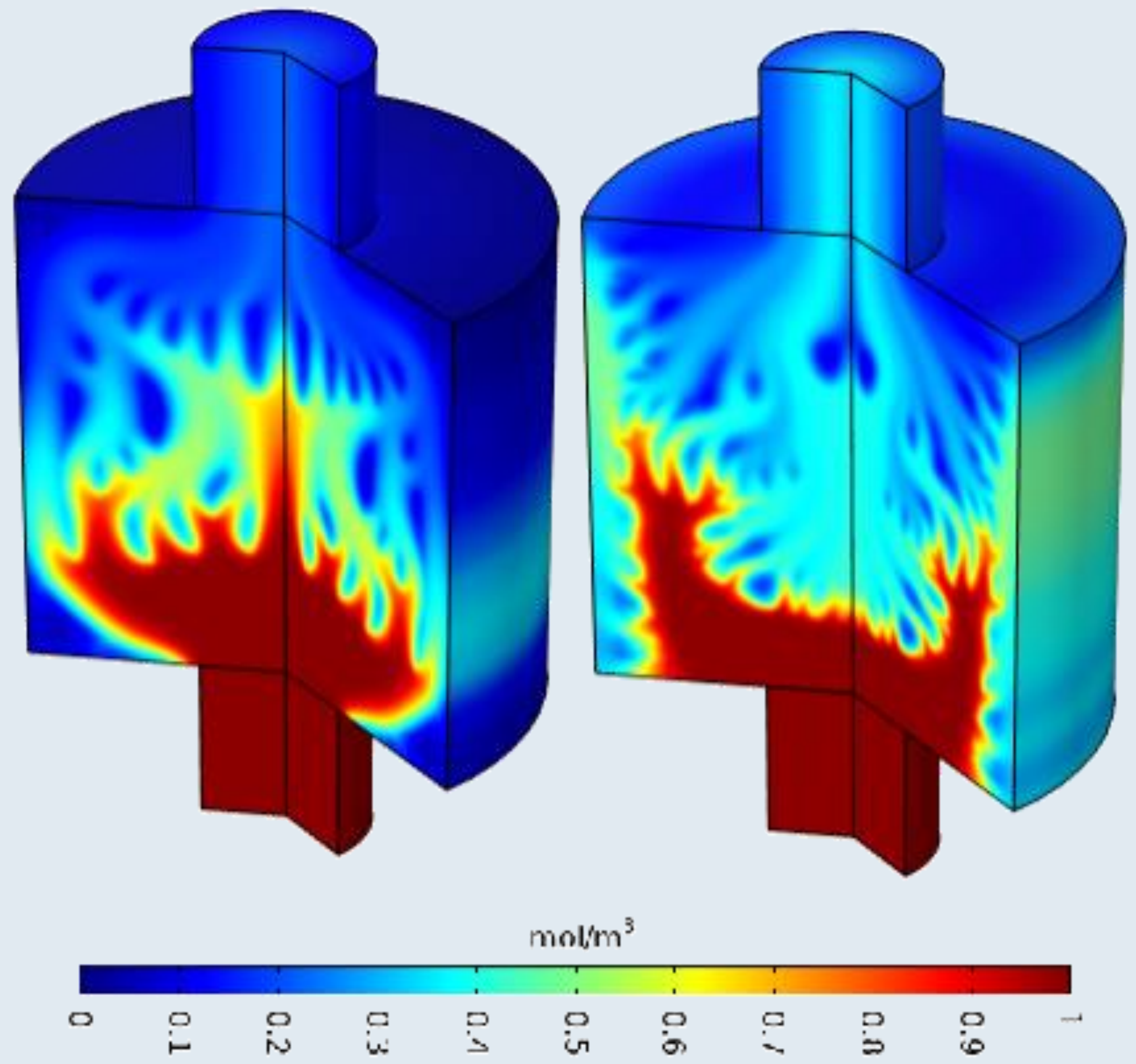

Non-uniform magnetic field-induced performance alteration of a topology-optimized PBMR

In this study, we provide a methodology for topology optimization aimed at enhancing the conversion of reactions of a ferrofluid reactant in presence of non-uniform magnetic field.

