

Review of different Models of Ferrofluid Generators

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Abstract—Ferrofluids are colloidal liquids made of Nano-scale permanent magnetic dipole. In the absence of an external magnetic field, The magnetic dipoles are randomly oriented in a carrier fluid and the magnetization of the fluid is zero. When an external magnetic field is applied, the dipoles rotate and produce a net magnetic moment such that the average direction of the fluid magnetization is parallel to the external field. When a container carrying the magnetized fluid is subjected to seismic excitations with a frequency that matches one of the infinite modal frequencies of the fluid column (resonance conditions), large amplitude surface waves, both horizontal and rotational, are excited. The motion of the sloshing liquid changes the orientational order of the magnetic dipoles and creates a time-varying magnetic flux. This flux induces an electromotive force in a coil wound around the container generating an electric current.

1. INTRODUCTION

The paper avows the models designed for electricity generation by using ferrofluid flowing in the system. The principle involved in the designing is the unique property of ferrofluids to produce a net magnetic moment by rotating dipoles. If the fluid is allowed to flow inside the system, there is a continuous change in the orientation of dipoles and hence the electromotive force is generated producing electric current.

Ferrofluids can be defined as a uniform mixture of magnetic particles, soap-like molecules and carrier fluid that will behave as a single unit in a magnetic field. ferrofluids are discovered by Steven Papell in 1965 under a project governed by NASA. First commercially usable liquid was developed by a team under Ron Rosegweig and field was named as Ferrohydrodynamics. For more than 40 years, the primary application for ferrofluids has been in loudspeakers. Ferrofluids have been used for science demonstrations and artistic displays for many years.

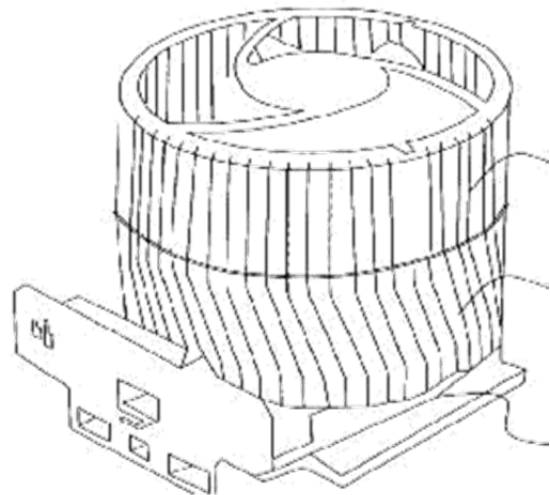
In the paper, two different models of ferrofluid based generators are reviewed and compared on the basis of conversion rate of heat to power and some other parameters. First model considered for the study is **DEVICE AND METHOD FOR**

FERROFLUID POWER GENERATOR (US PATENT, Pub. No.: US 2004/0182099, Inventor: Li-Chieh Hsu, Hsinchu, Pub. Date: Sep. 23, 2004) and second model is **MAGNETIC FLUID POWER GENERATOR** (US PATENT, Pub. NO. US 2013/0076158, Inventor: Susan MOTISSE, Burleigh Heads (AU), Pub. Date: Mar. 28, 2013).

The paper further deals with the shortcomings of the models and possible methods to improve the working. The application of ferrofluid is further extended to power generation and its possible applications in various space sciences projects are covered.

2. DEVICE AND METHOD FOR FERROFLUID POWER GENERATOR

The invention provides a device and method for ferro fluid power generator and cooling system, Wherein the Waste heat of electronic device is a heat source to vaporize fluid and form bubbles as a forwarding pump of the ferrofluid. The fluid with magnetic nano particles is pumped forward and rotated by a fluid mechanism, the pass through a high density coil to result in the time varying magnetic flux and induced current.





No additional heat-dissipating device is needed for this invention to dispose the Waste heat, which is further reused to produce electricity, such that double effects of cooling and power saving may be achieved (fig, 1a).

This method is comprised of the following steps: Providing a close loop pipe system, Which is connected to the electronic device With direct contact, and Which has a fluid containing magnetic particles; and providing a coil, Which is Wound around portion of the pipe system Wherein, When the heat is conducted to the fluid and is absorbed therein, part of the fluid is vaporized to generate bubbles to reach the cooling effect, and the bubbles pump the fluid forward and push the magnetic particles to pass through the coil, such that a time varying magnetic flux is generated in the coil by the magnetic particles and a induced current is generated by the coil as Well.

