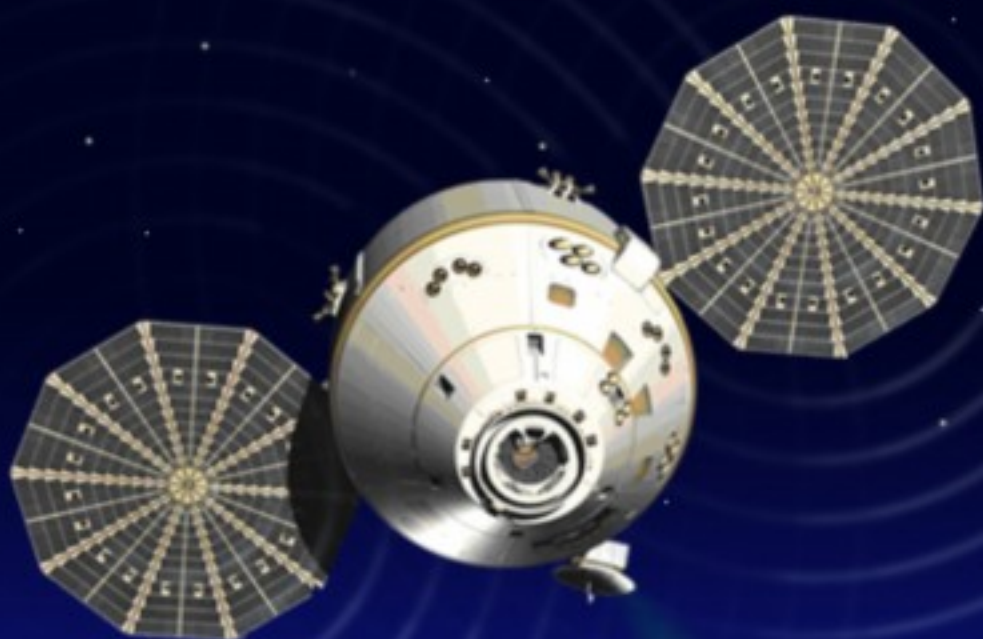


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Repulsive-Magnets-Type Acceleration Limit Switch

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Abstract: We have developed a repulsive-magnets-type vibration limit switch. This limit switch employs the magnetic switching phenomenon of a mechanical structure by effecting a change in the magnetization of the magnetic material between repulsive magnets in the structure. The plot of switching acceleration vs. frequency shows a resonance frequency that is close to the frequency range of human motion. The resonance frequency and magnitude of switching acceleration are controlled by the components of the limit switch. *Copyright © 2008 IFSA.*

Keywords: Repulsive magnets, Accelerometer, Acceleration limit switch, Magnetic switching phenomenon

1. Introduction

Many types of accelerometers have been developed [1]. An induction-type accelerometer enables a person to drive without a battery [2]. These accelerometers are expressed by a vibration equation that comprises a spring constant and damping constant. These accelerometers have a resonance frequency which is sensitive. By using this resonance frequency, the accelerometer enables to detect only specific frequency.

This paper introduces the magnetic switching phenomenon of a mechanical structure and its application as a novel acceleration limit switch. The structure consists of a fixed magnet, a moving magnet, and a fixed part of a soft magnetic material/magnet (Fig. 1). The moving magnet is made to move between the

fixed magnet and the fixed part by adjusting the shape of the soft magnetic material (left side of Fig. 1). The moving magnet is made to vibrate by using a shaker; it is made to connect with the fixed part by changing the magnetized state of the magnetic material when the shaker gives vibration acceleration greater than a certain value (right side of Fig. 1). By using a conductive tape, the mechanical structure can also be used as an electric acceleration switch (Fig. 1). This acceleration limit switch has the advantages of auto-detection and simple structure and does not require a battery. It is available as a mobile acceleration monitor.

