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A heating coil insert to combine MFH and preclinical MPI

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Introduction

Magnetic particle imaging (MPI) is a rapidly developing imaging modality, which determines the spatial distribution of magnetic nanoparticles. Magnetic fluid hyperthermia (MFH) is a promising therapeutic approach where magnetic nanoparticles are used to transform electromagnetic energy into heat. In this work a heating coil insert designed for a preclinical MPI scanner is presented.

Methods

The heating coil insert is composed of heating windings and compensating windings. The solenoid heating windings generate a 700 kHz magnetic field up to 10 mT in amplitude for effective heating of the MNPs. The compensation windings are in series with the heating windings but wound in the opposite direction, which generate a compensating field to minimize the induced voltage in the MPI scanner. A particle swarm optimization algorithm is developed to optimize the geometry of the coil.

Results

The transfer function of the integrated system shows a damping of the signal of 101 dB, 88 dB and 54 dB for x, y and z channel respectively at 700 kHz. The good compensation result indicates the power level of the induced signal is safe for the receive chain of the MPI scanner when the send power of the heating coil insert is below 1 kW. The average magnetic field generated by the heating coil insert over an area of 22.5 mm × 18 mm × 12 mm around the center of the heating coil is 11.2 mT, with a standard deviation of 4×10^{-4} mT. The high power test shows the setup works with 650W power at 700.8 kHz.

Conclusion

Within the scope of this work, the heating coil insert for the preclinical MPI scanner is implemented, which allows for the generation of a high frequency magnetic field suitable for MFH. The next step will be to complete the safe integration of the insert into the MPI system.

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Actuation of a magnetically coated swimmer in viscous media with a magnetic particle imaging scanner

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Introduction

The untethered navigation of helically shaped swimmers by rotating magnetic fields enables to reach regions of the body which are difficult to access. This can be used to improve minimally invasive intervention procedures, to apply targeted drug delivery or local hyperthermia. Here, a mm-sized magnetic swimmer is presented, which can be steered by the fields of a magnetic particle imaging (MPI) scanner. The velocity of the swimmer is being investigated for different viscosities of the surrounding fluid.

Methods

The design of the swimmer was adopted from vertical axis wind turbines, the helical Savonius shape was chosen and 3D-printed in the size of a few millimeters. It was coated with magnetic nanoparticles to introduce a magnetic moment. The homogeneous focus field of a preclinical MPI scanner was used to apply a magnetic field with a rotating field vector. To investigate the swimmer's velocity in different fluid viscosities, different mixing ratios of water and glycerol were used for the surrounding medium.

Results

The magnetic torque is competing with the viscous drag force acting on the swimmer. Three regimes of motion were observed: a corcskrew like movement for low viscosities, afterwards a slap-stick movement, before the drag force exceeds the magnetic force and no movement was induced. Further, it has been observed that the boyency of the swimmer has an impact on the velocity as it increases with increasing viscosity.

Conclusion

The actuation of a mm-sized helically shaped swimmer coated with magnetic nanoparticles was conducted with an MPI scanner. The swimming behavior was investigated for different viscosities of the surrounding medium. Velocities of several mm/s could be observed. The swimmer shows three regimes of motion with increasing viscosity. The results indicate that it is possible to steer the swimmer in different body fluids, such as blood.