Use Of Piezoelectric Accelerometers As A Hybrid System In Automobiles

Sean D'Silva
Department of mechanical engineering, Rajiv Gandhi Institute of Technology, Mumbai,India.

Sumit Jain
Department of mechanical engineering, Rajiv Gandhi Institute of Technology, Mumbai,India.

Mayur Ingale
Department of mechanical engineering, Rajiv Gandhi Institute of Technology, Mumbai,India.

Abstract

This paper explains how piezoelectric accelerometers can be used to generate electricity that can be used to run a secondary electric motor in a hybrid automobile. The piezoelectric crystals can be mounted on the chassis of the vehicle. As the vehicle takes a turn in any given direction or even when it accelerates and decelerates the piezoelectric crystals come into play due to the acceleration forces acting on them .These forces can vary in magnitude and accordingly electricity is generated which is then stored during the course of operation or usage of the automobile .The electrical energy is used to drive an AC motor which is used in the hybrid system. The overall efficiency of this hybrid system can also be increased when it is used in conjunction with regenerative braking.

Keywords:
chassis, vibration, vehicle, electrical energy.

1. Introduction

1.1 Introduction to Piezoelectric Accelerometers

Piezoelectric accelerometers convert one form of energy into another and provide an electrical signal in response to a quantity, property, or condition that is being measured. A piezoelectric accelerometer utilizes the piezoelectric effect of certain materials to measure dynamic changes in mechanical variables. (e.g. acceleration, vibration, and mechanical shock)

Features of piezoelectric accelerometers

- High sensitivity, small size
- Wide band: from low- to high-frequency measurement
- Wide measurement range: from very faint vibrations to high accelerations
- High physical strength
- High environmental resistance
- No power supply required (except for models with internal pre-amplifiers.

1.2 Working:

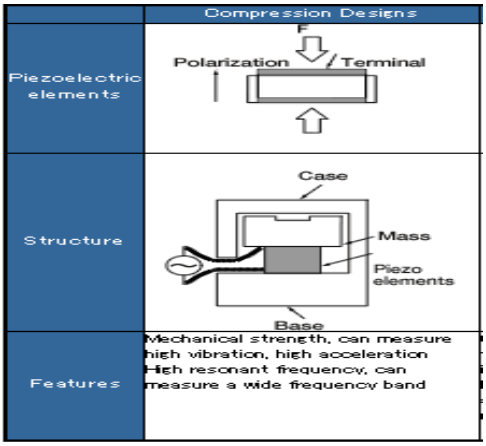
The piezoelectric element is a functional material that generates an electric charge when applied to an inertial force (F). The quantity of the electric charge (Q) is constant depending on the composition. The basic structure of a piezoelectric accelerometer is as follows. The piezoelectric element is sandwiched between a constant mass (m) and a base. From Newton's Second Law, the relationship between the acceleration (α) applied to the accelerometers sensor, and the inertial force (F) applied to the piezoelectric element can be expressed .Therefore, since (d) and (m) are constant, the generated electric charge (Q) is linearly proportional to the acceleration (α)α

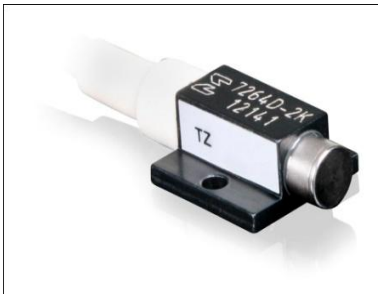
$$Q=d\times F \quad (1)$$

$$F=m\times\alpha \quad (2)$$

$$Q=d\times m \quad (3)$$

I





I

1.3 Forces acting on the car chassis

The force acting on the chassis can be calculated with the help of the equation:

$$F = \frac{mv^2}{r} = \mu mg$$

Where,

m=mass of the vehicle
v=velocity while taking the turn
r=radius of curvature of the road
μ=co-efficient of friction between the wheels and the road surface
g= gravitational force (9.8 m/sec)