The magnetic array is constructed by arranging an array of magnetic field outside the pipe system, such that the phase angles of spinning magnetic particles may be aligned.

Consequently, when the magnetic particles enter the induced magnetic field, the time varying magnetic flux is increased. The ferrofluid is essentially a mixed fluid With magnetic particles, low boiling point liquid, and Water. The low boiling-point liquid is a non- electrolytic chemical coolant, such as: fluoride solution of FC-87, PF-5052,FC-72, or any combination of the above. The magnetic particle is a magnetized Nano iron particle.

The induced current is an alternate current (AC) With high frequency, so a rectifier may further be added to transform the AC. into D.C. (direct current). If the electronic device is a CPU (central processing unit) installed in a notebook or any other chip thereof, then the converted D.C. may be used to recharge the Lithium battery inside the notebook. The electronic device may be any kind of micro mechanical-electrical device.

The model provides a magnetic power generating method. It uses the Waste heat from an electronic device, the heat is absorbed by a fluid apart of which is vaporized into bubbles to drive the fluid with magnetic particles to pass through a coil. After that, the magnetic ferrofluid generates time varying magnetic flux and then induced current.

The invention indeed provides a device and method for ferrofluid power generating and cooling. It is no longer necessary to use traditional power consuming fan, additional mechanism, or extra energy for cooling and heat dissipating. In this invention, an advanced electronic cooling scheme of phase change and an power generator system using Waste heat as energy source are combined together to reach the effects of cooling and power saving. In addition, heat-dissipation by phase change may greatly improve the heat dissipation efficiency without consuming extra energy or generating any noise. The principle of the invention is to use low boiling-point magnetic nano ferrofluid. When the fluid absorbs heat and results in its phase change, the vaporized bubbles drive fluid with its magnetic particles forward and pass through the micro-coil to generate electric power. The invention therefore may be further applied to any heat- generating chip set or micro mechanical-electric device or auxiliary power generating equipment which utilizes thermal energy.

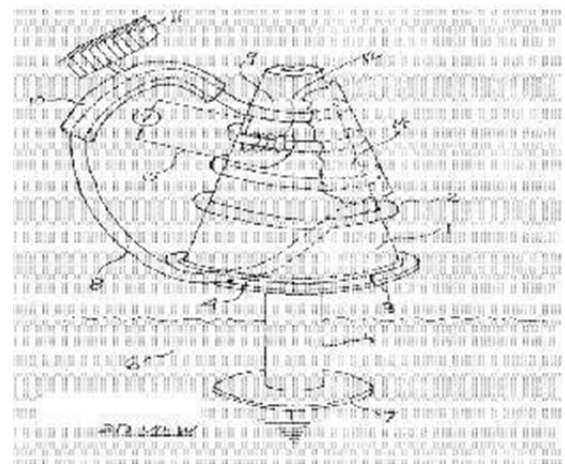
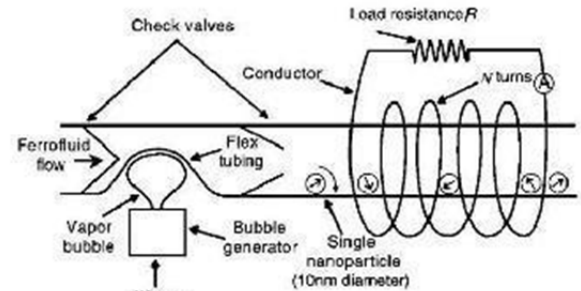


Fig. 3: Circuit diagram of the model

3. MAGNETIC FLUID POWER GENERATOR

A device for converting thermal energy to electrical energy by moving magnetized ferrofluid or magnetic nanoparticle fluid through a specially-Shaped hermetically sealed conduit coiled with insulated conducting Wires. The moving fluid creates a changing magnetic flux through the coils. Usable current is generated in the induction circuit. The conduit carrying the magnetic fluid is coiled in a special shape around a shaped magnet or magnet assembly with plates. Convection currents occur in the fluid.

