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Nanorobotics in Blood Vessels

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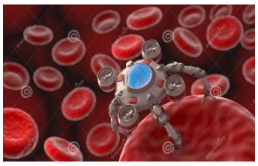
Abstract*— Nowadays the use of nanorobots for medical diagnostics is huge. Nanorobots are used to treat these diagnostics and it will be widely used in future. Here, we design a control method which controls the motion of Nanorobots that are sent into human's blood vessels and it is used as medical therapies. This study investigates the control mechanism for locomotion of nanorobots in blood vessel repair applications. Each nanorobot operating as artificial platelets has only essential characteristics for self-assembling into a mass at the injured blood vessel to reduce blood loss.Electromagnetism can be used to guide the nanorobots to move to a particular point or part of the body. Coils are also used here.

***Index Terms*— Drug delivery, simulation, simulation results,platelets,electromagnetism,magnetic actuation.**

I. INTRODUCTION

Number of normal platelets in a person should be at least 150000-400000 per microliter. A small sized robot acts like a vehicle which can travel through blood vessels and is used to treat tumours by delivering medicines which are difficult to treat in other ways. Nanorobots can travel all over the body where blood vessels are present. They can discover and detect different types of chemicals present in our body, which includes biochemical, biological and biomechanical characters. By using nanorobotic medicines the disease can be easily cured without any side effects and surgeries. For example, when there is a small crack in our body, there will be a blood clot because of platelets which stick together. The process of platelets sticking together is known as hemostatic process. These platelets are named as Thrombocytes where thrombus means a clot. Thrombocytopenia is a state where the number of platelets will be lesser than the required platelets per microliter and it causes excessive bleeding. In this method a huge amount of blood will be lost which might also cause intracranial haemorrhage that may also result in death. Thrombocytopenia can be cured in many ways. One of the common ways to cure this disease is by using platelet transfusion. But after transfusion these platelets stay in our body only for ten days, and later they are also demolished which leads to a condition where platelet transfusion should be done at least two to three times for a month which is a difficult procedure. Therefore nanorobots are used to cure the injuries within a physical body and these nanorobots act just like artificial platelets.



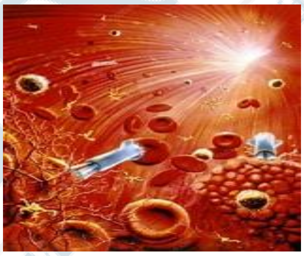


Fig: An illustration of nano robots in blood vessels.

In the above figure, nano or micro robots are transferred into blood vessels which acts like artificial platelets.

II. MAGNETIC ACTUATION PRINCIPLE

Magnetic actuation can be described using Maxwell Helmholtz coils in nanorobotics. Magnetic actuation in nanorobotics will be conducted by force and torque on embedded magnetic objects with made of materials which is magnetizable through applied magnetic fields

$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{B} = 0 \quad (1)$$

where B is defined as an external magnetic field and ∇ is known as gradient operator. The above equation is trace free and symmetric. A magnetic torque τ acts on a magnetic object m when misalignment occurs between the magnetization of the object and the orientation of the magnetic field as follows

$$\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B} = \begin{bmatrix} 0 & B_z & -B_y \\ -B_z & 0 & B_x \\ B_y & -B_x & 0 \end{bmatrix} \begin{bmatrix} m_x \\ m_y \\ m_z \end{bmatrix} \quad (2)$$

A magnetic object in this is a nonuniform magnetic field when there will exits a magnetic force **f** as shown below

$$\mathbf{f} = (\mathbf{m}\cdot\nabla)\mathbf{B} = \begin{bmatrix} \frac{\partial B_x}{\partial x} & \frac{\partial B_x}{\partial y} & \frac{\partial B_x}{\partial z} \\ \frac{\partial B_x}{\partial y} & \frac{\partial B_y}{\partial y} & \frac{\partial B_y}{\partial z} \\ \frac{\partial B_x}{\partial z} & \frac{\partial B_y}{\partial z} & -\left(\frac{\partial B_x}{\partial x} + \frac{\partial B_y}{\partial y}\right) \end{bmatrix} \begin{bmatrix} m_x \\ m_y \\ m_z \end{bmatrix} \quad (3)$$

