Potential to Harvest Sound Energy from Noise Pollution

Phys 536 Winter 2023

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Problem to be solved

- Modern cities have several sources of pollution, smog, light pollution, and noise pollution
- Modern cities also have significant energy needs
- It is possible to harness some of the noise pollution and convert it into electrical energy

Sound Sources

- Any ability to harvest sound energy and convert it into electricity requires a predicable source of sound pressure
- Reliable noise sources include natural and human generated sources
  - Waterfalls
  - Ocean Waves
  - Generators or drilling equipment
  - Airports
  - Subways/Train yards
  - Highways and roads
- This discussion will focus on transportation sources from airports, trains, and roadways

Sound Point Sources

- Individual cars, trains, and planes can be considered point sources of sound energy when measured from some distance away
- The amount of sound pressure decreases by $1/r^2$ for point sources. This means at twice the distance away from the point source, the sound pressure level decreases by a factor of four
- For airplanes taking off and landing and trains along a track, this means the sound pressure is only high for a short period of time

Sound Line Sources

- A collection of cars or trains can be considered a line source of sound energy when measured from some distance away
- A line source radiates sound cylindrically. Sound pressure levels decrease at a factor of 1/r
- Line sources of sound energy are given by equation

$$I_2 = I_1 - 10Log_{10}(\frac{d_1}{d_2})$$

- Where I_2 is the sound intensity at point a distance d_2 away from the source. I_1 is a known sound intensity level at a distance d_1 away from the line source

Airport and Train Sound

- Airplanes near airports can generate ~105 dB of sound
- Airports are also inconsistent noise sources. Planes may take off/land/taxi at different intervals
- An example of a subway system, the New York Subway system, generates up to approximately 100 dB of sound when a train is present
- Subways and trains are also inconsistent as the trains are only present for a short amount of time for areas along the tracks
  - However the noise levels when on the train are consistent and potentially can be used as a source of sound pressure to be harvested

Roadway Sound

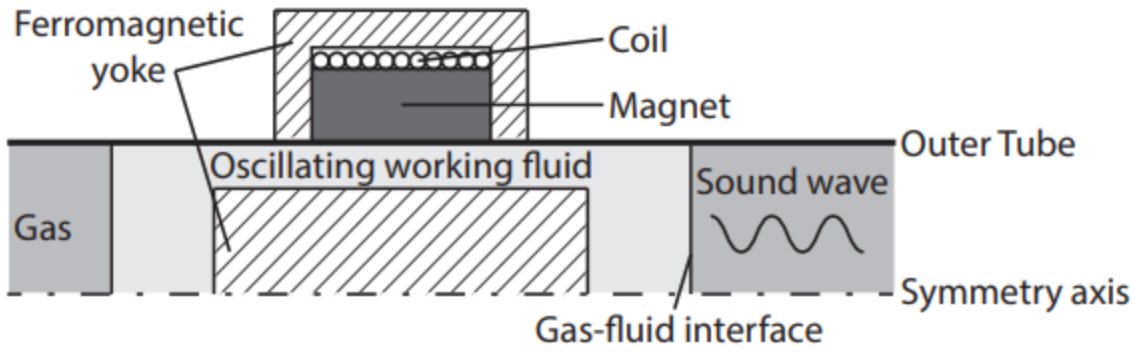
- Roadways show more promise as a noise source for harvesting energy as they are more constant than airports or train lines
  - Traffic levels are predictable and present for a longer duration than the airplanes and trains which act more like point sources
- Typical roadways provide ~80 dB of sound energy at 50 feet from the roadway
  - This value is reduced by 3 dB for every doubling of distance from the road

Techniques

- Several techniques are available to convert the sound energy into electrical energy
  - Magnetohydrodynamic devices
  - Electromagnetic induction
  - Piezoelectric devices

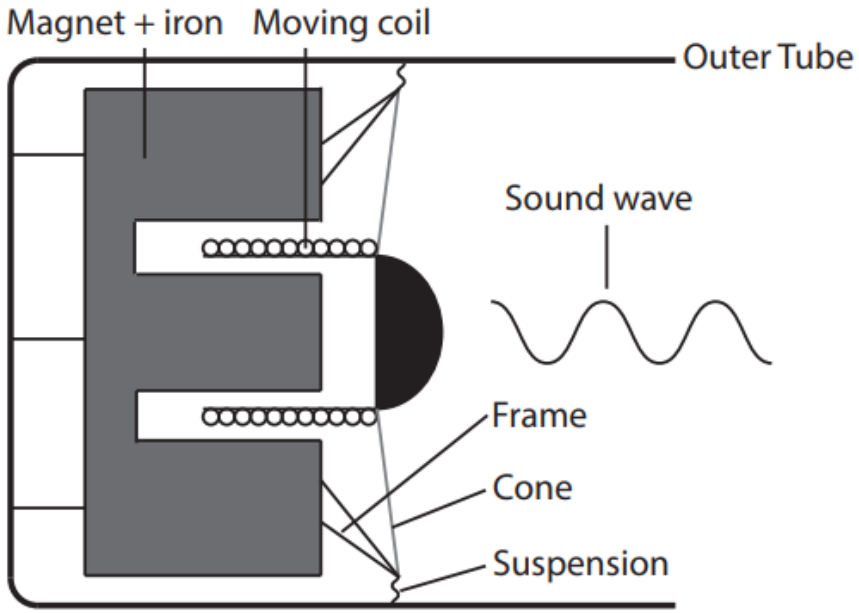
Magnetohydrodynamics

- MHDs operate by use of a permanent magnet creating a magnetic field through a conductive fluid. This fluid is then exposed to the acoustic environment, causing the fluid to move within the B field. The resultant electric current is captured by a coil within the device