If the radius of curvature of the road (r) is not known it can be found with the help of this equation. Once that is found out the force acting can be calculated.
For example, the vehicle is moving at a speed of 60km/hr and the radius of curvature of the road is 90 meters. The force can be calculated as:

Consider,
m= 1000 kg
v= 60 kmph= 16.667 m/sec
r= 90 meters
Now,

$$F = \frac{1000 \times (16.667)^2}{90}$$

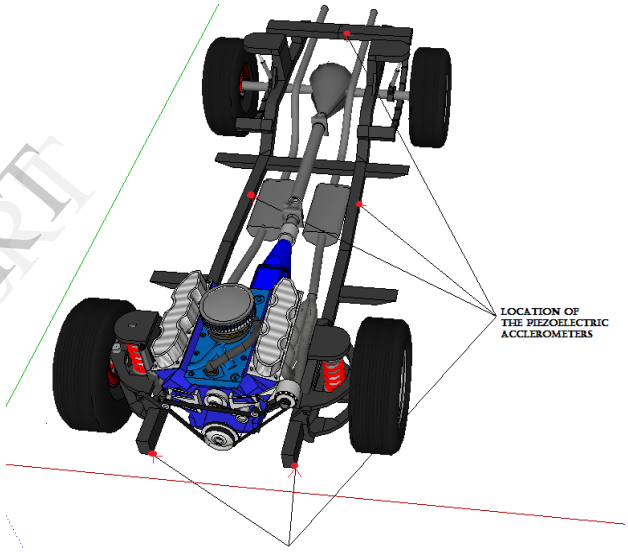
$$\therefore F = 3086.54\ N$$

This force can be utilised by the piezoelectric accelerometers to generate electricity which can be used for charging the battery in a hybrid system.

2. Components and design

2.1 Location on the chassis

The piezoelectric accelerometers can be located at different points on the chassis as shown in figure. In this way power generation can be maximized as electricity can be generated when the vehicle is turning, moving forward.



1

2.2 Hybrid system

A hybrid vehicle is a vehicle that uses two or more distinct power sources to move the vehicle. The term most commonly refers to hybrid electric vehicles (HEVs), which combine an internal combustion engine and one or more electric motors. However other mechanisms to capture and utilize energy are included. The piezoelectric accelerometers can be used on the following two types of hybrid systems effectively.

Parallel hybrid:

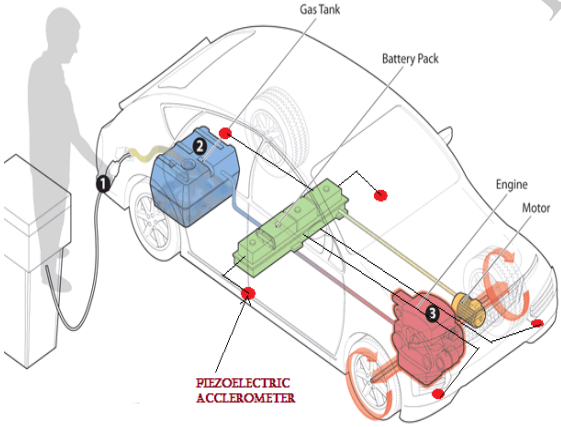
In a parallel hybrid vehicle, the single electric motor and the internal combustion engine are installed such that they can power the vehicle either

individually or together. In contrast to the power split configuration typically only one electric motor is installed. Most commonly the internal combustion engine, the electric motor and gear box are coupled by automatically controlled clutches. For electric driving the clutch between the internal combustion engine is open while the clutch to the gear box is engaged. While in combustion mode the engine and motor run at the same speed.