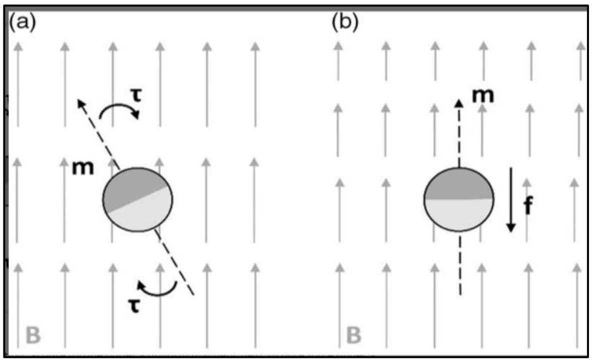


Fig: Diagram of magnetic interaction: a) pure torque under a uniform magnetic field; b) pure force under

The above two effects execute actuation once or simultaneously,6-DOF stir can be conducted. Note the equations ie equation 2 and equation 3 abstract the magnetic infinitesimal robots into a dipole, which is reasonable due to the sufficient distances relative to their sizes.40 Supposing that the magnetic field is fully flexible, only minimum 5-DOF actuation is possible under this dipole approximation (3-DOF force control and 2-DOF choker control) because the robot can't rotate along its magnetization axis.28 However, the remaining DOF can be introduced using a force couple using special multi magnet robots; with this, 6-DOF steering is possible.36, 41 Regarding the magnetic field itself, 8-DOF exist (3-DOF magnetic field factors and 5-DOF field grade factors).

III. ELECTROMAGNETIC MANIPULATION SYSTEM AND GUIDANCE METHOD

The nano robots has properties which are magnetic and has a way of manipulation for their movement of the materials .Movement of materials which are magnetic on a 3D DOF can be done by using 6 coil or windings of solenoids on XYZ axis .Copper fields and the coil or windings must be parallel , hence we must provide energy to generate for moving nanoparticles . Radial part is avoided .Multi coil or windings can make microrobots to actuate .Gradient can be generated by a single coil or winding which is electromagnetic.The placoid magnetic certain vary supported our single coil model to monitor at any point or place within the boundaries where we use three motionless set of coils which is magnetic .The circumference of the coil is the space or separation between the twirls or coils which are magnetic .The coils are impertinent to each other where there are three different coils.

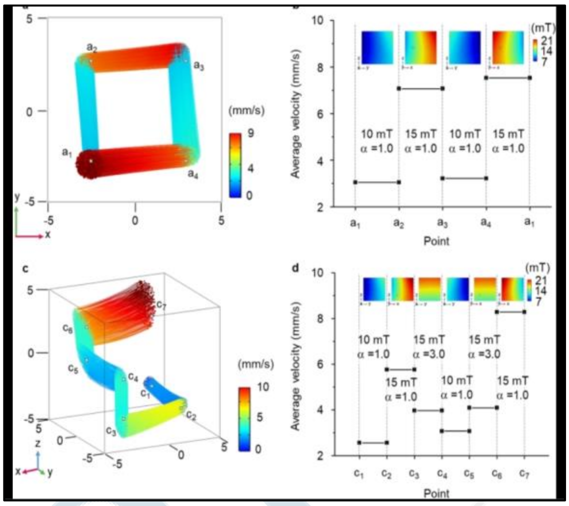


Fig: Electromagnetic actuation

First mode: circuit which is serial with coil or windings which are parallel .Totally distinct power controls the various coil or windings of the axis. Mercenary or freelance power monitors all the available collateral coil or windings i.e.(x1x2 , y1y2 , z1z2).There are about different sets of parameters and 7 different states .Here there are 4 coil or windings for the XY-axis,4 coil or windings for the XZ-axis,4 coil or windings for the YZ-axis and also the XYZ-axis coil or windings are also having four coil or windings.

Second mode: the mercenary or freelance power will be providing the coordinate axis on the individual coil or winding .Two various mercenary or freelance power monitors and controls the coil or windings which are paired in the x1 and x2 coil or windings .The second mode can be utilized in three different states .The three ways or manner can be one coil or winding of x2,x1 and x2 coil or windings of coordinate,2 x1 coil or windings which is multiplied twice.

Third mode: The power which is mercenary or freelanced on a independent coil or winding is provided on the axis which is coordinate .the mercenary or freelance energy monitors and controls the coil or windings which are constant paired on the y1 and the y2 coil or windings .Three states are also used for this third mode .the three ways or manner include one of the y2 coil or winding, two coil or windings or one y1 coil or winding,y1 or y2 coordinate axis.

