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Induced Voltage Characteristics by Back Iron Effect for Electromagnetic Energy Harvester using Magnetic Fluid

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Introduction

Background

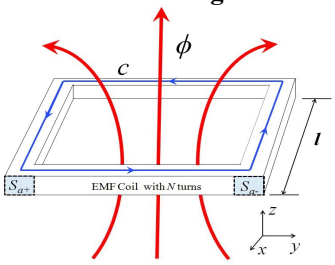
- Existing Concept of Energy Harvester
  - ✓ Constitution of Stationary Induced Coil and Moving Magnet
  - ✓ No Magnetic Circuit for Feedback of Magnetic Flux
- Operation by Large External Vibration

Designed Energy Harvester

- Implementation using Ferrofluid : Possibility for Low Frequency and Small Vibration
- Adoption of Back Iron Yoke
- Comparison of Electromotive Force(EMF) Characteristics for Energy Harvester with Air Yoke and Back Iron Yoke

EMF in Magnetic Circuit

Schematic Diagram



EMF in Closed Loop

$$E_a = N\frac{d\phi}{dt} = N\frac{d}{dt}\int_s \mathbf{B}\cdot\mathbf{ds} = N\frac{d}{dt}\oint_c \mathbf{A}\cdot\mathbf{dl}$$

$$E_a = l\frac{N}{S_a}\frac{d}{dt}\left(\int_{S_{a+}} A_z\, ds - \int_{S_{a-}} A_z\, ds\right)$$

$$E_a = l\frac{N}{S_a}\frac{d}{dt}\left(A_{a+}{}^{t} - A_{a-}{}^{t}\right)$$

Experimental Setup

Configuration of Experiment

Shaker and Scope

Harvester with Air Yoke

Harvester with Back Iron Yoke

- Ferrofluid : Fluidity and Magnetic Property
- Back Iron Yoke Effect : Decrease Reluctance → Increase Magnetic Flux → Increase EMF

Energy Harvester

- Details of Ferrofluid Harvester

Part	Property	Value
Magnet	Dia. & thickness	25 mm
	Res. induction	220 mT
EFH1	Relative Perm.	2.59
	Amount	91 ml
Iron core	Type	Steel 45C
	Relative Perm.	1000
Coil	Resistance	161.3Ω
	Inductance	74.3 mH

- Supplementary Information
  - ✓ Shaker : 0-300 rpm
  - ✓ Oscilloscope: GDS-2102A
  - ✓ PM : Nd Magnet
  - ✓ Enameled wire: ϕ 0.4 mm
  - ✓ Ferrofluid : Ferrotec®

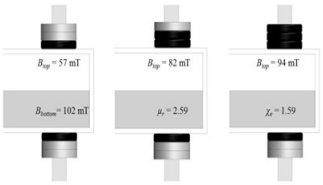
Experiment Results

Conditions for Ferrofluid Volume and PM Flux

- Variables for Experiment

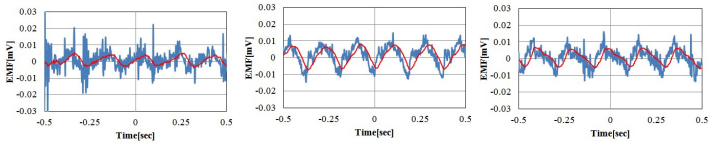
Factor	Model	Quan. & Mag.	Remark
Magnetic flux density	M1	220 mT	At the upper magnet surface
	M2	350 mT	
	M3	420 mT	
Ferrofluid Volume	F1	60 ml	Container volume : 182 ml
	F2	91 ml	
	F3	121 ml	

- Permanent Magnet Arrangement



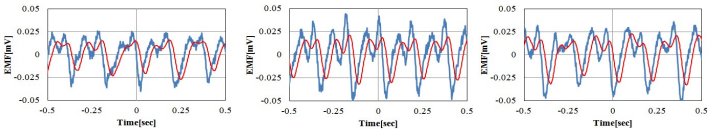
Instantaneous Values of Induced Electromotive Force

- In Case of Air Yoke



M1 M2 M3

- In Case of Back Iron Yoke

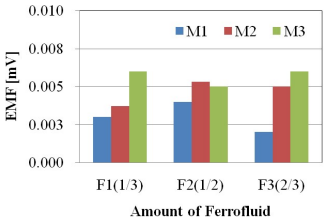


M1 M2 M3

- ✓ Ferrofluid Volume : F2(91 ml)
- ✓ External Vibration : 5 Hz

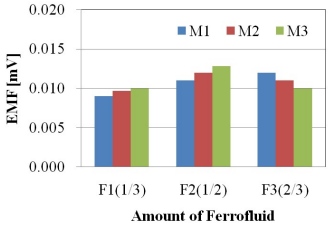
Comparison of RMS Value of the Electromotive Force according to Ferrofluid Volume and Magnetic Field

- Air Yoke



- ✓ The EMF is increased in proportion to the magnetic field intensity.
- ✓ It is caused by decrease of sloshing motion due to stick ferrofluid to the permanent magnet.

- Back Iron Yoke



- ✓ The EMF increases in proportion to the magnetic field intensity.
- ✓ The back iron effect increases the amount of magnetic flux and magnetic flux variation with respect to time.

Conclusion

- Ferrofluid based Energy Harvester can Apply to the System with the Small and Low Frequency Vibration.
- The Energy Harvester with Back Iron Yoke Generates Large EMF due to Abundant Flux Variation.