Reactor Vibration Reduction Using Global Topology Optimization Algorithms

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Abstract

Gapped-iron core reactors are widely used in power systems to compensate for the reactive power of the system. However, under the interaction of electromagnetic force and magnetostriction at the air gap, the reactor core is deformed, causing vibration. In this paper, a Global Magneto-Structural (GMS) topology optimization algorithm is proposed to obtain the optimal topology of lower vibration reactor.

Main Contents

- This GMS algorithm combines magnetic topology optimization with structural one. And the magnetic topology optimization solution is used as the initial seed of the structural one in order to reduce the calculation time.
- The parameters including magnetostriction coefficient λ and relative permeability μ_{Fe} in GMS and FEM can be obtained by measuring the magnetization and magnetostriction properties of silicon steel.
- The finite element calculation results of the reactor before and after the GMS optimization is compared and analyzed.

Structure

As the distribution of air gaps in the reactor, magnetic flux leakage will occur when the magnetic field lines of the reactor change from high-permeability material to low-permeability material. At the same time, the electromagnetic attraction between the air gaps will aggravate the core deformation and cause vibration. Therefore, the materials in the optimized are redistributed to improve this phenomenon. The optimized area is shown in the Fig. 1.

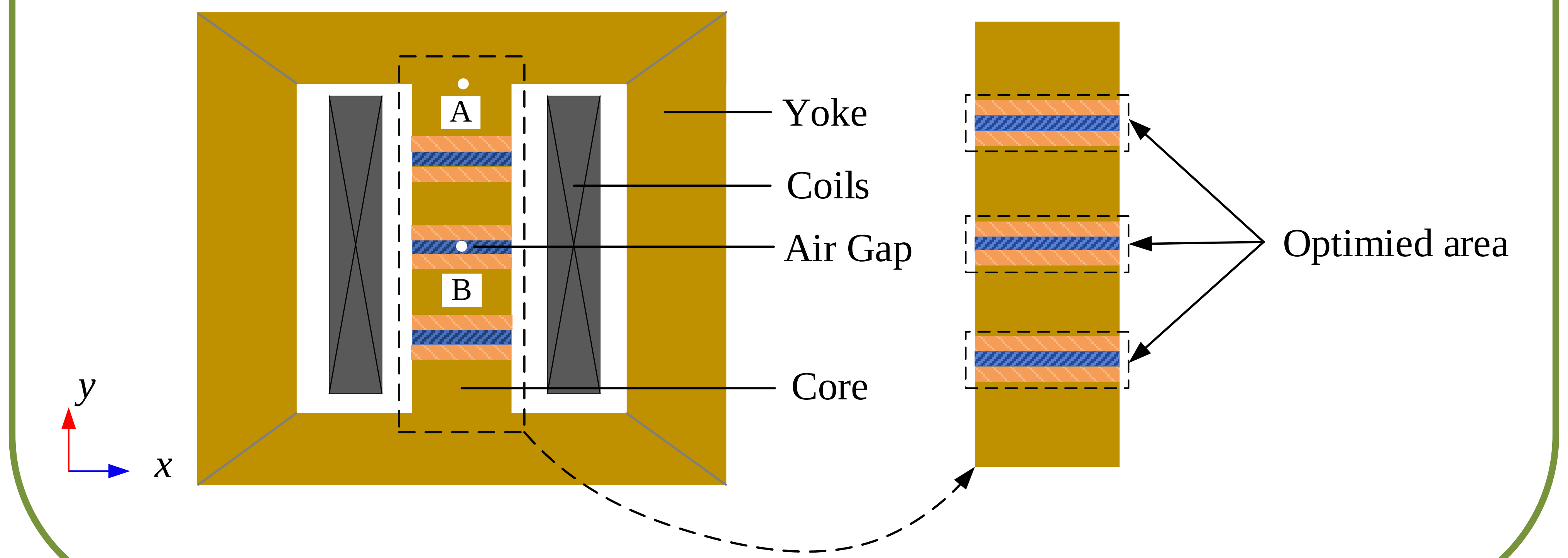

Fig. 1. The overall structure of reactor and the details of the core.

measurement system of magnetization and magnetostriction

To obtain the parameters of magnetostriction coefficient λ and relative permeability μ_{Fe} in GMS and FEM , under the IEC standard, the magnetization and magnetostriction properties of silicon steel is measured by the measurement system which is shown in Fig. 2.

