Impact Torque Analysis of New Electromagnetic Impact Mechanism Employing 3-D Finite Element Method
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Introduction

- This paper describes impact torque characteristics of a new electromagnetic impact mechanism employing 3-D FEM.
- In this mechanism, the induced current in a coil is controlled by switching current ON/OFF depending on the rotation angle of a rotor magnet in order to reduce average torque.
- The effectiveness of this mechanism is verified by carrying out the measurement on a prototype.

Electromagnetic Impact Mechanism

Permanent magnet
Magnetic body
Conductor
Coil
Motor

Operational Principle

- The un-magnetized ring magnet is rotated in high speed using a motor.
- The induced current flows in coils caused by the time variation of interlinkage magnetic flux of coils.
- The Lorentz force is generated from the induced current and the magnetic flux of the ring magnet.
- The reaction force acts on the rotor as a brake, which is also the load on the motor.

Operational Principle

3-D mesh of EMH mechanism except air
Magnetic flux
Lorentz force
Induced current
Reaction force (Load on motor)

Coil

Magnetic field and electric circuit analysis

Where, $\Phi$ is magnetic vector potential, $\sigma$ is the reluctivity of medium, $J_e$ is the eddy current density, $\phi$ is the reluctivity of vacuum, $A$ is the magnetic field, $\theta$ is the conductivity, $\sigma_e$ is the current, and $\sigma_m$ is the interlinkage flux of induction coils. It is assumed $\theta M_{\mu e}$ when coils are open, and $\theta M_{\mu m}$ when they are closed.

Rotation motion analysis

(1) The rotation magnetic region is equally divided according to rotation speed and time interval.
(2) The material data and magnetization directions of the rotation magnet are changed in every step for the rotation motion analysis. The rotation speed of magnet is constant.

Double node method

Double node • Two electronic scalar potential $\phi$
Normal node • Conductor
Conductor • Edge current
Conductor • Double node method

Analysis Method and Conditions

Dynamic Characteristics (Rotation speed: 1000rpm)

The Condition of Model

Model 1: Eddy current is considered
Model 2: Eddy current is not considered
Model 3: The outer core is composed of silicon steel lamination

Verification by Experiment

Conventional method

Experimental setup

Peak Torque vs. Rotation speed
Peak Current vs. Rotation speed

1. Analyzed peak current agrees well with the experimental results.
2. Analyzed peak torque is a little higher than the experimental results at each rotation speed. This difference is thought to be the measurement error.

Conclusion

- This paper proposed a new electromagnetic impact mechanism by switching current ON/OFF depending on the rotation angle of a rotor magnet in order to reduce average torque.
- The usefulness of this mechanism was shown by the computed results by the 3-D FEM.
  *Peak torque almost keeps the same value (54.53mN-m)
  *Average torque decreases about 96% (22.0 ⇒ 0.83mN-m)
  *Average current decreases about 96% (1.1 ⇒ 0.042A)
- The validity of the analysis was confirmed by carrying out the measurement on a prototype under no current control.