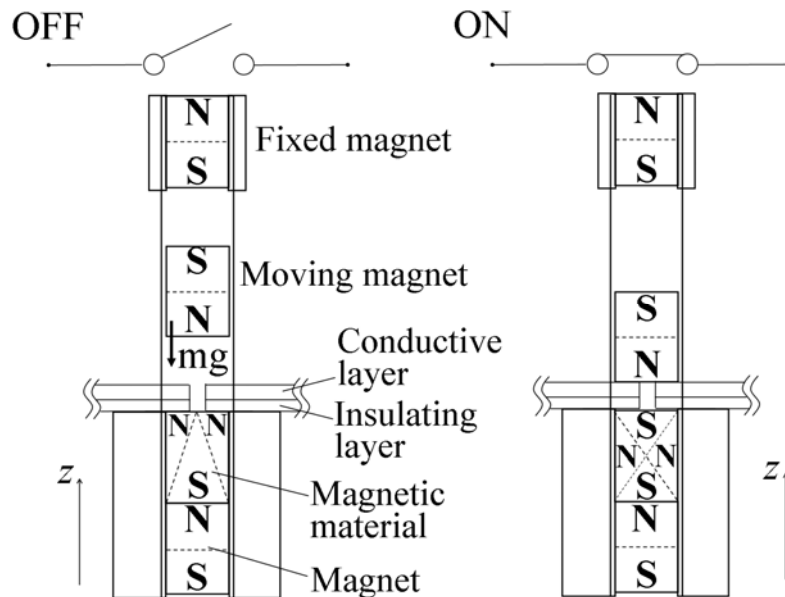


Fig. 1. Schematic view of repulsive-magnets-type acceleration limit switch.

This paper aims to provide a correlation diagram for the components of the limit switch by investigating it experimentally.

2. Experimental Details

Fig. 2 shows schematic views of three limit switches. First, we investigate the effect of the length of the magnetic material between the repulsive magnets on the resonance frequency and magnitude of switching acceleration by using model 1 in Fig. 2 (a). The magnetic material is an iron column with a diameter of 3.2 mm. The length of iron assumes values of 1.58, 3.28, and 6.39 mm. An NdFeB magnet with a diameter and length of 3 mm and 1.5 mm, respectively, is used. The moving magnet consists of 8 magnets and its total length is 12 mm. Both the fixed magnets consist of one magnet. These magnetic materials are positioned in a plastic pipe with an internal diameter of 3.6 mm, an external diameter of 4.2 mm, and a length of 50 mm. Second, we investigate the effect of the distance between the repulsive magnets on the resonance frequency and magnitude of switching acceleration by using model 2 in Fig. 2 (b). The distance d between both the fixed magnets is either 47 or 37 mm. The magnetic material is a steel ball with a diameter of 3.5 mm. The magnets and plastic pipe are similar to those in model 1. Finally, we investigate the influence of several magnets on the abovementioned two parameters and the strength of the magnetic field by using model 3 in Fig. 2 (c). SmCo magnets with a diameter and length of 6 mm and 5 mm were used. The moving magnet consists of 7, 5, and 3 magnets. The total length l_m is 35, 25, and 15 mm, respectively. There is only one fixed magnet on the lower side. The fixed magnets corresponding to the abovementioned three moving magnets consist of 1, 2, and 4 magnets, respectively. The total length l_{fm} is 5, 10, and 20 mm, respectively. The magnetic material is a steel ball with a

diameter of 6.35 mm. A plastic pipe with an internal diameter of 7 mm, an external diameter of 10 mm, and a length of 98 mm is used.