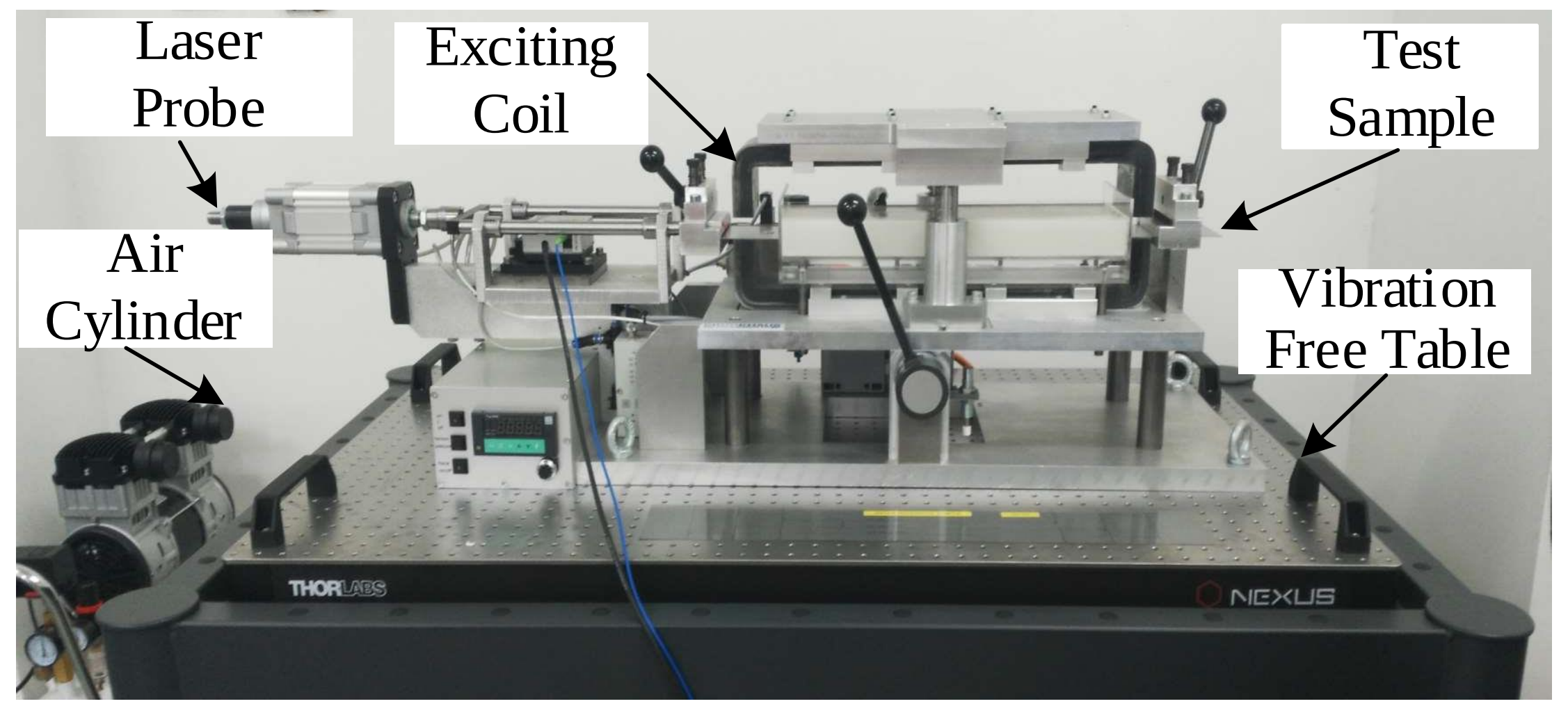

Fig. 2. measurement system of magnetization and magnetostriction

TABLE I. Parameters of measured silicon steel sheet 50ww470

QUANTITY	Parameters
length	600mm
width	100mm
weight	231.44g
density	7770(g/m^3)

