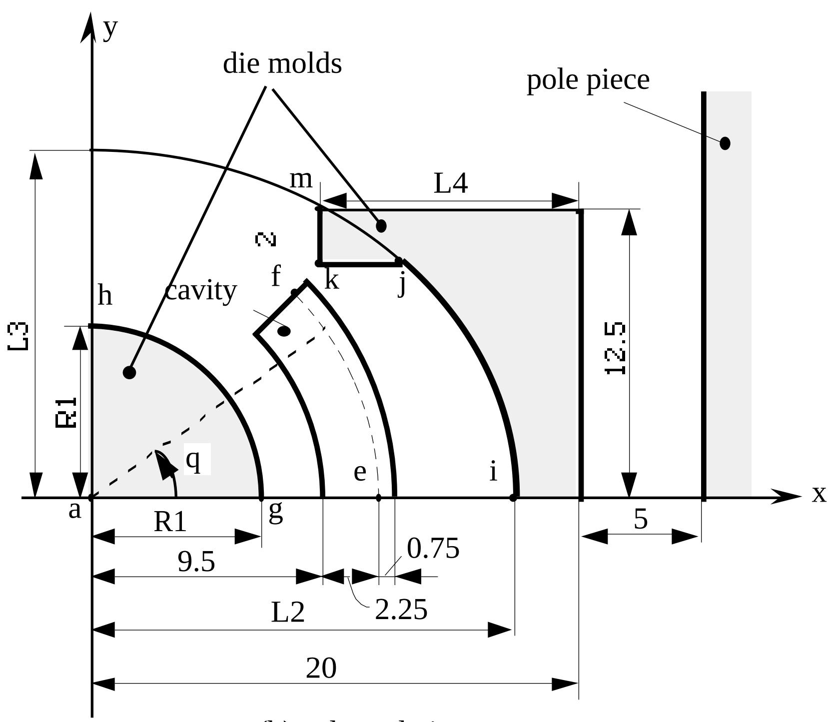
Reference

[1] N.Takahashi, K.Ebihara, K.Yoshida, T.Nakata, K.Ohashi and K.Miyata: “Investigation of simulated annealing method and its application to optimal design of die mold for orientation of magnetic powder”, IEEE Trans. on Magnetics, 32, 3, pp.1210-1213, 1996.



a-b-c-d: Dirichlet boundary
d-a: Neumann boundary

(a) whole view



(b) enlarged view

Fig.1 Model of die press with electromagnet.

