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Omni-Directional Impact Micro switch with Extended Holding Time

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Abstract

The Omni-directional impact MEMS switch was designed and characterized for the purpose of impact sensing. In order to turn on the circle reliably, the connect time should be long enough, the structure of flexible electrode was designed to extend the holding time. The structure consists of electrode A and B, electrode A is the sensing mass simultaneously, the sensing mass is suspended by helix cantilever that is fixed to the pedestal, the outer ring is the electrode B, which is suspended by helix cantilever that is fixed to the outer frame. Between the two electrodes, there is a gap, the gap separates electrode A and B, thereby keeping the switch in the open state. The distortion during the impact process extended the contact time. The dynamics of the switch is simulated, the simulation results show that the response time of the switch is 0.135ms, it is short enough, and the contact time which is also called holding time is about 20 μs *, the extended time make the switch turn on more reliably. These results satisfy the required specifications for the ammunition systems.*

Keywords*: MEMS, inertial switch, universal, annular.*

1. Introduction

MEMS impact switch, the product of combination of mechanics and electricity, which was also known as the inertial switch or acceleration switch, is the MEMS actuators provided the action of switch closure to be sensitive to change in acceleration. These MEMS impact switches can be divided into two classes, mechanical switch and accelerometer switch. The mechanical switch is able to ensure connection or disconnection in physics by sensing the change of the acceleration, and it does not require the durative electric energy before it begins to works. Because of its passiveness, it has the strong anti-jamming ability. The acceleration switch which works only by accepting some electric signals, does not implement the connection of two electrodes in physics. The acceleration switch translates the change of external acceleration into the change of resistance or electric current, then the electric signal is measured and compared by the measurement circuit, finally the electric signal which measures up the threshold accepted by the switch, and the control circuit is switched on. The feature of the acceleration switch is that the switch works by measuring and comparing, and require the electric power all the time, it could be suffering the interference such as the electromagnetism. The features, e.g., high efficiency, rapid response, accuracy, high reuse frequencies, make the MEMS impact switch employed in a wide variety of applications such as automobile airbag deployment systems, vibration alarm systems, etc. Especially in the ammunition system, the switch size dwindles over several times will make room for extending other functions and enhancing the power of the ammunition.

The United States, at the turn of the century, reported a kind of MEMS inertial switch [1] which sense the change of unidirectional acceleration, and its inertia hammer whose top constraints by the thermodynamic or electromagnetic force to ensure that the inertia hammer does not move downward in non-working status. When the switch entails work, the circuit supplies power and thermodynamic or electromagnetic force removes the constraints of inertia hammer which is stuck in the right place at the bottom after the downward movement, the bottom of cantilever beam distorts under inertia hammer, and connects circuits. A passive universal inertia switch [2] , which is of normal open, instantaneous action, and non-locking of inertial threshold and able to be coupled with fuse circuits, was proposed by Robinson et al. in

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patent in 2002, the switch can sense multi-direction acceleration, but the square mass decided that the switch has different sensitivity in different direction. Micro-inertial switches that Greywall et al. proposed adopted that the structure of loop mass supported on helical spring in patent in 2006 [3], the helical spring decided that the switch is suitable for low G-value. By adjusting voltage to regulate acceleration threshold, threshold adjustable acceleration switch of Korea high-tech research institute utilized inertial and resultant force of electrostatic forces caused by the inside electrode voltage [4-5].

The mechanical switch is passive and has the strong anti-jamming ability, but the contact time of the two electrodes is short because of the rigidity collision, the control circuit is hard to take the signal during the short time. The acceleration switch can easily extend the contact time by using electricity, for example using the squeeze film effect [6] and other method in RF switch, but the acceleration switch require the electric power all the time, it could be suffering the interference such as the electromagnetism, and is not suitable for the atrocious condition when using it in ammunition. In this paper, the Omni-directional impact MEMS switch with extended holding time using flexible impact is developed, it works by sensing the impact acceleration, be integrated with electronics, and lack of a requirement for continuous power, so it is easy to avoid the outside electronic disturbance.

2. Structure

2.1. Working Principle

The working principle of the impact switch is shown in Figure 2. The impact switch contains two electrodes, A and B, A is the sensing mass simultaneously. Every electrode is connected with flexible cantilever for the aim of flexible impact. When the impact switch is under large acceleration enough, the sensing mass A moves towards B, and the A contacted with B, the right flexible cantilever began to distort. The process of the distortion is the contact process of the two electrodes, the holding time extended by flexible distortion.