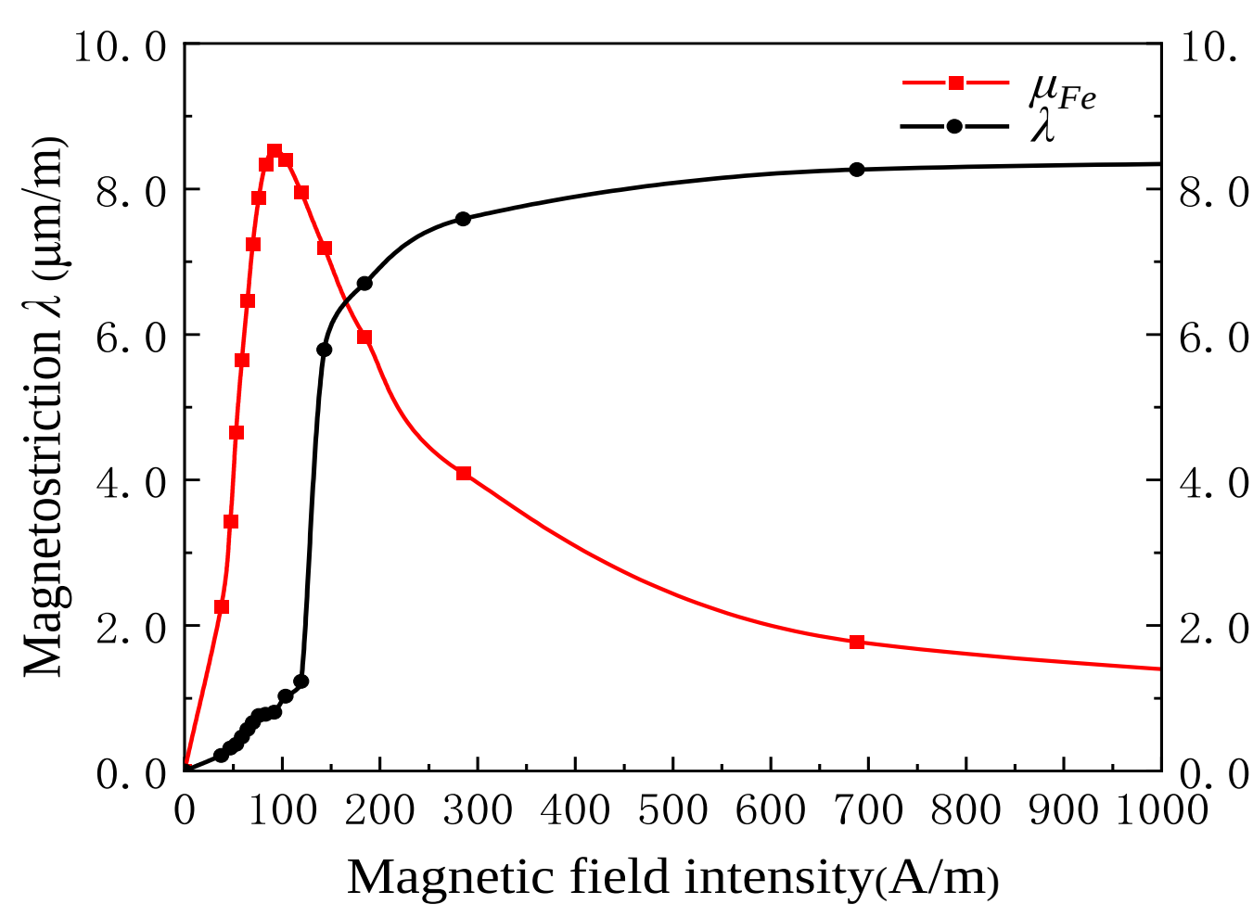

Fig. 3. The curve of magnetization and magnetostriction.

Results

Based on the SIMP, the penalty interpolation function of relative permeability and Young's modulus can be expressed as follows

$$\mu_r = (\mu_{\mathrm{Fe}} - \mu_0)\rho^{\mathrm{p}} + \mu_0 \qquad E = E_0 \rho^{\mathrm{p}}$$

And the penalization factor p is set as 4.