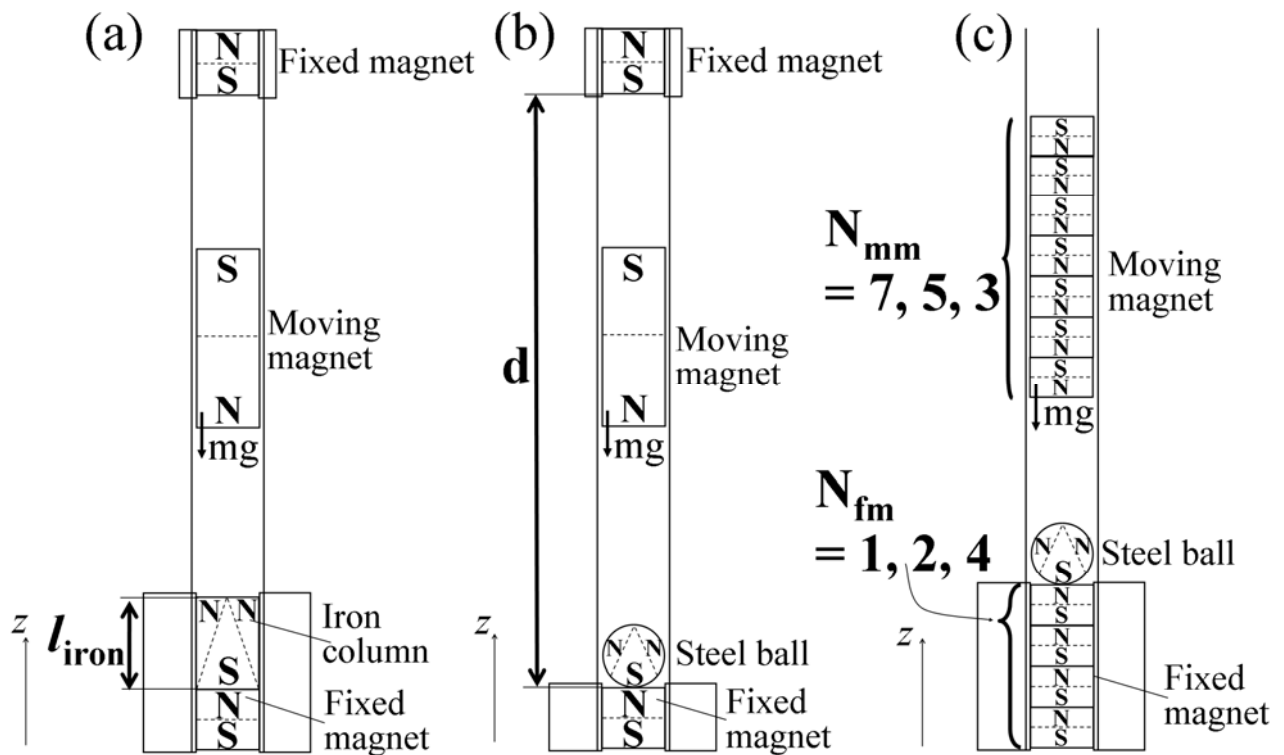


Fig. 2. Various models of acceleration limit switch. (a), (b), and (c) show model 1, model 2, and model 3, respectively.

A long stroke shaker (AR BROWN MODEL113) is used as the source of vibrations, and it is made to vibrate by a signal amplified by an amplifier (AR BROWN MODEL114). A Vibrating measurement is performed more than three times for various frequencies from 2 to 20 Hz at different acceleration values up to 2 G. These acceleration values are measured by an acceleration sensor (COLUMBIA RESEARCH SA-120R).

3. Results and Discussions

As shown in Fig. 3, the plot of switching acceleration v.s. frequency shows a resonance frequency. The resonance frequency ranges from several Hertz to ten and several of Hertz.

By decreasing l_{iron} as shown in Fig. 3 (a)–(c), the resonance frequency and magnitude of switching acceleration increase. If l_{iron} is very large, the moving magnet is not able to repel the material; on the other hand, when the length is very small, the moving magnet is not able to connect to the fixed part.

By decreasing the distance between the upper fixed magnets and the lower fixed magnet, as shown in Fig. 3 (d) and (e), the resonance frequency and magnitude of switching acceleration increase.

Fig. 3 (f)–(h) show plots for different numbers of fixed magnets (N_{fm}). When N_{fm} is decreased, the strength of the magnetic field H decreases, the resonance frequency increases, and the magnitude of switching acceleration decreases.

Figs. 3 (h)–(j) show plots for different numbers of moving magnets (N_{mm}). When N_{mm} is decreased, H decreases, the weight of the moving magnet m_{mm} decreases, the resonance frequency decreases, and the magnitude of switching acceleration increases. From has been previously described for the strength H , the weight m_{mm} has more effective than the strength H for N_{mm} . In other words, when m_{mm} is decreases, the resonance frequency decreases, and the magnitude of switching acceleration increases.

