Optimization of Dies for the Magnetic Development Roller using Genetic Algorithm

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Abstract

To optimize a multi-pole magnet roller a finite element method with Genetic algorithm is carried out. A multi-pole magnet roller recently used in the development system of the electrophotography, such as copiers, or laser printers. One procedure for producing the magnet roller is the extrusion molding with applying magnetic fields to the material. This scheme forms magnetic characteristics or flux density pattern by controlling to apply magnetic fields. For desired magnetic characteristics, we must adjust various parameters such as a shape of dies and current in the coils, but the fabrication required many efforts and resources. To make this process more efficient, a FEM simulation tool for the molding process has been developed. And Genetic algorism, which can optimize many parameters, is acquitted to decide these parameters. Then a high flux magnetic density at the main pole can be obtained in comparatively shorter fabrication time than the past.

Introduction

Generally, the development unit of the electrophotography system includes a developing roller, in other words, a magnet roller fixed in place within a rotatable sleeve.

Each fixed magnetic pole of the magnet roller forms particular magnetic pole on the outer periphery of the sleeve. At a depositing magnetic pole, the developer is drawn up onto the sleeve. The developer is carried with the sleeve rotation. At the main magnetic pole, the developer is transferred from the sleeve to a latent image and the printing image is formed. Furthermore, at the releasing magnetic pole, the developer is released from the sleeve every time the sleeve completes one rotation. Therefore, the magnetization state on the roller has a large effect on the characteristics of the development unit. Then it is important to realize a desired magnetic characteristic. The optimization of such fabrication conditions becomes important.

Recently, genetic algorithm (GA), which is a search technique by using the computation, is applied to some optimization of a manufacturing design. And it makes good results. So, we tried to optimize the shape of magnetic field orientation of dies by using genetic algorithm.

Dies of electromagnetic unit in an extrusion molding

Usually, a magnetic roller inside the development roller is made of raw materials such as plastic magnetic material or gum magnetic materials. It is manufactured by the extrusion molding under the high magnetic filed. This process includes an orientation and a magnetization. Both processes can be carried out simultaneously. However, we process the production of magnet through each divided step [1].

In the orientation process, we continue mixing parasitic material with a magnetic powder such as ferrite with applying the magnetic field from outside. Then the axes of easy magnetization in the magnet are aligned the same orientation. We can make a magnetic pole strong or weak by controlling the orientation and the intensity of the outer magnetic fields. However, the extrusion molding machine is a large equipment, and not adequate to make fine control. So after the magnetic roller is demagnetized, it is re-magnetized by electromagnets to be adapted for the purpose-designed magnetic flux density distribution. It is called a magnetization process.

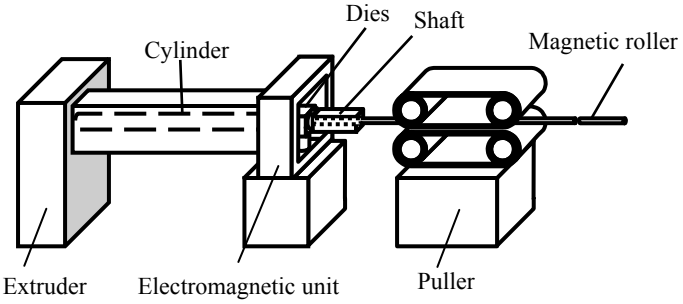

Figure 1. Extrusion molding machine

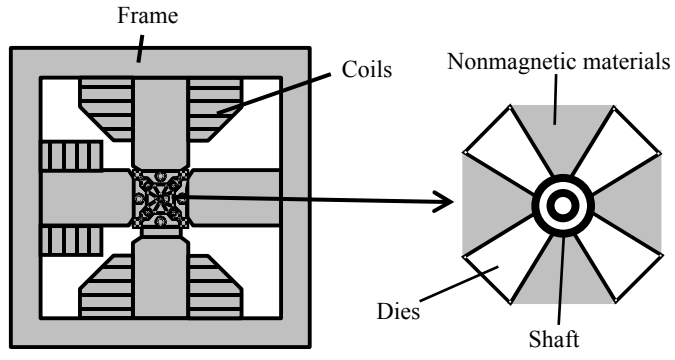

Figure 2. Electromagnetic unit

The schematic of the electromagnetic unit in the extrusion molding equipment is shown in figure 1, and the dies of the electromagnetic unit are shown in figure 2. The dies are set up at the center of the electromagnetic unit. The dies that consist of magnetic material are tucked between nonmagnetic materials. The coils in the electromagnetic unit generate the magnetic filed by electrical current. And the magnetic field passes through the section of dies.

