Multi-objective optimization of magnet compositions by machine learning

Hyuga Hosoi[1], Yamano Hayate[1], Kinoshita Akihito[1], Sakuma Noritsugu[1], Umetani Yusuke[1], Shoji Tetsuya[1], Thomas Schrefl[2]
(1. Toyota Motor corporation (Japan), (2. Donau University Krems (Austria)

Background / Objective

● **The demand for electric motors is increasing as a result of the rapid production of electrified vehicles.**

● **Rare earth elements (Nd, Pr) added to NdFeB magnet could face imbalances in supply and demand.** (Fig.1)

Fig.1. Trends in raw material costs

We aim to rapidly develop **various types of magnets** optimized **for different products, utilizing cost-effective elements (Ce, La).**

Research Highlights

● **Prepared magnetic powders** (Fig.2)
$(Nd,Ce,La,Pr,Dy,Tb)_{13.55}(Fe,Co,Ni)_{80.54}(B,C)_{5.91}$
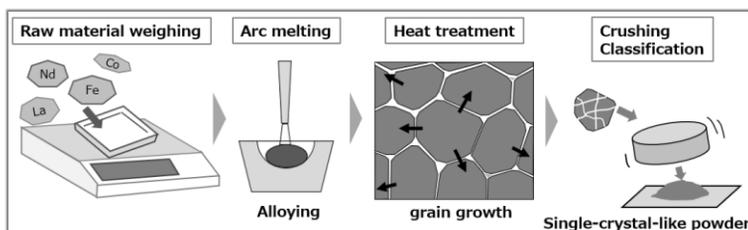Classified single-crystal-like powders were obtained.

● **The physical properties evaluation**
(M_s and H_a at 300~453 K)
M_s: saturation magnetization
H_a: anisotropic magnetic field

Fig.2. Experiment procedure

● **Regression analysis of M_s and H_a** (Fig.3)
Explanatory variables
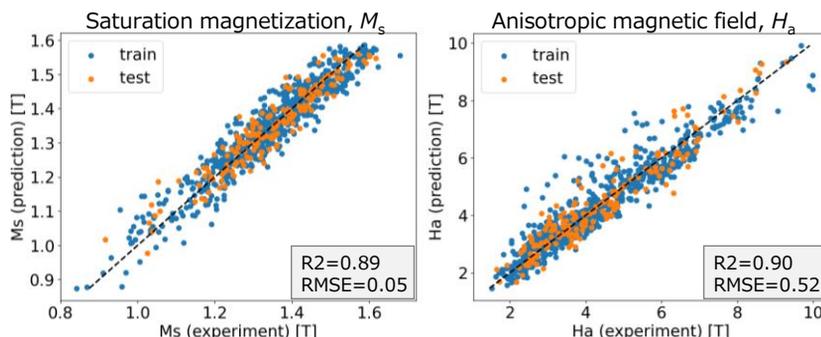:Ce, La, Pr, Dy, Tb, Co, Ni, C, tempreture
⇒Good predictive accuracy (R2≧0.89)

● **Multi-objective optimization** (Fig.4)
Optimization method: genetic algorithm
・M_s and H_a ※maximization search
・cost ※minimization search
Optimal solutions were obtained and visualized.

● **Evaluation of the predicted values** (Fig.5)
The predicted values were achieved by experiment.

Fig.3. Regression analysis results of M_s and H_a

Immediate proposal of magnet compositions suited to different application is possible in response to change in market conditions. These analysis (regressions, multi-objective optimization and so on) can be easily performed using WAVEBASE system. ※WAVEBASE: Could-Based Material Data Analysis service
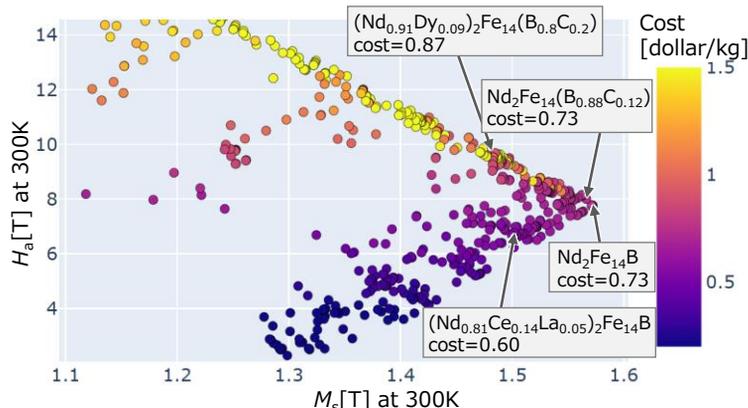
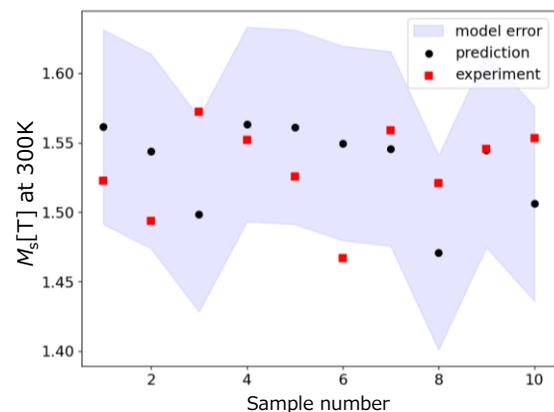WAVEBASE

Fig.4. Results of the multi-objective optimization

Fig.5. Evaluation of the predicted values

References

(1) H. Yamano, et al: Efficient optimization approach for designing power device structure using machine learning, *Japanese Journal of Applied Physics,* **62**, SC1050 (2023).
(2) M. Yano, et al: Material data analysis cloud service "WAVEBASE", *TOYOTA Technical Review,* **69**, 48 (2023).

Keywords

NdFeB, Machine learning, Genetic algorithm, WAVEBASE Multi-objective optimization