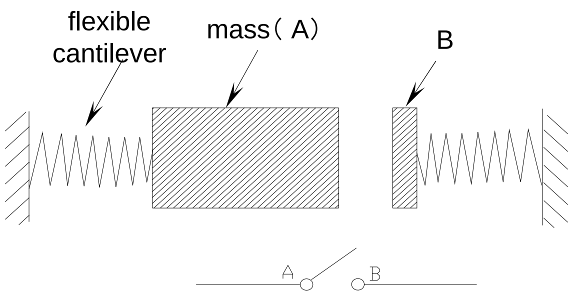


Figure 1a. initial state

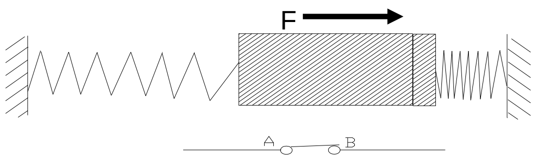


Figure 1b. Switch turned on

Figure 1. A simplified model for the switch

2.2 Switch Structure

The designed switch is a glass-silicon-glass sandwich. To describe the structure layer definitely, the top and bottom flat is not shown herein, the middle structure layer is the heart of the device, it consists of electrode A and B. Electrode A is the sensing mass simultaneously, the sensing mass is suspended by helix cantilever that is fixed to the pedestal which located in center and connected with the bottom glass cover, the outer ring is the electrode B, which is suspended by helix cantilever that is fixed to the outer frame. Between the two electrodes, there is a gap, the gap separates electrode A and B, thereby keeping the switch in the open state. The structure of the switch is shown in Figure 2.

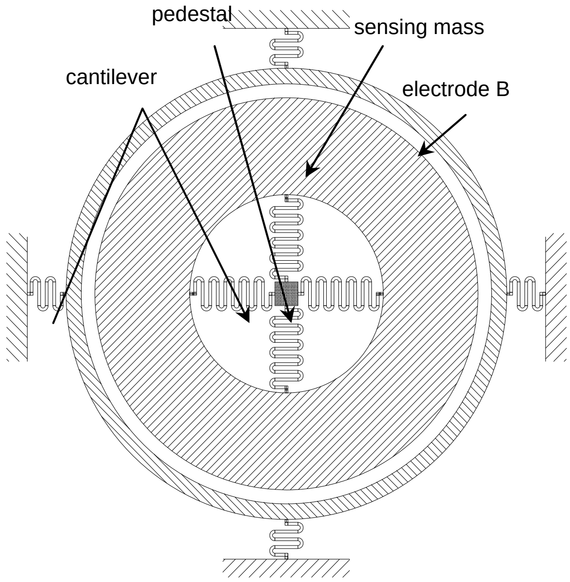


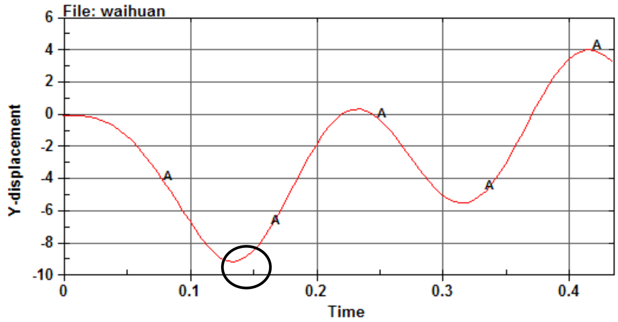
Figure 2. Front view of switch device

When the accelerations applied, the sensing mass will leave from its initial position and move towards the electrode B. If the acceleration is not high enough, the sensing mass will go near by the electrode B (but not contact) and soon is pulled to its home position again with the tension of the helix cantilever increasing. In contrast, When the absolute value of acceleration along a particular direction exceeds a certain threshold value, the sensing mass contacts with the fixed electrode, so the sensing mass moves with electrode B, and the helix cantilever which connected with the electrode B began to distort under the outside force, the ON-state is held because of the distortion and the duration of the ON-state extended by flexible distortion. Because of the peculiarly annular structure, the impact switch reacts the same threshold acceleration along any direction in the x-y plane.

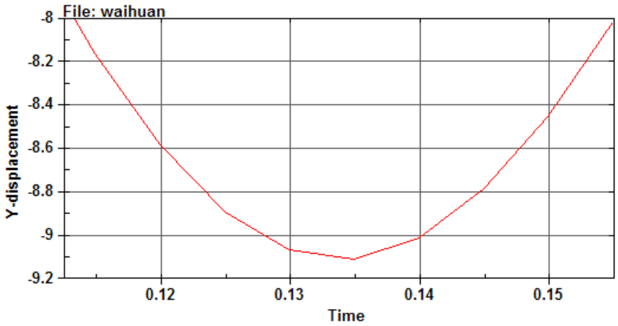
3. Dynamic Analysis of the Switch

When the sensing mass accepted the large acceleration from one direction, it moves towards the negative direction. Figure 3a shows the displacement of the sensing mass under the external force 800g. From Figure 3a, the displacement of the sensing mass increases along with time adding, at about 0.135ms, the annular proof-mass impacted with the fixed electrode. Figure 3b is the large part figure of the Figure 3a, the initial gap between the electrode A and B is 8 μm, the maximum displacement of the electrode A reached 9.14 μm, it illustrates that the electrode B and the cantilever that connected with electrode B distorted during the impact.