So we design the shape of the die configuration to control the magnetic field for magnetizing the magnetic roller. After these materials undergo through cooling and solidification, the magnetic roller is demagnetized and cut in to a proper length.
Figure 3 shows a magnetizer including yokes and magnetizing members implemented. This process modifies the magnetic characteristics.

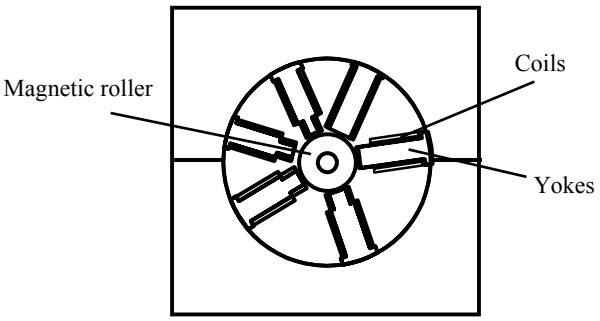

Figure 3. Magnetizer

Simulations of a magnetization by the extrusion molding

It needs cost and period to make the dies of the electromagnetic unit. Without making trial models, we could not know whether a die's magnetic configuration is adequate or not. Therefore we have developed the simulation tool of magnetization by the extrusion molding. The procedure of the simulation includes following 4 steps. These steps are shown in figure 4.

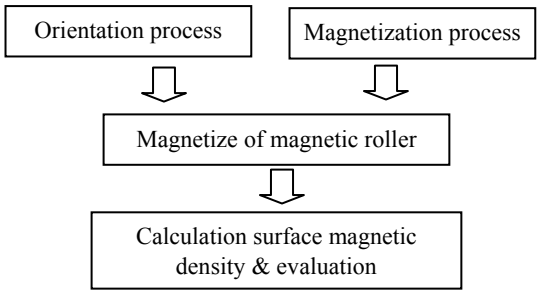

Figure 4.The process of magnetic simulation

1) Analysis FEM model for the magnetic filed orientation calculation

With inputting conditions, such as a roller diameter, character of material, width of die shape, and so on, the simulation tool makes FEM modeling geometry of the electromagnetic unit, generates mesh, and runs magnetic static field calculation automatically.

2) Magnetization filed calculation

The second step is the calculation of the magnetic field, which is made by a current flow in the electromagnet coil around the yoke in the magnetizer. Actually we use a pulse current, but in the analyses we use static field calculation for reducing calculation time.

3) Magnetization of magnet roller

The relation between the orientation and magnetization determines value of the magnetization. The magnetization at each mesh is calculated under consideration of value and direction of the magnetic flux density.

4) Static magnetic field of magnetic roller

The fourth step is the calculation of the static magnetic field on the surface around the magnetic roller. This calculation is based on the magnetization, which is obtained from the previous step. Accuracy of the calculation is above 90% in orientation process and about 80% in the magnetization process. These are acceptable accuracy to design die, and yoke. Thus, transient analysis in the magnetization process could be necessary for accuracy improvement
To use this simulation tool, number of trial model pieces can be reduces. At times after much trial and error, we cannot find the good condition, because many parameters interact each other.

Genetic algorithm

Genetic algorithms are inspired by Darwin's theory about the evolution of organisms [2]. Solution to a problem solved by genetic algorithms is evolved. In genetic algorithm, a set of many parameters is treated as individual and, each parameter is treated as gene. In this problem, input data aggregate for the simulation tool are treated as individual.

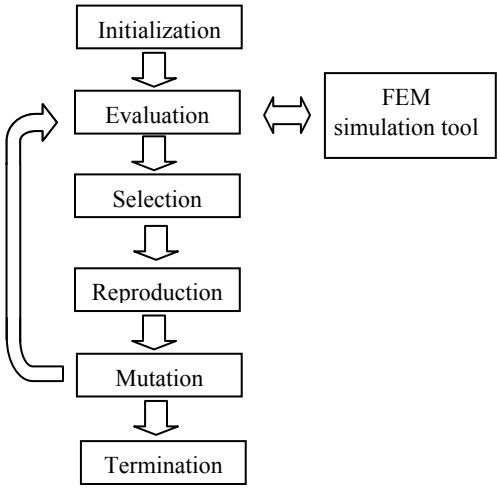

Figure 5.The process of GA

The algorithm is started with a set of individuals called population. Solutions from one population are taken and used to form a new population. This is motivated by a hope, that the new population will be better than the old. Solutions that are selected to form new solutions are selected according to their fitness; the more suitable they are, the more chances they have to reproduce. Genetic algorithm steps are shown in figure 5.