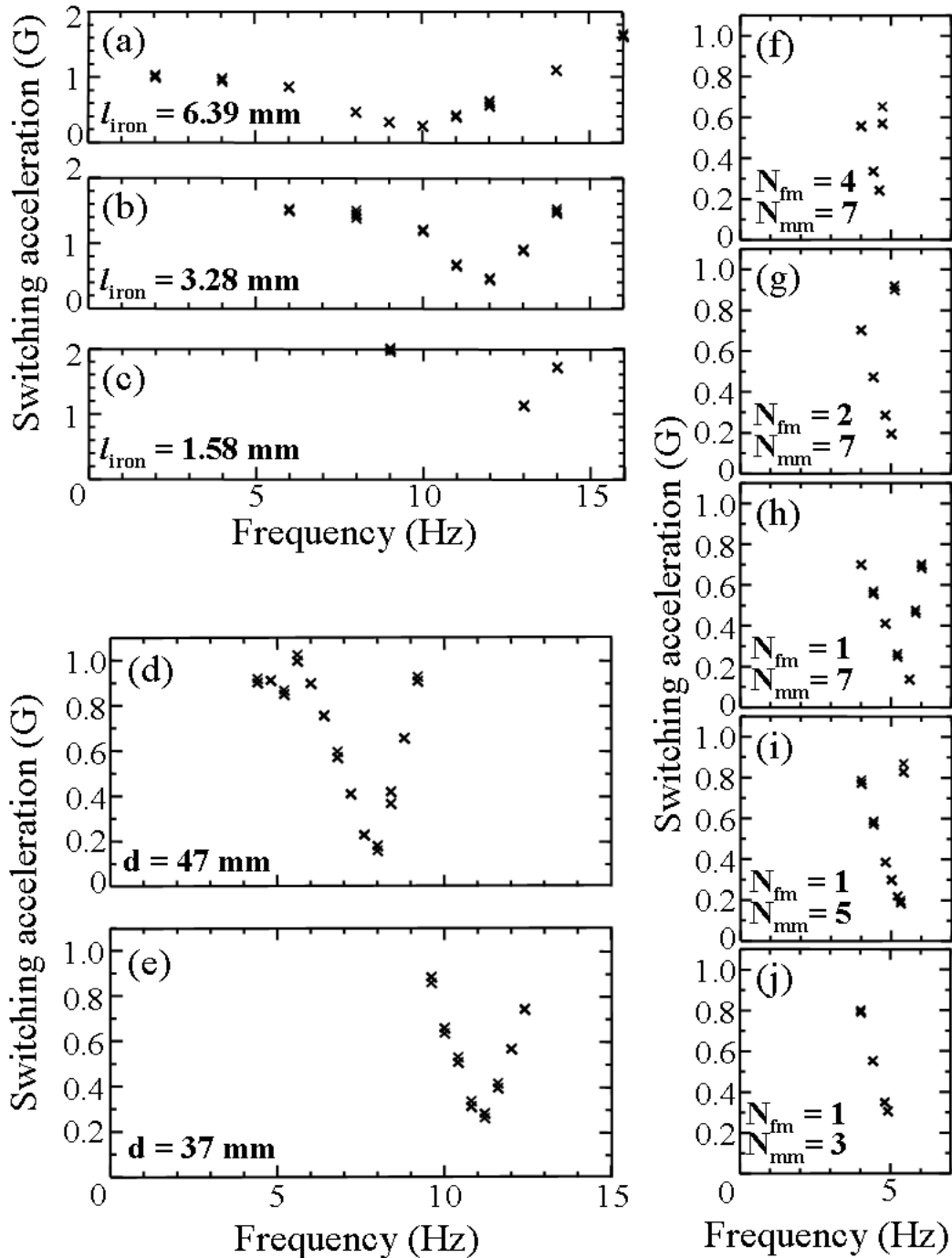


Fig. 3. Switching acceleration plotted as a function of frequency. (a), (b), and (c) show plots for model 1 for $l_{iron} = 6.39$ mm, 3.28 mm, and 1.58 mm, respectively. (d) and (e) show plots for model 2 for $d = 47$ mm and 37 mm, respectively. (f), (g), and (h) show plots for $N_{fm} = 4$, 2, and 1, respectively, when N_{mm} is fixed at 7. (i) and (j) show plots for $N_{mm} = 5$ and 3, respectively, when N_{fm} is fixed at 1. (f)–(j) are for model 3.

By comparing these results of the switching acceleration, the spring constant and damping constant of the vibration equation can be derived. An investigation of relations between these constants is an issue in the future.

Fig. 4 shows the correlation of the frequency response for the parameters l_{iron} , d , H , and m_{mm} . There are two patterns. These patterns are helpful as a guide in the designing of the limit switch.

