Spin Energy Harvester for[1] Armaments Applications

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Abstract[1]

Armaments that carry explosives are supposed to blast at the target site and require detonators. These are basically external power sources that trigger the explosives. Batteries that are used for this purpose were required to be replaced by a self-generating unit using the rotational energy these missiles carry during their flight incorporating piezoelectric material. The aim of this paper is to present one such model that has been solely developed for this purpose. It is loosely based on the concept of a centrifugal clutch used in automobiles and has an arrangement of four heavy radial masses held together by an elastic material to the central shaft. Upon the high speed rotation, they are expected to hit the inner periphery of a circular disc composed of piezoelectric material, which would produce stress, hence strain and give a proportional power output.

Keywords: Self-generating, piezoelectric, rotational energy, centrifugal clutch, stress

1. Introduction

The head of an armament contains explosives that need detonation upon reaching the target. The detonation has always been carried out using batteries that supply power of 12V, 20mA to a trigger material which then ignites and explodes the missile. These armaments are stored in warehouses for periods as long as 30 years. The batteries in due course require constant charging or replacement at frequent intervals; otherwise the armaments would be rendered useless at the time of need. This constant maintenance requires a budget which can possibly be saved if an alternative is successfully developed. The aim here is to develop a rotational energy harvester, a self-sufficient unit that would produce power using piezoelectric material utilizing the spin energy that the missile is supplied with at the time of launch. There have been no eminent prior works on harvesting the rotational energy of a missile.

A mechanism to generate output using eccentric rotating mass, magnets and piezoelectric beam was modelled and analyzed (Reza Ramezanpour et al.). In this mechanism the eccentric mass is made to swivel by energy supplied by an external source. The mass has a magnet fixed at its base and the piezoelectric beam also has magnet attached to its tip which causes the piezoelectric beam to vibrate whenever the magnet at the rotating base interacts with the magnet at the PZT tip and a voltage is obtained. Another mechanism that harvests vibrational energy using rolling mechanism with help of piezoelectric material was modelled and analyzed (Hong-Xiang Zou et al.). The mechanism consists of the outer cylinder, ball bushing, inner cylinder and the piezoelectric sleeves. The ball bushing, in which a number of ball arrays is embedded and is installed on the inside of the outer cylinder. The piezoelectric sleeves are installed on the outside of the inner cylinder. One piezoelectric unit has one *PZT layer and two raised metal layers bonded to both sides of the PZT layer. The*[4] vibration is transmitted to the device and the balls move back and forth. When the ball contacts the raised part of piezoelectric unit, the rolling force is produced and applied to the piezoelectric unit, and the *voltage can be generated due to piezoelectric effect.*[5] An article about a universal piezoelectric generator unit, which has a housing inside which Belleville spring units are placed was presented (Jahangir Rastegar et al.). Although these generate electric current upon external excitation, they do so due to linear vibrations and not rotational motion. These Belleville spring units have piezoelectric stacks attached to them, and as the ammunition is fired, the springs due to inertia tend to get compressed, and while at flight, these have no extra forces acting upon them. This results in the constant fluctuating force acting upon the piezoelectric stack, in turn producing the desired electrical impulse.

2. Design and Manufacture

The design is of a very primitive nature. All the sizes and dimensions of the components have been designed such as to fit with the dimensions of the piezo ring. The

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ring has an external diameter of 53 mm and internal 45 mm. The outer casing is composed of nylon which was turned on the lathe. The masses made of steel were also turned on the lathe, provided with a slot passing through the centre for the rubber and then cut into four pieces using cutting wheel. The central shaft has two nylon bushes mounted at the back which carry brass rings on them. These brass rings have wires attached from the positive and negative end each of the piezo ring. When the entire unit rotates at 1500 RPM, another circuit has its one set of poles connected to a Cathode Ray Oscilloscope (CRO) and other set containing carbon brushes which are in constant contact with the brass rings to pick up the voltage and current for the display.

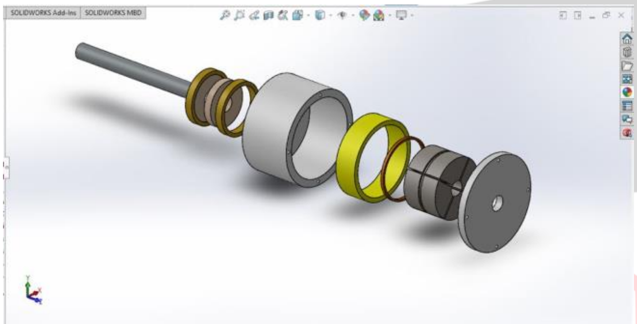

Fig. 1 CAD Model of the energy harvester

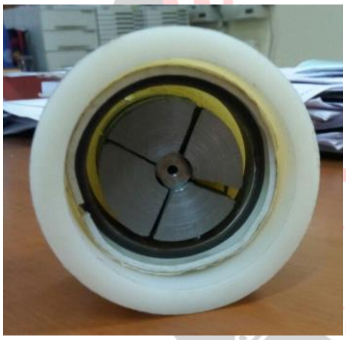

Fig. 2 Front view of the energy harvester

Fig. 3 Rear view of the energy harvester

2.2 Mathematical verification

Although the force exerted by the rubber band cannot be definitely calculated and subtracted from the centrifugal force of the masses, it was important to deduce logically how much force can be practically deducted from the centrifugal force of the masses. So a trial was conducted in which the two ends of a rubber band were stretched with a force and the deflection was noted to calculate how much the stiffness constant was. As expected the stiffness constant was rather not constant but a changing parameter depending upon the force. It was easy to comprehend the result, the stiffness was maximum when the applied force was minimum, and the rubber kept becoming slack as the force exerted increased.