1) Initialization

Initially many individual solutions are randomly generated to form an initial population. In this case the population size is about 10-20.

2) Evaluation

Evaluate the fitness of each individual in the population. In this case, fitness is defined as below. As the representative values, peak values Br_{max}, half angular width W, center of the both angles at $Br_{max}/2$ Deg_C, angle at 0.0T Deg_0, are picked out form the character of each magnetic pole. Fitness index P is calculated by expression (1).

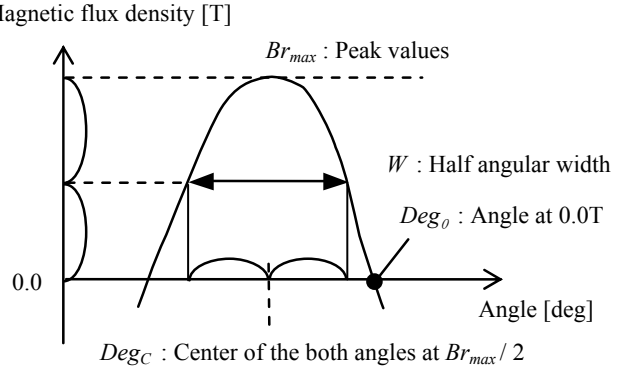

Figure6. The representative values of a pole

$$P = \sum_i \{ k_1(i) \cdot | Br_{max}(i) - Br_{max\_ob}(i) | + k_2(i) \cdot | W(i) - W_{\_ob}(i) | + k_3(i) \cdot | Deg_c(i) - Deg_{c\_ob}(i) | + k_4(i) \cdot | Deg_0(i) - Deg_{0\_ob}(i) | \} \quad (1)$$

Where the subscript $\_ob$ expresses representative values of target magnetic character, and k is weighting coefficient set by importance and offset between scales, and i is the pole number.

3) Selection

The lower the value of the fitness is, the better the individual property is. A few worst individuals are deleted in the population by the evaluation.

4) Reproduction

The individuals selected in the previous step are copied to those in the new population. A few worst individuals are exchanged to a few best individuals. This elitism can very rapidly increase performance of genetic algorithm, because it prevents losing the best-found solution.

5) Mutation

The mutation is a method of changing a value of several genes. It is selected by a chance. A new population except the elites is generated from the individuals with the mutation.

6) Termination

This generational process is repeated until a fixed number of generations.

Simulation Result

We explain the sample case that is optimization with genetic algorithm in terms of die for the magnetic development roller. It is large and costly equipment, so optimization effect is high. The purpose of designing is to get the low cost magnetic roller. We try to obtain a high flux density at the pole without using a high-coercive force material, so called high cost magnetic material.

Figure 7 shows the specifications of magnetic flux density on the roller. The value of the magnetic flux density at the main magnetic pole needs high, because it carries developer through the interstices between a development roller and a photoreceptor. If the strength of the magnetic field is not strong enough, the developer cannot go through the interstices and flies apart. This specification of magnetic flux density can be obtained by using a high-coercive force material.

Genes in individual are shape parameters of die and current value. In this case, an individual has 15 genes. The weighting coefficient k_1 for the development magnetic pole set high.

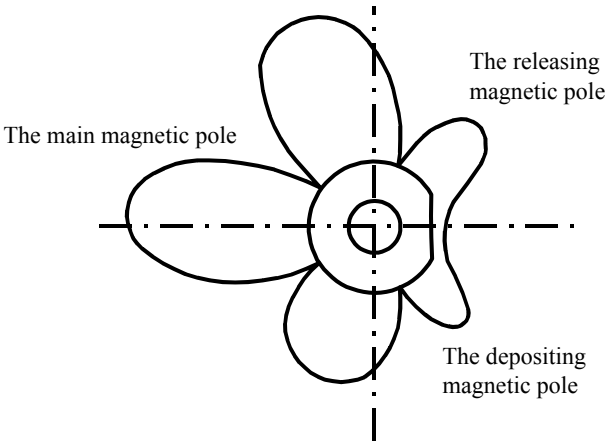

Figure 7. The specifications of magnetic flux density

Figure 8 shows a relation between the fitness index and the generation. For 20th-30th generations, the fitness is improved greatly, and after 30th generations it is improved gently.