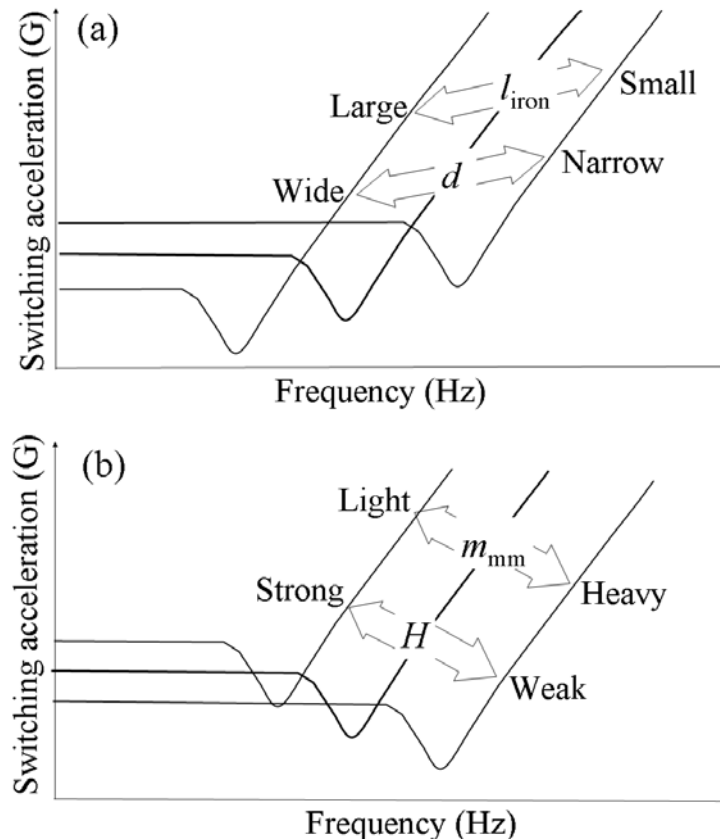


Fig. 4. Correlation diagram for various parameters on the switching acceleration vs. frequency plot. (a) and (b) show pattern 1 and pattern 2, respectively.

4. Concluding Remarks

We have developed a repulsive-magnets-type vibration limit switch which enables to respond to a motion of human. This limit switch has the advantages of auto-detection and simple structure and does not require a battery.

The resonance frequency and magnitude of switching acceleration are controlled by the components of the limit switch.

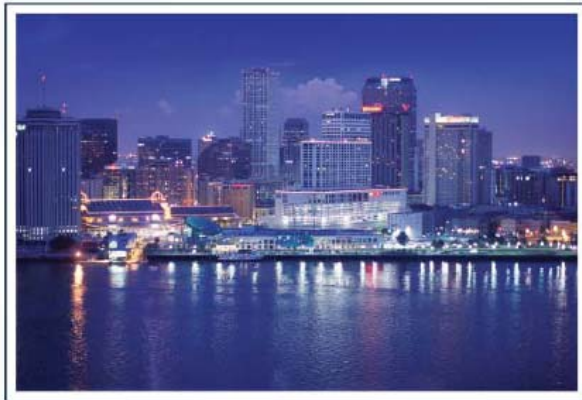
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Important Dates

- **15 September 2008:** Abstract submission deadline
- **15 November 2008:** Notification of acceptance
- **01 January 2009:** Final manuscript submission deadline

For additional information, please visit the Sensors Applications Symposium website at www.sensorapps.org

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In addition, some special sponsored and conference issues published annually.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 6-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm> Authors must follow the instructions strictly when submitting their manuscripts.

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Smart Sensors Systems Design

A five-day advanced engineering course
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General Information

This course is suitable for engineers who design different digital and intelligent sensors, data acquisition, and measurement systems. It is also useful for researchers, graduate and post graduate students. Course will be taught in English.

Course Description

An advanced engineering course describes modern developments and trends in the field of smart sensor systems and digital sensors design.

After a general overview of data acquisition methods, modern smart, digital and quasi-digital sensors, smart systems details are discussed. A systematic approach towards the design of low-cost high-performance smart sensors systems with self-adaptation and self-identification possibilities is presented.

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Online Registration:

http://www.sensorsportal.com/HTML/SSSD_Course_2008.htm

Deadline for Registration:

31 October, 2008



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