Table 1. Experimental result for spring stiffness coefficient

Weight (force)	Elongation	Stiffness
125 gm	4 cm	122.625 N/m
250 gm	7.5 cm	54.5 N/m
375 gm	12.5 cm	38.72 N/m

*The values of the stiffness constant calculated above taking free length as 3 cm and using spring formula F = kx

The force of the rubber band was subtracted using the stiffness constant value of 38.72 N/m because of the fact that the linear elongation of the rubber band in the experiment and in the model were around about same.

Radius of centre of mass = $\frac{19.5-5}{2} + 5 = 12.5$ mm

When the mass will hit the periphery, it will move radially outward by 3 mm, so new radius is 12.5 + 3 = 15.5 mm (r)

Speed of rotation is 1500 Rpm, so $\omega = \frac{2\pi\,(1500)}{60} =$ 1570.796 rad/s

Total mass of all the four units (weighed) = 0.094 kg

So total centrifugal force = $m\,\omega^2 r = 0.094 \times 157.0796^2 \times \frac{15.25}{1000} = 35.415$ N

Subtracting the force exerted by the rubber band we get

F = 35.415 – 2kx where x is the elongation in the band length

$x = 2\pi r_2 - 2\pi r_1 = 18.85$ mm. For this elongation we have selected the stiffness value 38.7 N/m

F = 35.415 – 2(38.7)(18.85/1000) = 33.95 N

Using the piezo formula for static voltage of the ring, we get

$V = g_{33} F_3 [Od. - Id.] / 2[Od.^2 - Id.^2] = 4.95$ V

V = 4.95 V

3. Results:

When the set up was run at the required speed, the CRO displayed the following result:

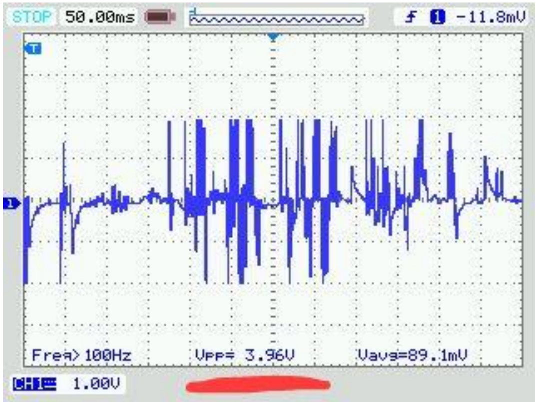

Fig. 4 Output on the CRO

As seen in Fig. 2, the model developed could successfully provide pulses, the peak value of which was 3.96 Volts.

Table 1. Experimental result for spring stiffness coefficient

	Voltage:
Theoretical	4.95 V
Practical	3.96 V
Deviation	0.9 V

Conclusion and further discussion:

The experimental and calculated values of voltage differ only slightly, in the acceptable range. Manufacturing imperfections and disturbances from the AC motor and other minor losses are accountable for the observed difference. This simple model verifies the functioning of the piezo ring and sheds light into the unexplored area of rotational energy harvesters. This model could only produce a single pulse against the required production of continuous pulses through the course of the trajectory. This area is vast and will require many more inputs into the development of many such models that can utilize the spin energy and convert it into electrical power.

References

Reza Ramezanpour, Hassan Nahvi, Saeed Ziaei-Rad (2017), Increasing the Performance of a Rotary Piezoelectric Frequency Up-Converting Energy Harvester Under Weak Excitations, Journal of Vibrations and Acoustics.

Hong-Xiang Zou, Wen-Ming Zhang, Ke-Xiang Wei, Wen-Bo Li, Zhi-Ke Peng, Guang Meng (2016), Design and Analysis of a Piezoelectric Vibration Energy Harvester Using Rolling Mechanism, Journal of Vibrations and Acoustics.

Jahangir Rastegar and Richard Murray (2017), Proc. SPIE, Energy-harvesting power sources for a wide range of applications.

[1]Submitted to Savitribai Phule Pune University

[4]vibrationaccoustics.asmedigitalcollection.asme.org

[5]Hong-Xiang Zou, Wen-Ming Zhang, Wen-Bo Li, Ke-Xiang Wei, Kai-Ming Hu, Zhi-Ke Peng, Guang Meng. "Magnetically coupled flex tensional transducer for wideband vibration energy harvesting: Design, modelling and experiments", Journal of Sound and Vibration, 2018.