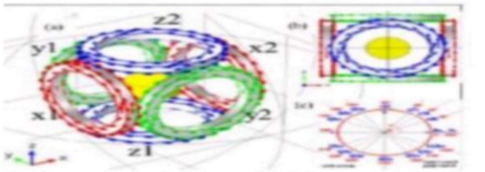


Fig-2: proposed coil system of EMM schematic diagram on the COMSOL Multiphysics: (a) 3D Cx,Cy and Cz coils design; (b) 2D top side xy-axis; (c) equation of a ROI angle cycle

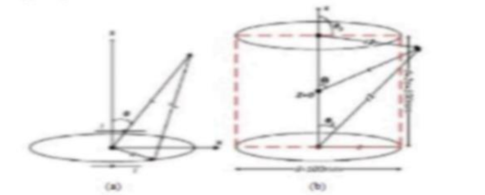


Fig-3:(a) Parameterization for xz-plane for single coil of radius a, current I, r lines in xz-plane; (b) parameterization for parallel coils, d=2a.

IV. SIMULATION PARAMETERS

A. Model

A particle tracing simulation utilising a numerical method with the COMSOL Multiphysics software tool is used to test the performance of the suggested setup and steering methodology. The cores were simulated as a soft iron at the centre of the coils using the specifications of the final design. In the steady state, the magnetic field formed by the coils was calculated using COMSOL's AC/DC modules. Air was considered as the surrounding medium, and two separate channels were modelled as blood vessels at the setup's core, as stated in the next section. The blood flow is described as a creeping stream with a fixed flow rate that varies between channels. In the steady state the flow velocity profile is estimated using COMSOL's CFD module. The fluid modelling parameters were chosen to closely resemble blood behaviour. The particles were discharged at the channel inlet's centre, and their travel course was monitored using COMSOL's Particle-Tracking module, with the particles being treated as spherical magnetite particles due to the drag force and predicted magnetic field in blood flow. The particle material and core material hysteresis curves were added to the model to give realistic results.

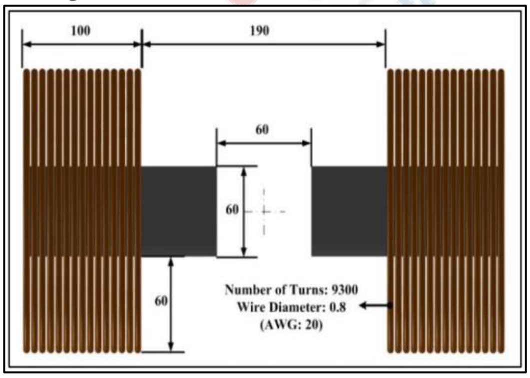


Fig: The actuation setup's final configuration and dimensions, all sizes are in millimetre.

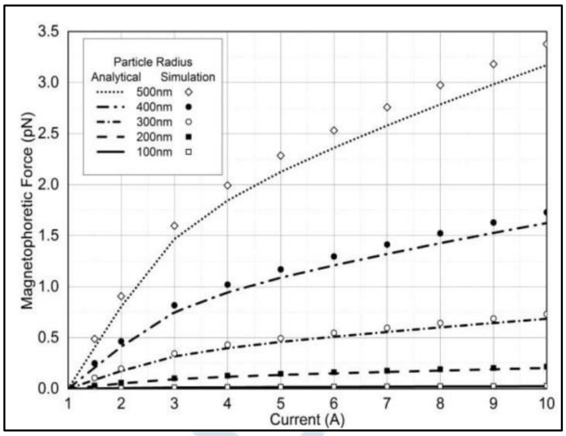


Fig: Analytical and simulation findings for a magnetophoretic force applied to a particle in the 1D actuation system's centre. The current in one of the system's coils is set to 1A. The current in the other coil of the system, which varied from 1A to 10A, is shown on the figure's horizontal axis.

B. Trajectory

A Y-shaped channel holding blood fluid was employed as a blood vessel model, and COMSOL was used to track particle movement caused by drag and a one-dimensional (1D) magnetic force. The channel form and its location in relation to coils are shown in the model setup. It's worth noting that the channel and coil scales are different in the following illustration. For all paths, the channel diameter was assumed to be 0.2 mm, the inlet channel length was 2 mm, and the intake flow velocity was retained at 5 mm/s. The particles are considered to have a radius of 450nm, and 10 A and 1A currents are applied to the coils, respectively. In the first simulation, one particle is discharged at the inlet's centre and guided to the desired outlet by electromagnets. The particle as well as the routes, all lead to distinct outlets. In the following simulation, 50 particles were released into the channel and their paths were captured for two seconds, dispersed uniformly on the inlet surface. Particle trajectories are shown as a result of the process. Although the majority of particles were sent to the correct exit, some were not. This happened because some of the particles were initially located extremely far from the centre of the inlet, needing a stronger magnetic field to draw them to the correct outflow.