Figure 4a shows the displacement of the electrode B during the impact. From Figure 4b, at about 0.135 μs, the electrode B receives the impact, the maximal displacement of the electrode B reaches to 1.14 μm and then vibrates about its equilibrium position with the amplitude attenuating acutely.

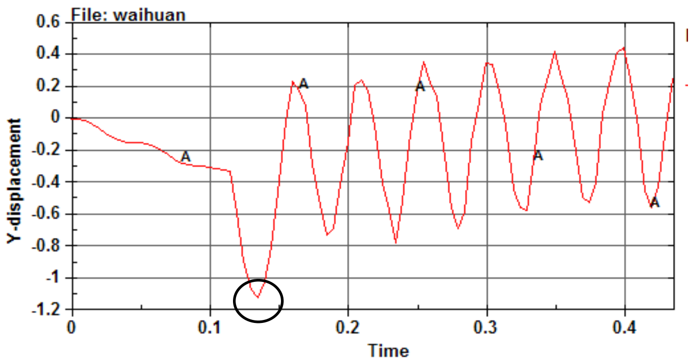


a. The displacement of the sensing mass

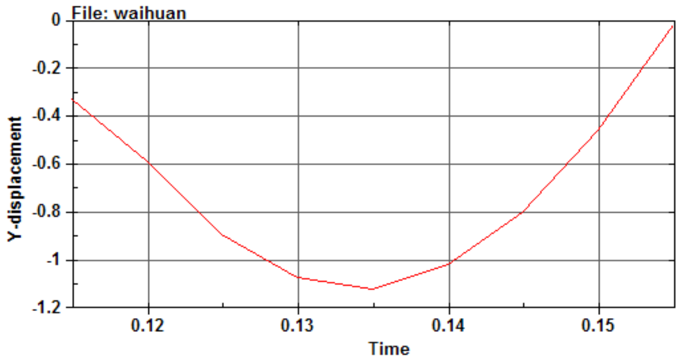


b. The large part figure of the Figure 3a

Figure 3. The motion of the sensing mass



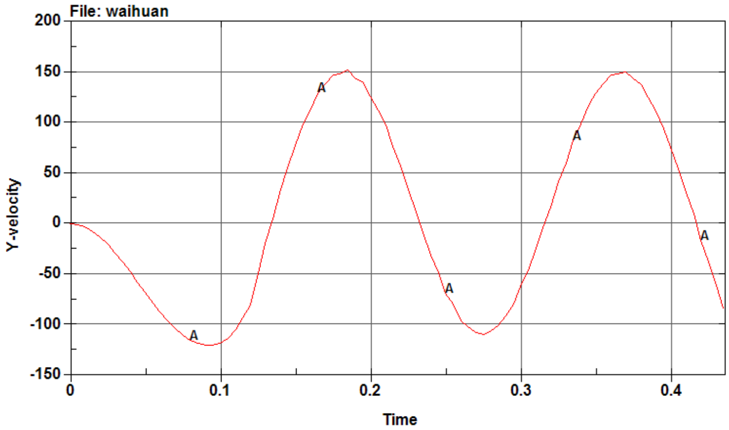
a. The displacement of electrode B



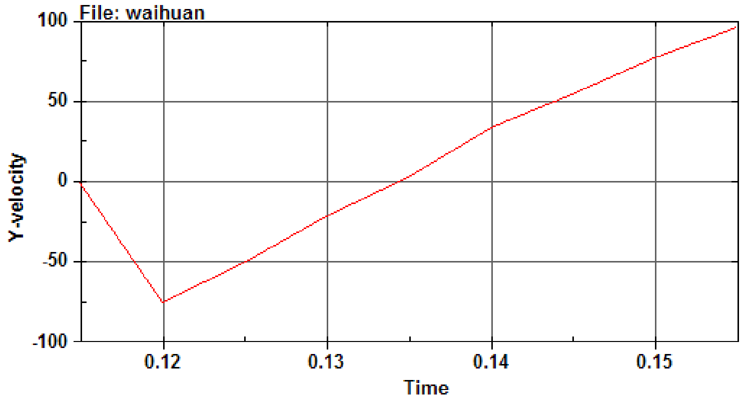
b. The large part figure of the Figure 4a