The main objective of this invention is to provide a method of generating electrical power. The system is comprised of a closed loop of conduit carrying ferrofluid or nanomagnetic particle fluid. The ferrofluid moves by convection currents which are driven by a temperature differential. The convection currents are changed by the application of a magnetic field positioned to optimize the movement of the ferrofluid or nanomagnetic particle fluid. The movement of the magnetic dipoles within the ferrofluid changes the flow pattern of the convection currents. The conduit is wrapped with insulated copper conducting Wire forming part of the induction circuit. As the ferrofluid moves it produces a time varying magnetic flux through the coil forming part of the induction circuit where usable current is produced. The conduit forms a closed circuit and in the first embodiment the inside diameter of the conduit remains the same in the closed circuit loop. The conduit is hermetically sealed. The ferrofluid or nanomagnetic particle fluid is heated by a heat source such as the sun, atmosphere or Water and is cooled by a heat sink such as the earth, ice or Water. The conduit is arranged in a helicoidal shape around the cool conducting cone surrounding the magnet and then is positioned under the cool plates under the magnet and then the conduit moves in a curved path the heat sink. Another objective of this invention is to optimize the flow pattern of the ferrofluid or Nano magnetic particle fluid by utilizing shaped conduits; by utilizing more than one magnet or magnet assembly; by utilizing curved surfaces; by utilizing a Weaving of the conduit around more than one magnet; by utilizing different shaped magnets; by utilizing different cross-section of conduit; by utilizing different cross-sectional variation of the conduit along its length.

The diamagnetic material is positioned to optimize diamagnetic properties to influence the flow of ferrofluid or nanomagnetic fluid and to create a large amount of acceleration in the ferrofluids. Also, conduit is wrapped With more than one insulated coil of conducting Wire. The coil of conducting Wire follows the shape of the conduit both in configuration and thickness.

The said heat source uses heat from the sun, atmosphere, Water, man-made materials or the earth. Heat sink releases heat to the atmosphere, man-made materials, the earth, and ice, and snow, bodies of Water, man-made materials or devices. The device has no solid moving mechanical parts and

requires no external pump. Spiral directions of the conduit may be reversed. The magnet or magnetic assembly or source for magnet is magnetizing the fluid may have 1 or many magnets.

4. COMPARISON OF MODELS

on the basis of pre decided parameters.

S.NO.	PARAMETERS	US PATENT-2004/0182099	US PATENT 2013/0076158
1	HEAT SOURCE	WASTE HEAT FROM DEVICES	SUN
2	METHOD OF HEAT TRANSFER	CONDUCTION	CONVECTION DUE TO TEMPERATURE DIFFERENTIAL
3	CONSTRUCTION	COMPACT	LARGE IN SIZE
4	PUMPING AGENT	LOW BOILING POINT LIQUID	MAGNETIC REPULSION
5	PIPE SYSTEM	BASIC CLOSED MICRO COIL SYSTEM	HERMETICALLY SEALED CONDUIT PIPE SYSTEM
6	EXTERNAL ACCELERATING DEVICE	VORTEX GENERATOR	DIAMAGNETIC MATERIAL
7	CURRENT GENERATION	LOW AMOUNT OF CURRENT IS GENERATED	HIGH AMOUNT OF CURRENT IS GENERATED
8	OTHER FEATURES	PROVIDES COOLING EFFECT TO THE CONNECTED DEVICES	USES THE RENEWABLE SOURCES OF ENERGY
9	POWER UTILITY	POWER GENERATED CAN BE FED BACK TO THE DEVICE	GENERATED POWER IS AVAILABLE FOR EXTERNAL USE

TABLE I: COMPARISON OF TWO MODELS BASED ON DIFFERENT PARAMETERS

A lot of scope of research is possible for modifying the models.

S. NO.	POSSIBLE METHODS OF FURTHER DEVELOPMENT OF MODEL	S.NO.	POSSIBLE METHODS OF FURTHER DEVELOPMENT OF MODEL
1	USING MULTIPLE NUMBERS OF MAGNETS	1	MAKING THE DEVICE MORE COMPACT AND IN BUILT WITH THE DEVICES.
2	OPTIMIZATION OF THE POSITION OF DIAMAGNETIC MATERIAL	2	ELIMINATING USE OF VORTEX GENERATORS
3	USING LARGER TEMPERATURE DIFFERENTIAL IN THE SYSTEM	3	IMPROVING RATE OF HEAT CONDUCTION BY PROPER SELECTION OF PIPE MATERIAL
4	OPTIMIZATION OF THE SHAPE OF CENTRAL MAGNET	4	ELIMINATING USE OF EXTERNAL FINS

TABLE II: METHOD OF MODIFICATIONS FOR US PATENT 2013/0076158. TABLE III: METHOD OF MODIFICATIONS FOR US PATENT 2004/0182099

5. FUTURE SCOPE

As analyzed with the help of comparative studies and later the shortcomings of the models, there are certain modifications that are needed to be done in the existing models.