C. Exit rate

The exit rate parameter is defined as the number of particles sent to the correct outlet divided by the number of particles directed to the erroneous outlet. The applied magnetic force steered the particles toward the correct outlet, which we presumed was the specified exit. Several simulations were run with different particle radius. The exit rate was calculated by counting the number of particles that reached the two outlet channels within 2 seconds for each simulation. The outcomes of these simulations are shown in

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the diagram above. These results reveal that larger particles have a higher escape rate due to the stronger magnetophoretic force applied on them.. For comparison, we've included the exit rates for the system without a core. The core's impact on system performance is evident from this exit rate. The capacity of our setup to guide particles in the appropriate direction by simply delivering a current to the coils is demonstrated by combining these results and the particle trajectory results.

V. SIMULATION RESULTS

The main purpose of the developed soft microrobot is to cross a conventional guidewire in multi-blood-vessel branches. Microrobot rotation was managed by changing the direction of the magnetic field, and rectilinear motion was managed by the master/slave system. A trajectory planning algorithm was developed to improve the human operator navigation capabilities. The trajectory details consist of the vessel length(rectilinear displacement) and the vessel angle in the bifurcations (rotational displacement)extracted and used to evaluate rectilinear and rotational displacements. A term called exit rate is used to estimate the steering performance of MNRs using the three various types of Electromagnetic configurations. Exit rate is the ratio between the number of the MNRs reaching the proper exit to the total number of the MNRs released at the main inlet. Accordingly, the high value of exit rate represents the high number of the MNRs that reach the correct exit compared to those that reach the wrong outlet.

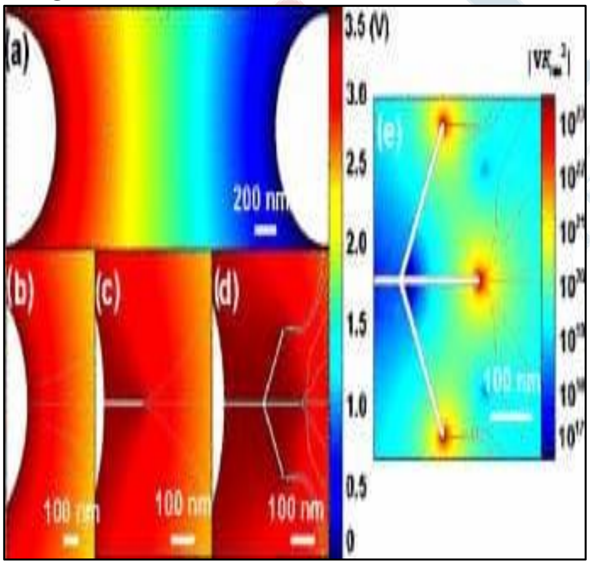

Fig: Simulation results showing particle trajectories beneath the combined influence of DEP and viscous drag forces. (a) shows the potential plot with a collection of particles moving short distances from their initial location, (b)–(d) show the potential outline plot with particle trajectories at growth stages 1–3, and (e) plot of ∇ E rms pair around a 3 branched nanowire

VI. CONCLUSION

In the last decades have witnessed nice advances and break-throughs in micro Robots, together with innovative manufacturing approaches, reconfigurable and programmable navigation techniques, advanced theoretical models, spectacular proofs of concept, and clinically orienting application trials. This review introduces basic information of magnetic fields and magnetic materials and they offer over the experimental setups of magnetic manipulation systems.

In summary, a decent understanding of the mechanism of magnetically driven micro/nanorobots and corresponding impact factors (e.g., geometrical form, field configuration, fluids properties, and boundary) may be a precondition for the conceptualization, functionalization, and automation of micro Robots. High abstraction mobility, quick, and precise programmability square measure the final word analysis goals of small-scale robots, though there's a long way to travel to translate sturdy decreased robots from bench to bedside, goodish advances square measure transferral fantasy nearer to reality.

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