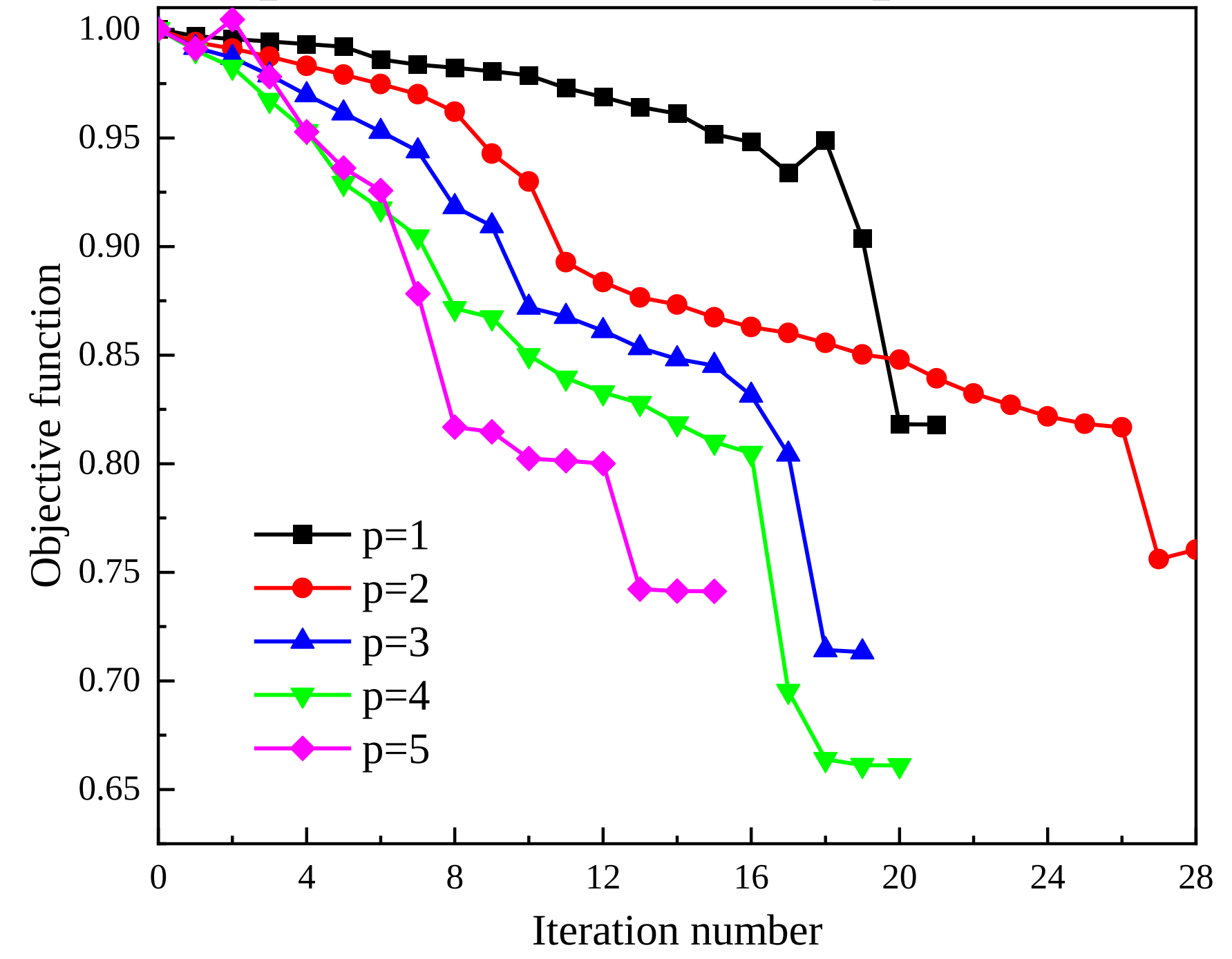

Fig. 4. Convergence process of objective function under different p value.