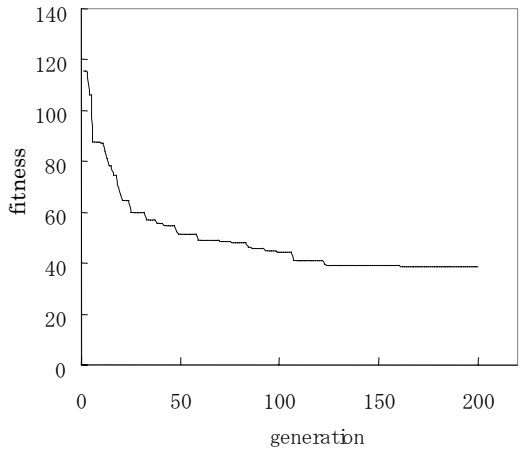

Figure 8. The change of the fitness

The model in termination is difference form previous model which is gotten. It shows in figure 9.

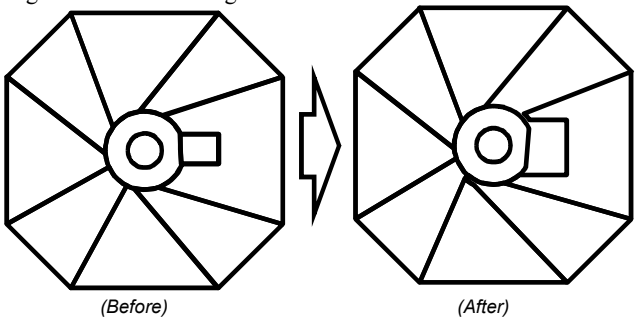

Figure 9. The Sharp of change of the fitness

Based on this result, we make dies and magnetic roller. Figure 10 shows character of the magnetic roller and simulation result. The accuracy of this calculation is high.

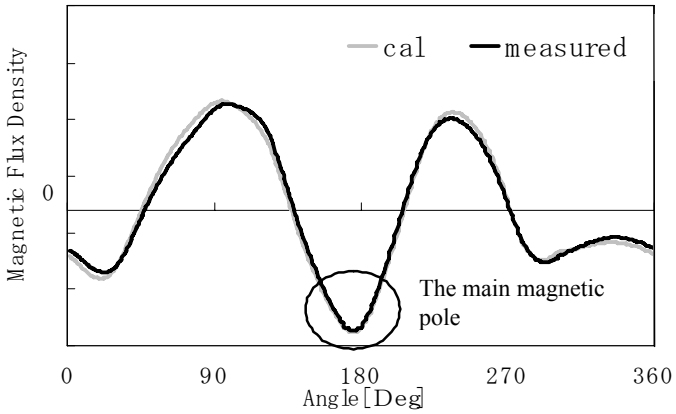

Figure 10. The calculation accuracy

Figure 11 shows the character of this magnetic roller and the previous magnetic roller. The value of the main magnetic pole is improved. It is about one week to get this result, on the other hand it needs about a month without this method.

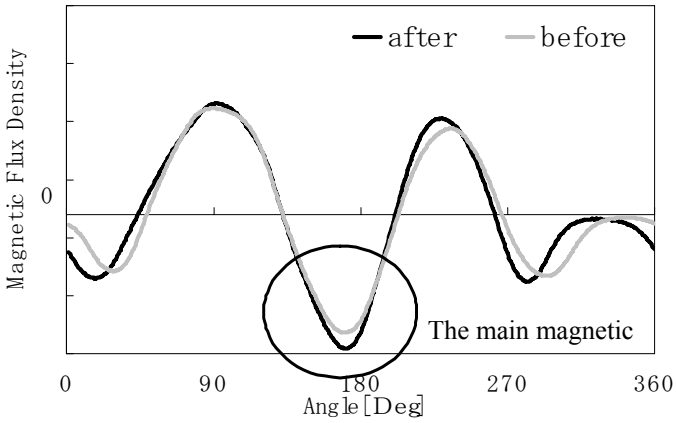

Figure 11. The efficiency of the new model

Conclusion

We have tried to apply an appropriate technique for designing a development roller. We have developed the simulation tool using genetic algorithm. And a several good conditions of manufacturing a magnetic roller are obtained by the scheme.

A magnetic roller is made according to the simulation results and the characteristic of the development is verified. A high flux density at the main magnetic pole is obtained without using a high-coercive force material. We get the low cost magnetic roller in a short period.

References

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[2] H.Kitano, "Genetic Algorithm" Sangyo tosho publishing Co, ltd. ISBN-10:4782851367(1993) [in Japanese]

Author Biography

Yasuo Miyoshi received his ME from Hiroshima University in 1992 and entered Ricoh company, Ltd. He works at Imaging Engine Development Division, and is engaged in the research and development of printing technologies.