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Introduction & Goals

Packed bed microreactors (PBMR) and ferrofluids are independently enormously used in a broad range of applications in the healthcare sector. In a PBMR, one of the primary factors for controlling the reaction rate is the bed porosity which immediately affects the catalyst distribution and the reactant flow. (Ref. 1) When exploiting ferrofluid as the reactant, an alternative approach is offered to regulate the flow in microreactors by employing external magnetic fields alongside the impact of pressure-driven flow.

In this study, we provide a methodology for topology optimization aimed at enhancing the conversion of reactions. Our approach involves establishing an optimal porosity for the catalyst bed used in ferrofluid reactions, while also considering the influence of an external non-uniform magnetic field on the improved reaction conversion. Depending on the orientation of the field, it is possible to achieve either a higher or lower conversion rate compared to the optimal conversion rate in the absence of a magnetic field.

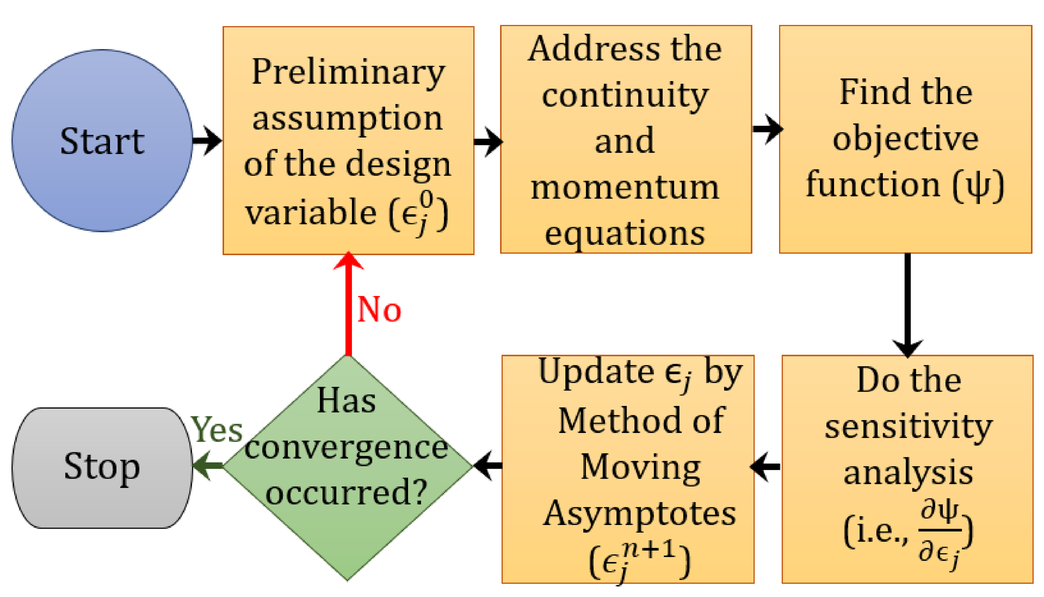

FIGURE 1. Flow chart for the topology optimization process. (Ref. 1)

Methodology

In the present work, we provide a topology optimization method for improving the reaction conversion of a first order reaction by achieving an ideal catalyst bed porosity for ferrofluid reactants and including the external non-uniform magnetic field that additionally modifies the optimized reaction conversion. The numerical simulations were conducted using COMSOL Multiphysics, a solver based on the finite element technique. The moving asymptotes technique (MMA) was used in our study to conduct topology optimization. The procedural flow for the topology optimization methodology used in this study is shown in Figure 2. In addition, the COMSOL Multiphysics software was used to address the flow field, reaction kinetics, magnetic field, and optimization techniques using its 'Fluid Flow', 'Chemical Species Transport', 'AC/DC', and 'Mathematics' modules, respectively.

Results

When comparing case-1 with case-2, the data shown in the figure 2 supports the conclusion that the vertical location of the magnetic field consistently leads to higher reaction conversion and average bed porosity compared to the horizontal magnetic field.

The conversion of the reaction and the average porosity of the bed exhibit an increase with the intensity of the magnetic field in case-1, whereas they show a reduction with the field strength in case-2. In the first scenario, the manipulation of H within the range of 0 to 500 A/m resulted in an escalation of the velocity inside the reactor, requiring augmentation of the bed porosity to achieve optimum performance. This phenomenon increases the flow field, leading to an enhancement in the conversion of the reaction. Conversely, in the case-2, there is a dramatic shift in the other direction.