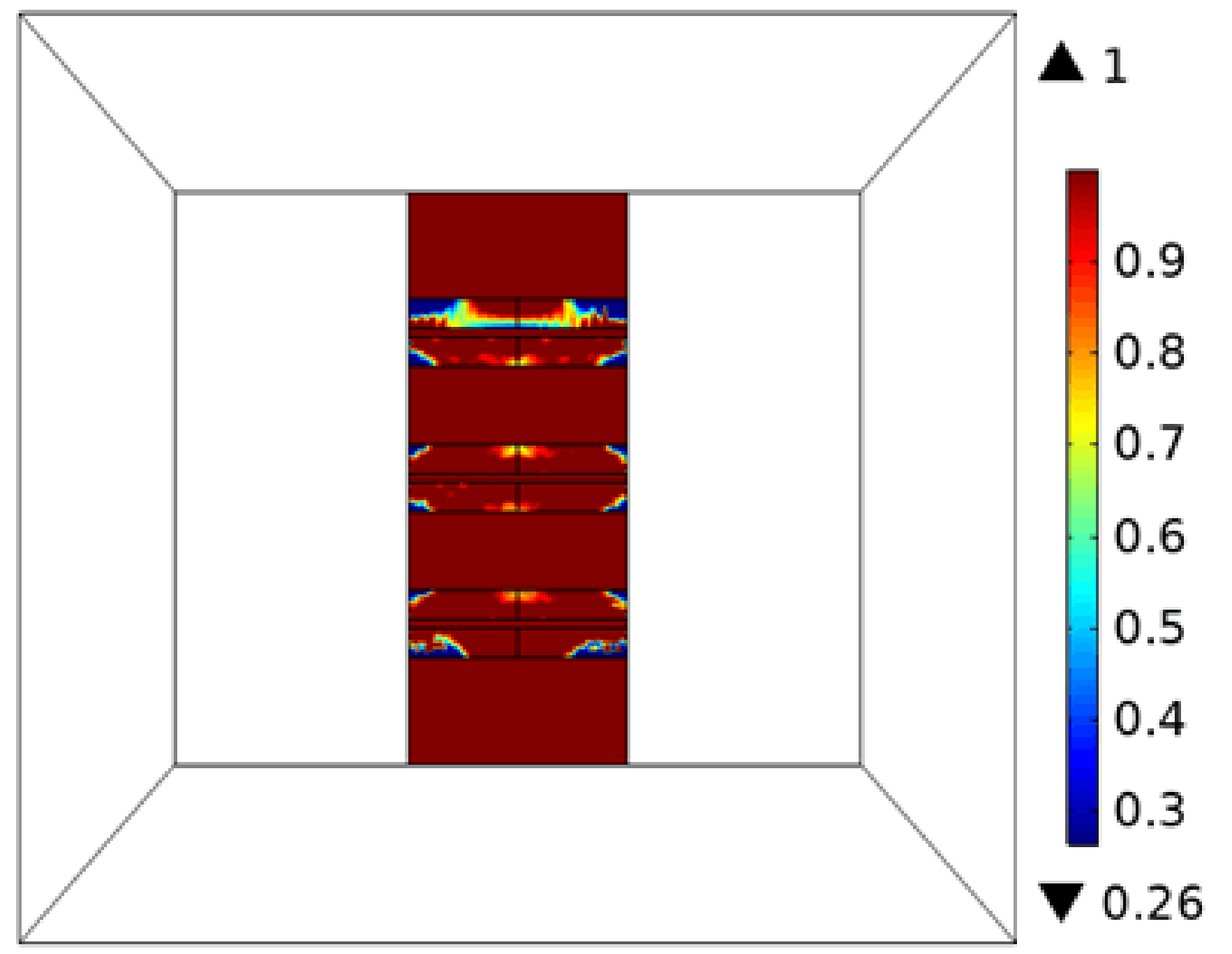

Fig. 5. Material distribution after the GMS topology optimization.

