An Optimal Design to Prevent Demagnetization of Dy-Free Magnet for a Traction Motor

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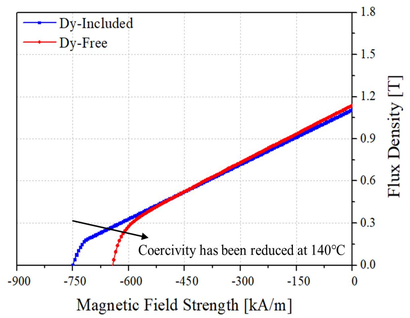
Introduction

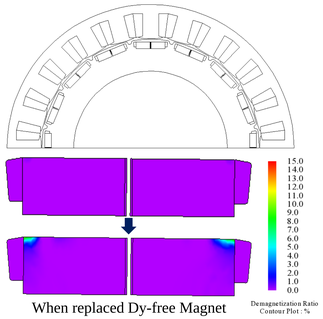
- Heavy rare earth elements such as Dysprosium(Dy) are added to the Nd magnets for withstanding severe conditions of traction motor
- However, the employment of Dy has critical issues regarding environmental problems and price fluctuations due to unstable supply
- To resolve the problem, studies for applying Dy-freee magnet to traction motor have been dealt recently.
  - Studies regarding manufacturing method to improve coercivity of Dy-free magnet such as hot demforming
  - Optimal designs of motor shapes to prevent partial demagnetization due to a low coercivity of Dy-free magnet
- In this paper, an optimal design to prevent demagnetization of Dy-free magnet was performed applying a novel optimization algorithm, which is intelligent multi-start mesh adaptive direct search based on kernel support vector machine

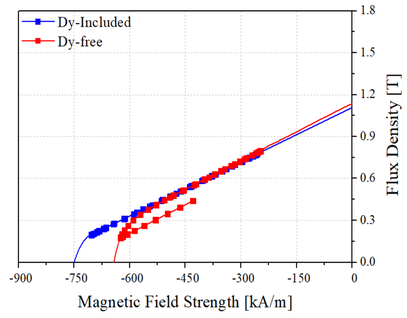
Demagnetization by Employing Dy-free Magnet for a Traction Motor

- Partial demagnetization was caused at the corner of the magnet, when Dy-free magnet was employed instead of Nd magnet



<Magnet BH Curve Variation>





<The result of Demagnetization Analysis>

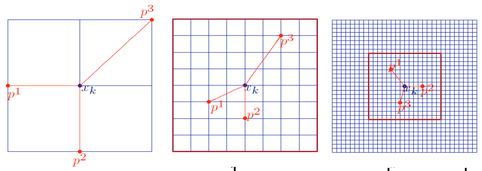
Mesh Adaptive Direct Search

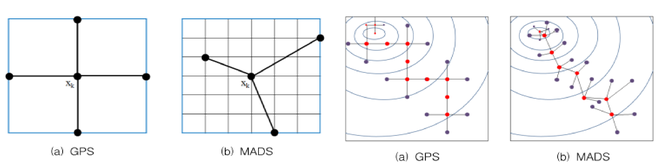
- Mesh Adaptive Direct Search is one of qualified local search algorithm, which generates trial points around the current best point and iteratively moves towards superior point by comparison

$$M_k = \bigcup_{x \in S_k} \{ x_k + \Delta_k^m D_z : z \in N^{nD} \}$$

$$P_k = \{ x_k + \Delta_k^m d : d \in D_k \} \subset M_k$$

$$\Delta_{k+1}^m = \tau^{\omega_k} \Delta_k^m \qquad \omega_k \in \begin{cases} \{0,1,\ldots,\omega^+\} & \text{: If an improved mesh point is found} \\ \{\omega^-, \omega^- + 1, \ldots, -1\} & \text{: Otherwise} \end{cases}$$