Optimization of the components that are being used is crucial and may be further exploited in order to have a highly efficient, cost effective, non-polluting and significant method of power generation. There are methods as discussed in table II and table III that are being studied and researched.

There are more than 2800 patents in the field of ferrofluids. The field is very vast and may be further exploited for much research and innovation. The paper reviewed two patented inventions of generators that use ferrofluid. There are various fields of sciences that are working or planning to work on the projects based on power generation by using ferrofluid. NASA is currently working on the project of building of an anti-gravity machine that uses the concept of magnetic levitation and is powered by the flow of ferrofluids.

The ferrofluids also find applications in energy harvesting projects that may possibly replace the traditional electromagnetic energy harvesters While the attained power

levels are still small as compared to the traditional electromagnetic energy harvesters, it is our belief that a ferrofluid based harvester has some unique advantages and can prove very beneficial in some targeted applications where the utilization of a moving solid magnet is not possible. Additionally, with the development of proper theoretical models to capture the response behavior of the harvester, the design parameters can be further optimized to improve the harvester's performance.

The synthesis of ferrofluid is very easy and cost effective. Ferrofluid can be developed by using household items like edible oils and toner. However, commercially used ferrofluids use complex manufacturing techniques and have very strong magnetic forces.

Ferrofluids have friction-reducing capabilities. If applied to the surface of a strong enough magnet, such as one made of neodymium, it can cause the magnet to glide across smooth surfaces with minimal resistance. This effect is known as magnetic levitation. This property is used in anti-gravity pumps where fluid is pumped up against the force of gravity. It intends to eliminate the use of traditional high power consuming pumps and provide alternative mode of pumping.

Ferrofluids are being developed for use as bearings (Fig. 5) for the generator design that can be vastly exploited as a research area. Another area of interest may be the use of ferrofluid in art and science demonstrations.

Ferrofluids have applications in space sciences where a high power consuming pump is required for pumping rocket fuel. Since there is absence of gravity in space, there is a huge problem of pumping of fuel. However, the ferrofluid only work by the presence of an external magnetic field and flow is very easy.

There are researches going on fabricating an anti-gravity device based on properties of ferrofluids. Ferrofluids have large applications in power generation.

6. SUMMARY

The paper shows the development in the field of ferrofluid power generation and the future scope of the field. It directs to review various models that are invented by various scientists and how they can be modified for a better use.

Two different models of ferrofluid power generators are reviewed and compared on the basis of some pre-existing parameters. Various possible shortcomings of patented models are discussed and their improvement is discussed.

Various advantages of using this method of power generation are included and a comparison with traditional power generation method is done.

The paper also includes some possible applications of these ferrofluids and how they are being used or may be used in the nearby future. The concept of magnetic levitation is also discussed and how it is being used in anti-gravity pumps.

The idea behind this review paper is to find methods to generate electric power by using heat sources which are abundant, easily available and useless otherwise. The models provide highly efficient power generation and cost is also less. Also, the above mentioned methods may be used for power generation with reduction of pollution level at the same time.

7. ACKNOWLEDGEMENTS

This material is based upon work done by Susan Motisse MAGNETIC FLUID POWER GENERATOR (US PATENT, Pub. NO. US 2013/0076158, Inventor: Burleigh Heads (AU), Pub. Date: Mar. 28, 2013) and DEVICE AND

METHOD FOR FERROFLUID POWER GENERATOR (US PATENT, Pub. No.: US 2004/0182099, Pub. Date: Sep. 23, 2004) invented by Li- Chieh Hsu, Hsinchu .Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views patent holders.

The comparisons are done on the basis of some parameters that are decided by the authors and do not derive any specific relation between the two models. The paper also includes material based upon some projects undergoing in NASA regarding fuel pumping in rocket. The authors do not intend to collect any data of above mentioned projects and only used them for reference.

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Biography

Author 1 is born on December 26, 1994 and is currently the student of JSS Academy of technical education. Noida (Uttar Pradesh) and is pursuing his bachelor degree in Mechanical Engineering. He has won a prize in a technical paper presentation contest in zealicon' 15.

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