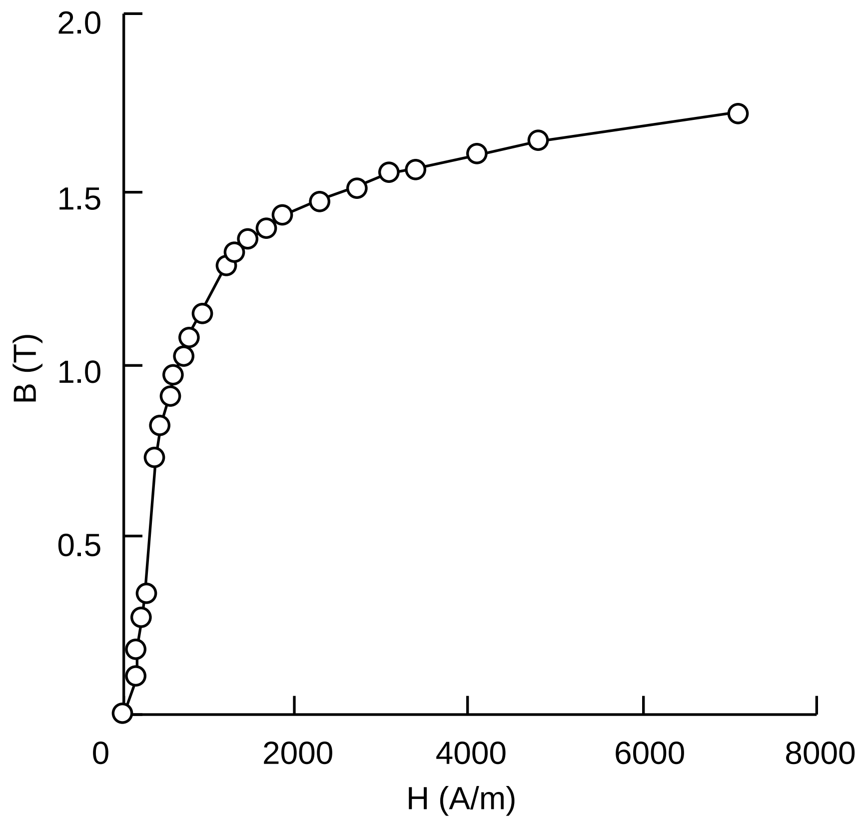


Fig.2 B-H curve of steel.

Table 1 Data of B-H curve

B (T)	H (A/m)	B (T)	H (A/m)
0.00	0	1.27	1164
0.11	140	1.32	1299
0.18	178	1.36	1462
0.28	215	1.39	1640
0.35	253	1.42	1851
0.74	391	1.47	2262
0.82	452	1.51	2685
0.91	529	1.54	3038
0.98	596	1.56	3395
1.02	677	1.60	4094
1.08	774	1.64	4756
1.15	902	1.72	7079

Table 2 Flux density in the cavity (see Fig.1 and Eqs.(1) or (2))

No.	Position along line e-f		$\|B\|$ (T)		θ_B (deg)	
	R (mm)	θ (deg)	4253AT	17500AT	4253AT	17500AT
1		5				
2		10				
3		15				
4		20				
5	11.75	25				
6		30				
7		35				
8		40				
9		45				

Table 3 Solution form

	Item	Specification
1	Field solution method	❑ 1. FEM ❑ 2. BEM ❑ 3. IEM ❑ 4. FDM ❑ 5. combination ( ) ❑ 6. others
2	Optimization method	❑ 1. deterministic ( ) ❑ 2. stochastic ( ) ❑ 3. coupling strategy ( ) ❑ 4. others ( )
3	Description of algorithm	
4	Objective function	same as Eq. (3) ❑ yes ❑ no specify:
5	Constraints	same as Section 2.3 ❑ yes ❑ no specify:
6	Element type	❑ 1. 1-st order ❑ 2. high order
		❑ 1. triangular ❑ 2. quadrilateral ❑ 3. others ( )
7	Number of elements	

<table>
<tr><td>8</td><td>Number of nodes</td><td colspan="3"></td></tr>
<tr><td>9</td><td>Convergence criterion for optimization runs</td><td colspan="3"></td></tr>
<tr><td rowspan="2">10</td><td rowspan="2">Total number of optimization runs</td><td>4253AT</td><td colspan="2"></td></tr>
<tr><td>17500AT</td><td colspan="2"></td></tr>
<tr><td rowspan="8">11</td><td rowspan="8">Initial and final shapes</td><td rowspan="4">4253AT</td><td rowspan="2">Initial</td><td>R_1=
L_2=
L_3=
L_4=</td></tr>
<tr><td>Free shape:
❑ yes
Please specify using a figure
❑ no</td></tr>
<tr><td rowspan="2">Final</td><td>R_1=
L_2=
L_3=
L_4=</td></tr>
<tr><td>Free shape:
❑ yes
Please specify using a figure
❑ no</td></tr>
<tr><td rowspan="4">17500AT</td><td rowspan="2">Initial</td><td>R_1=
L_2=
L_3=
L_4=</td></tr>
<tr><td>Free shape:
❑ yes
Please specify using a figure
❑ no</td></tr>
<tr><td rowspan="2">Final</td><td>Free shape:
❑ yes
Please specify using a figure
❑ no</td></tr>
</table>

12	The amplitude Wopt of objective function for final shape	4253AT		
		17500AT		
13	errors	4253AT	ε_{Bmax}(%)	
			$\varepsilon_{\theta max}$(deg)	
		17500AT	ε_{Bmax}(%)	
			$\varepsilon_{\theta max}$(deg)	
14	Computer	name		
		speed		(MIPS) (MFLOPS)
		main memory (MB)		
		CPU time (sec)	4253AT	
			17500AT	