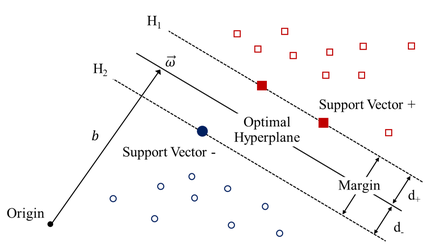
<Difference between GPS and MADS>

Conclusion

- Due to a low coercivity at high temperature, demagnetization was caused at the corner of the Dy-free magnet when it is employed instead of the conventional Nd magnet
- To prevent partial demagnetization, the optimal design of barrier shape was performed using a novel optimization algorithm
  - Multi-Start methodology based on kernel support vector machine provide reasonable initial points for mesh adaptive direct search
  - Mesh adaptive direct search find an adjacent optimum minimizing calculation cost, that can reduce the number of excessive FEA
  - The novel algorithm was verified on test function, Gold-stein function and Branin function
- Optimal model derived by the algorithm prevent partial demagnetization at high temperature

Intelligent Multi-Start Methodology based on Kernel Support Vector Machine

- Mesh Adaptive Direct Search can guarantee fast convergence on an adjacent optimum. However, it becomes trapped in local optima with complicated problems
- Kernel Support Vector Machine can provide promising initial points for Mesh Adaptive Direct Search



<Kernel Support Vector Machine>

- Equation of Hyperplane

$$\vec{\omega}^T \vec{x} + b = 0, \quad y_i(\vec{\omega}^T \vec{x}_i + b) - 1 \geq 0$$

- Margin Maximization

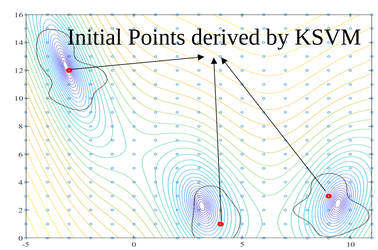
$$\max L_D = \sum_i \alpha_i - \frac{1}{2} \sum_i \sum_j \alpha_i \alpha_j y_i y_j \vec{x_i} \cdot \vec{x_j}$$

- Kernel Trick (Radial Basis Function)

$$K(\vec{x_i}, \vec{x_j}) = exp(-\gamma \|\vec{x_i} - \vec{x_j}\|^2)$$

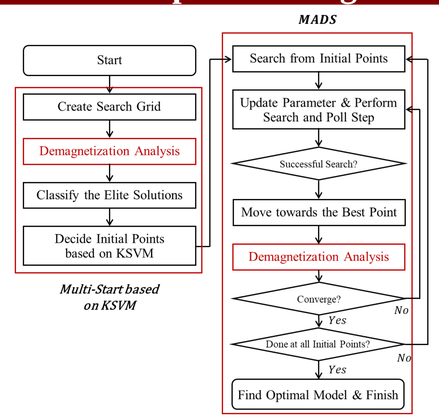
- Margin Maximization

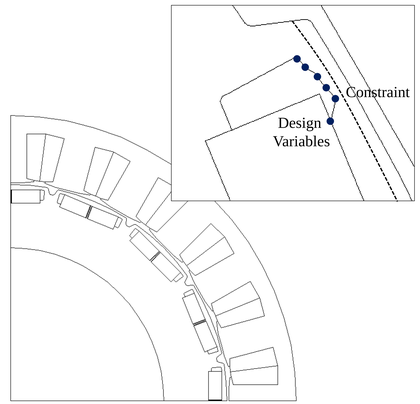
$$\max L_D = \sum_i \alpha_i - \frac{1}{2} \sum_i \sum_j \alpha_i \alpha_j y_i y_j K(\vec{x_i} \cdot \vec{x_j})$$



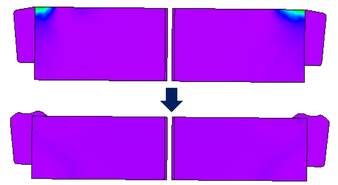
<Initial Points for MADS>

Optimal Design to Prevent Demagnetization of Dy-free Magnet





Variables	Result
X1	104.60 mm
X2	104.79 mm
X3	104.78 mm
X4	104.69 mm
X5	104.86 mm
x6	104.58 mm



<The result of Optimal Design>