Figure 4. The motion of the electrode B

Figure 5a shows the velocity of the sensing mass under the external force 800g. Figure 5b is the large part figure of the Figure 5a. Figure 6a shows the velocity of electrode B co responsively. Figure 6b is the large part figure of the Figure 6a. From Figure 5b and Figure 6b, from the impact time 0.135ms, the velocity of the sensing mass is as same as the electrode B, it shows that from the impact 0.135ms, the sensing mass moves with electrode, until 0.155ms, the contact time which is also on-state time is about 20 μs .

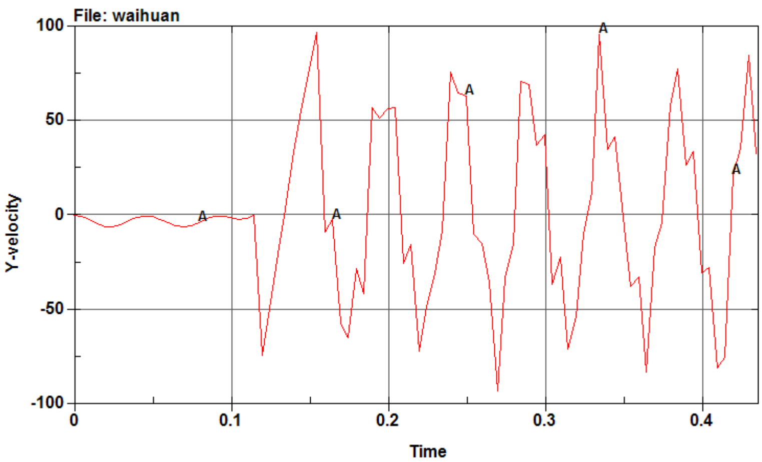


a. velocity curve of the sensing mass

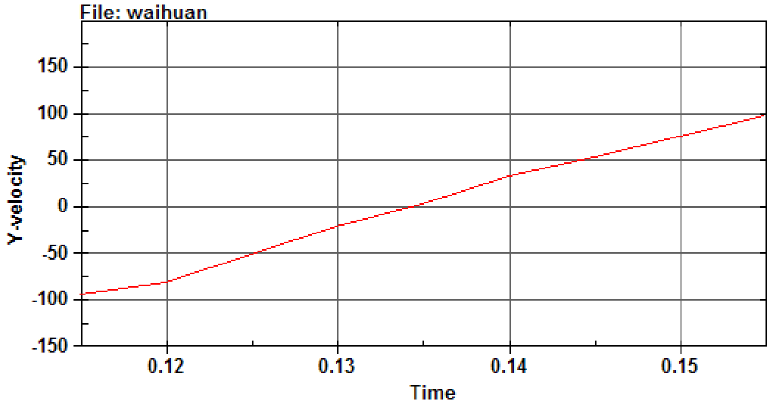


b. The large part figure of the Figure 5a

Figure 5. The velocity of the sensing mass



a. velocity curve of the electrode B



b. The large part figure of the Figure 6a

Figure 6. The velocity of the electrode B

4. Conclusion

The Omni-directional impact MEMS switch which performs extended holding time utilizing flexible impact is developed, The dynamics of the switch is simulated, the simulation results show that the response time of the switch is 0.135ms, it is short enough, and the contact time which is also called holding time is about 20 μs , compared with the pre-structure [7], the contact time extended about 15 μs ,the extended time make the switch turn on more reliably. These results satisfy the required specifications for the ammunition systems.

References

[1] CH Robinson. *Micro electro mechanical systems (MEMS) type high capacity inertial switching device*. U.S.6314887B1(Patent). 2001.
[2] CH Robinson. *Omni-directional micro scale impact switch*. U.S. 006765160 (Patent). 2001.
[3] Dennis S Greywall. *MEMS-based inertial switch*. U.S. 2006/0033598 A1(Patent). 2006.
[4] Jeung Sang Go, Young—Ho Cho, Byung Man Kwak. Acceleration Micro-switches with adjustable snapping threshold.*Transducers'95*. 1995 Jun 25-29; Stockholm, Sweden.
[5] Jeung Sang Go, Young Ho Cho and Byung Man Kwak. *Sensors and Actuators*. 1996; 83.
[6] M Tadao, E Masayosh. *Sensors and Actuators*. 2002; 100(10).
[7] Shuangjie Liu and Yongping Hao. *Advanced Science Letters*. 2011; 4.