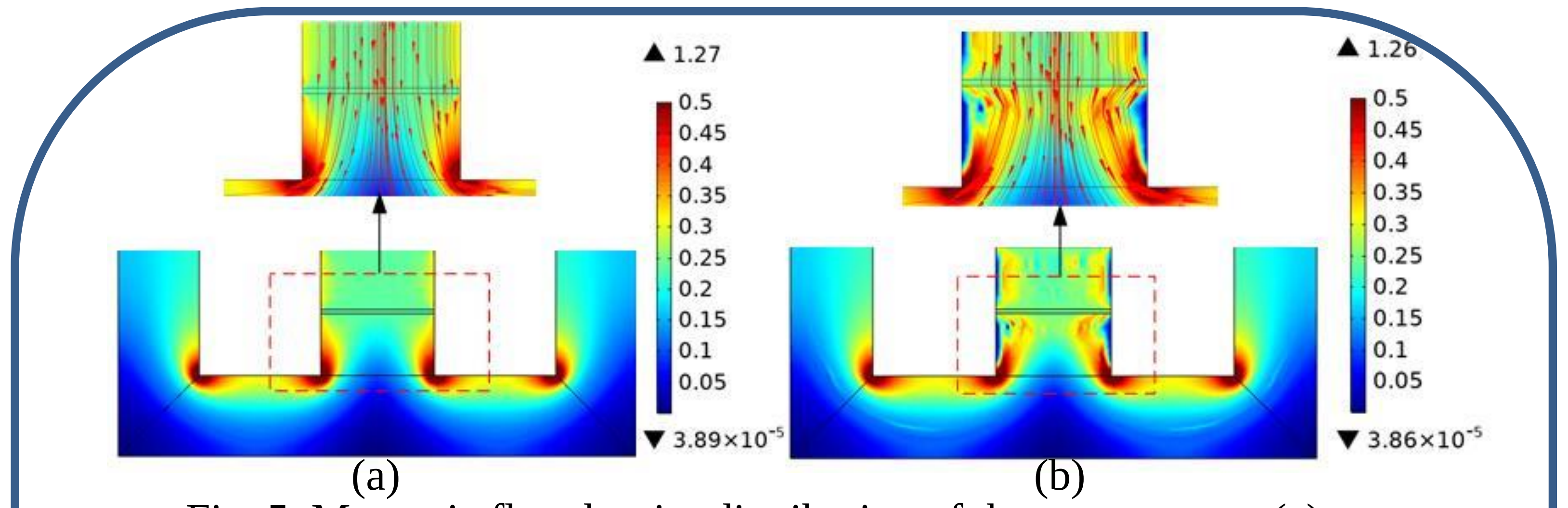

Fig. 5. Magnetic flux density distribution of the reactor core. (a) before optimization (b) after optimization.

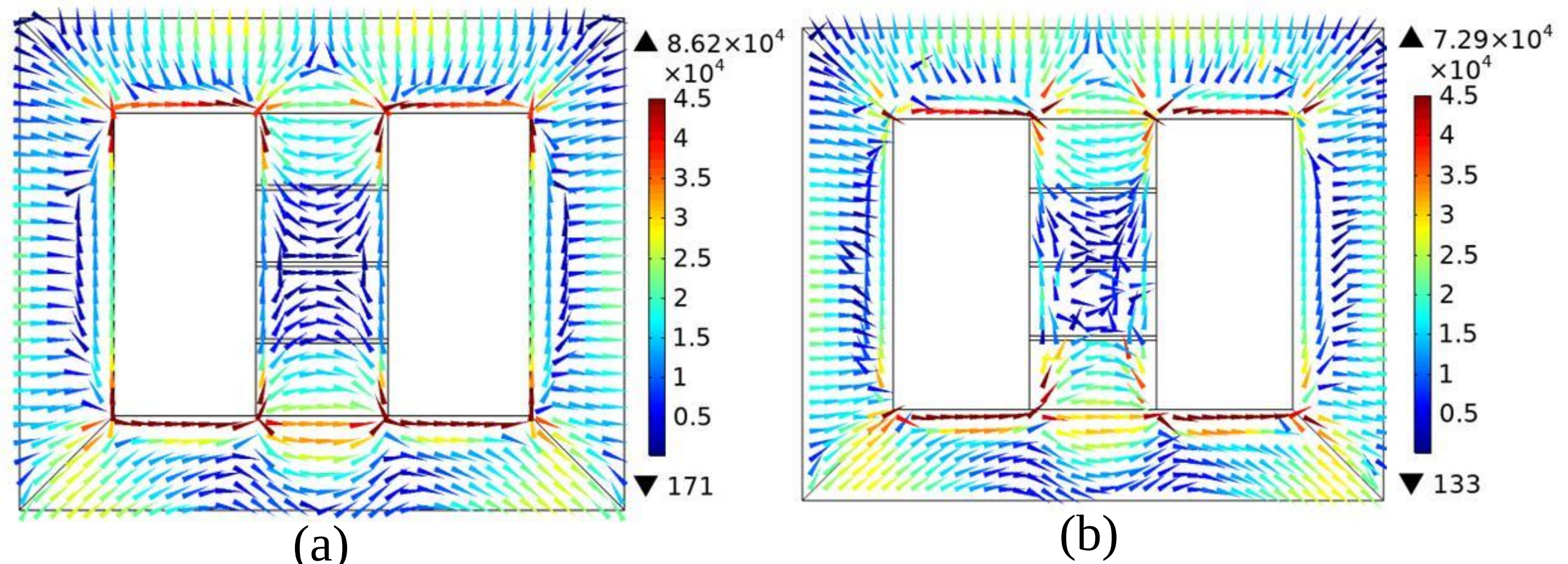

Fig. 6. Stress distribution of the reactor core. (a) before optimization (b) after optimization.