Electromagnetic Induction

- Electromagnetic induction is in essence a loudspeaker in reverse.
- The incident sound pressure moves a diaphragm connected to magnetic coil, thus inducing an electric current in an adjacent coil

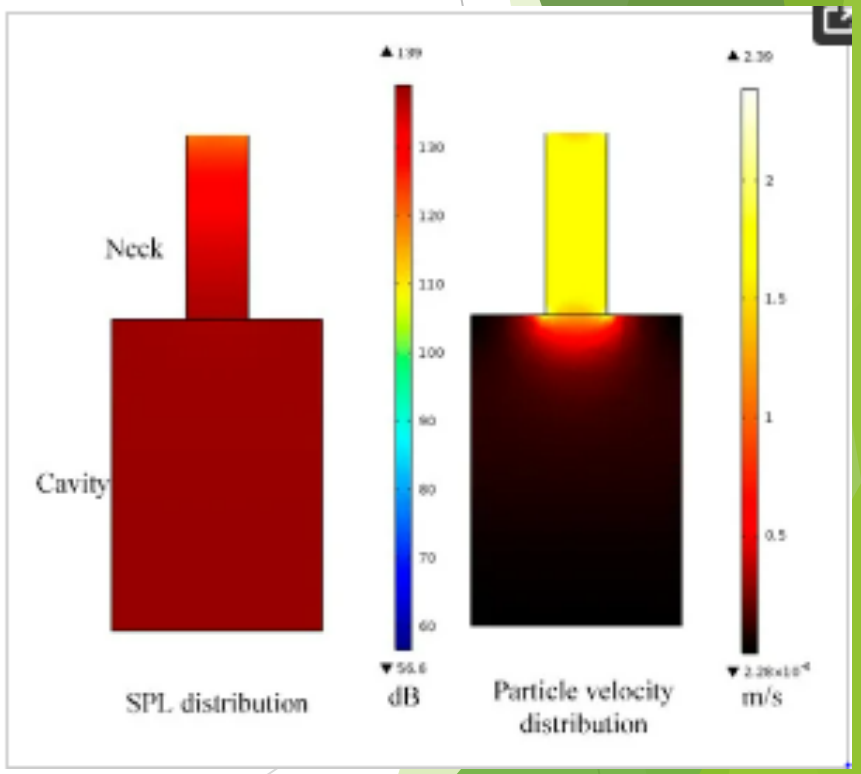


Piezoelectric Devices

- Piezoelectric devices are crystalline structure that generate a voltage when deformed. When connected to an electric circuit, this voltage can generate a current
  - Piezoelectric devices are typically very small and generate energy at specific frequencies
- However, the sound pressure levels are small and spread out across many frequencies
- A Helmholtz resonator can be used to amplify the sound pressure at one specific, predictable, frequency

Helmholtz Resonators

- Piezoelectric devices can utilize a tuned cantilever to increase efficiency
- Using a Helmholtz resonator will ensure a predictable frequency an to allow the tuned cantilever to be used effectively



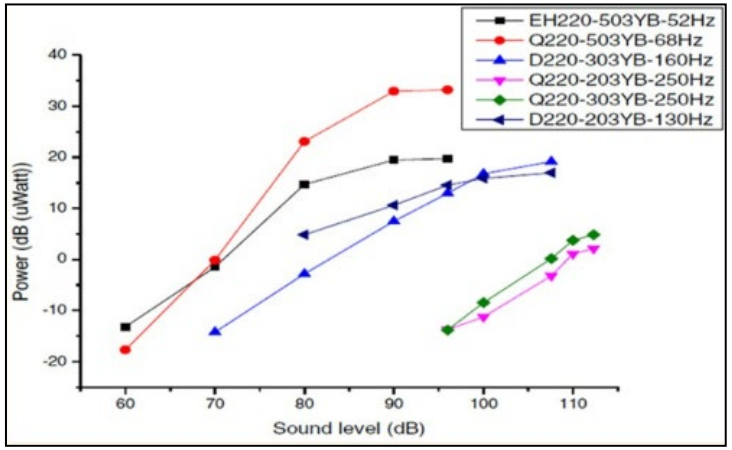
Summary of Power Harvested

- MHDs theoretically can produce ~300W, however experimentally they have only been able to produce a few mW
  - They are also complicated to design and use caustic or damaging materials as the conductive liquid
- Electromagnetic Inductors have shown ability to generate significant wattage, however they are expensive and have a limited life
  - Devices are also not effective as they operate primarily at a specific frequency. The incident sound covers a wide range of frequencies

Summary of Power Harvested

- Piezoelectric devices, when used with a Helmholtz resonator, are highly reliable and cheaper than inductors.

- They can also be tied together to create arrays of devices to generate more power than any individual device



Capabilities of Harvested Energy

- The electrical output from each of the sound energy harvesting techniques discussed are not likely to support widespread use of this alternative energy source
  - Ability to harvest sound energy is limited to a few mW per device due to sound pressure levels being mechanically small compared to other sources such as wind and waves
- However, there may be limited uses such as:
  - Wireless repeaters (use around 6W)
  - LEDs for signage along roads (use 2 to 10 W)
  - Charging batteries to reduce power draw of other devices

Sources

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