Plug-in hybrid:

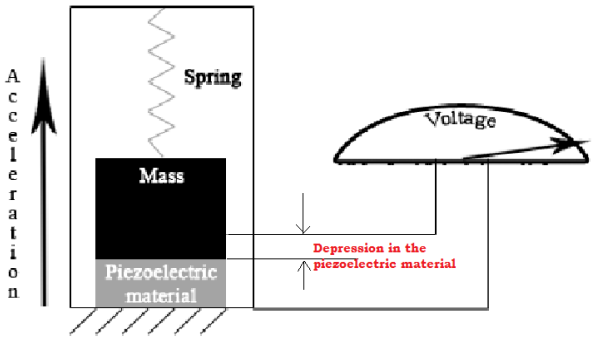
Another subtype of hybrid vehicles is the plug-in hybrid electric vehicle (PHEV). The plug-in hybrid is usually a general fuel-electric (parallel or serial) hybrid with increased energy storage capacity, usually through a li-ion battery, with allows the vehicle to drive on all-electric mode a distance that depends on the battery size and its mechanical layout (series or parallel). It may be connected to mains electricity supply at the end of the journey to avoid charging using the on-board internal combustion engine.

This concept is attractive to those seeking to minimize on-road emissions by avoiding – or at least minimizing – the use of ICE during daily driving. As with pure electric vehicles, the total emissions saving, for example in CO_2 terms, is dependent upon the energy source of the electricity generating company.



ŏ

2.3 Extra power developed when used as a vibration pickup



ŏ

An electromechanical transducer is capable of converting mechanical vibrations into electrical voltages. Depending upon their sensing element and output characteristics, such pickups are referred to as accelerometers, velocity pickups, or displacement pickups. When the vehicle moves over bumps on the road these vibration pickups come into play and generate electricity which complements the accelerometers and improves the overall efficiency of the hybrid system.

The accelerometer consists essentially of a mass which is seismically supported with respect to a surrounding case by means of a spring and guided to prevent motions other than those along the seismic direction of support. The mass exerts a force on the spring's support which is directly proportional to the acceleration being measured. This, in turn, is converted into an electrical voltage by means of stresses produced in a piezoelectric crystal.

3. Benefits and drawbacks

3.1 Benefits

1) It is a clean source of hybrid power for the vehicle.
2) This system can be retrofitted into an existing hybrid automobile without major modifications.
3) Electricity is continuously generated as long as the vehicle is in motion unlike that of regenerative braking where power is produced only during braking.
4) Very little maintenance is needed to maintain this system.

5) Overall saving in fuel costs and also lower emissions generated.
6) It can be used in conjunction with regenerative braking so as to generate more hybrid power.
7) No significant increase in weight of the automobile due to which performance won't be affected.

3.2 Drawbacks

1) The initial cost of investment for the system may be high.
2) Power generated from the piezoelectric accelerometers may not be of a significant magnitude to propel the vehicle over long distances.
3) The total electricity generated depends on the speed at which the vehicle is travelling. Hence a continuous steady flow of electricity cannot be generated. More the speed , more will be the power generated as the forces acting on the accelerometers will be larger.

4. Conclusions and future work

The total power output of this system is not of a high order. This system can however be coupled with other hybrid technologies and make the overall product more efficient. There is a need of alternate modes of power generation apart from that of the usual fossil fuel power in order to reduce emissions and help improve the environment. More research needs to be done on improving the power generation capabilities of piezoelectric accelerometers to improve the scope of this project. In the future more advanced versions of MEMS (Microelectromechanical systems) accelerometers can be used for the same applications which will be more efficient.

5. References

[1] "Electric and Hybrid cars:A History",*Book Title*, Curtis D. Anderson, April 25, 2010
[2] "Mechanical Engineering Measurements", *Book Title*, Parag Tambe, 2012
[3] "Basic Piezoelectricity", *Book Title*, John Potter Shields .
[4] "Piezoelectric Materials and Devices: Applications in Engineering and Medical Sciences , *Book Title*, M.S. Vijaya.
[5] "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles and Fuel Cell Vehicles:Fundaments,Theory and design", *Book Title*, Mehrdad Ehsani, Yimin Gao, Ali Emadi, 2nd edition.
[6] "Piezoelectric Materials: Advances in Science, Technology and Applications", *Book Title*, Carmen Galassi , Maria Dinescu , Kenji Uchino , Michael Sayer