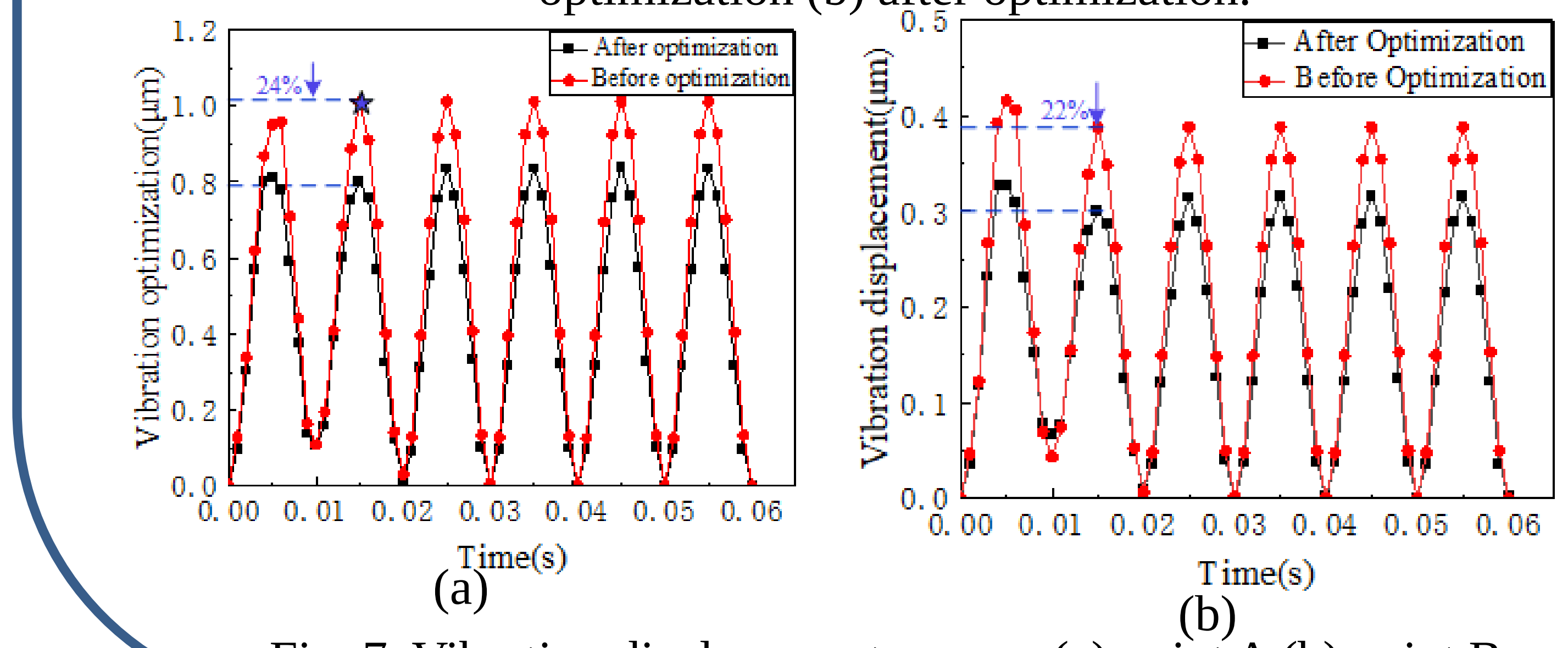

Fig. 7. Vibration displacement curves. (a) point A (b) point B.

Summary

- The GMS topology optimization algorithm combines the Solid Isotropic with Material Penalization (SIMP) with the Global Convergent Method of Moving Asymptotes (GCMMA) to enhance the convergence while ensuing the computational efficiency.
- A threshold function is presented to eliminate the intermediate density and improve the problem of blurring the optimal material boundary.
- After optimization, the vibration displacement of the gapped-iron core reactor is reduced by up to 24%.

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