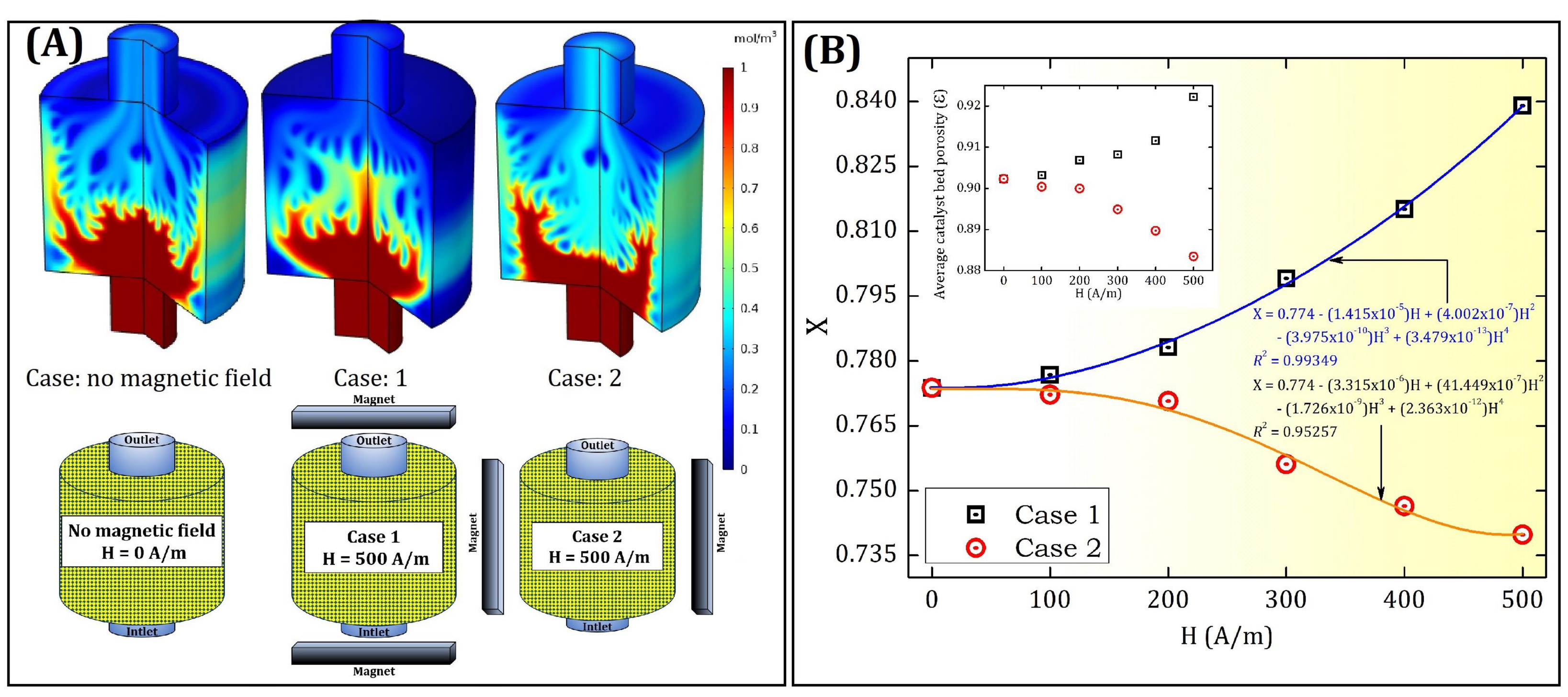

FIGURE 2. (A) illustrates the concentration distribution inside the optimized reactor for (i) no magnetic field, (ii) case 1, and (iii) case 2 with H = 500 A/m. (B) depicts the alteration of reaction conversion (X) with magnetic field strength (H).

REFERENCES

1. D. Bhattacharjee and A. Atta, "Topology optimization of a packed bed microreactor involving pressure driven non-Newtonian fluids," *Reaction Chemistry & Engineering*, vol. 7, no. 3, pp. 609–618, 2022.