Proposing Smart Piezoelectric Sensor Networks for Sustainability Research

Benedicte Adair

Rochester Institute of Technology

What Are Piezoelectrics?

Piezoelectric materials are crystal structures that produce an electric field when faced with external forces. Conversely, an electric field can produce kinetic energy just as efficiently. These are known as the direct and inverse piezoelectric effect respectfully.[1] Due to these material characteristics, piezoelectrics are highly efficient on the small scale but quickly reach saturation and are no longer useful under higher energy demands.[2]

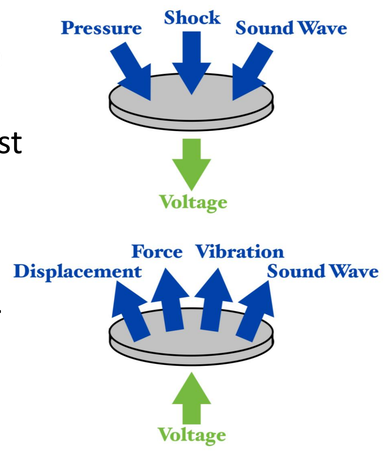
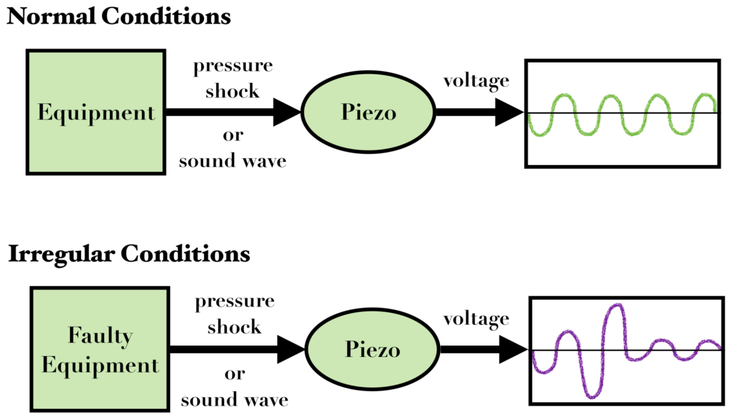
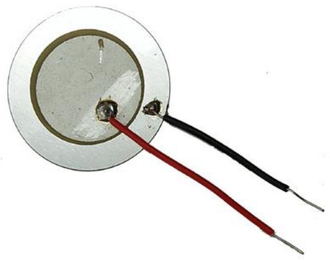


Fig 1: direct piezoelectric effect (top) and inverse piezoelectric effect (bottom). Adapted.[F1]

Piezo Sensors for Maintenance





Figs 2 & 3: Simplified diagram of how piezoelectric sensors detect problems (left) and picture of a sensor (right).[F2]

Accelerometer	Flow Sensor	Level Sensor
vibration of machinery	flow of liquids	how much material in a container
shock	sound wave	pressure

Table 1: Kinds of piezoelectric sensors.[3] Inputs from figure 1 are added as well.

Factory Applications

Like smart homes, smart factories take advantage of modern technology to connect all their important devices and self-monitor for things that require human intervention. In the factory setting, a network of piezoelectric sensors connected by either Bluetooth or Wi-Fi send data collected from various machines. Whenever that input deviates from the norm, a worker is notified to schedule the necessary maintenance checks. This can be referred to as preventative maintenance (PM).[4]

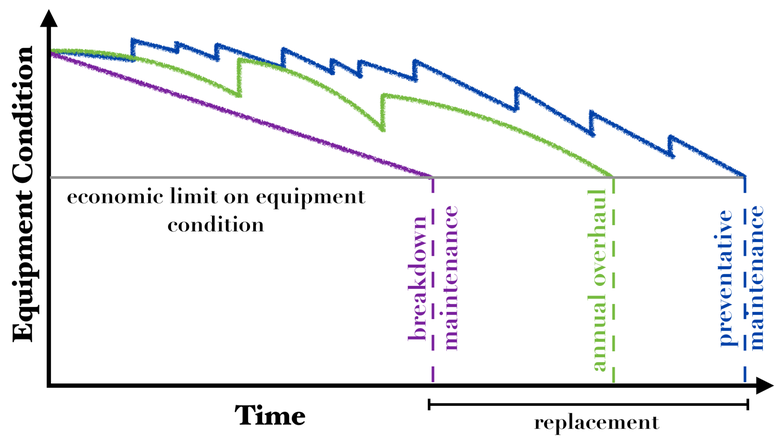


Fig 4: Comparative time in which it is less expensive to replace equipment for different maintenance schemes. Adapted.[F3]

- More than 90% of factory machines are not connected to a maintenance network.[5]
- Despite having over 30,000 sensors, oil rigs only analyze 1% of the data.[6]
- It is 50% more expensive to fix an equipment error after a failure.[7]
- A single piezoelectric sensor costs around $3.[8]

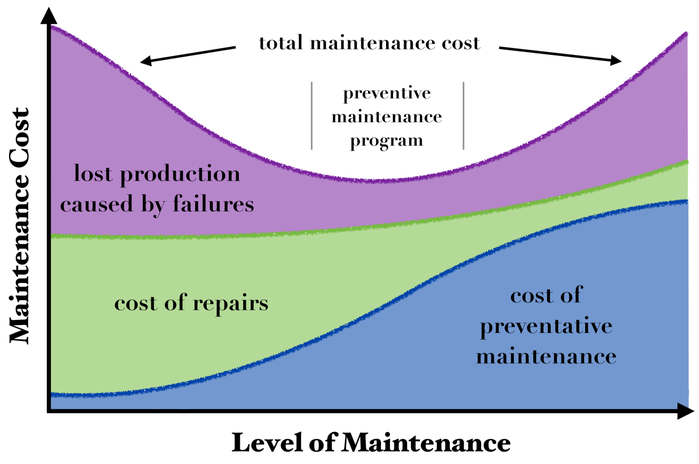


Fig 5: Maintenance costs at different levels of preventative maintenance implementation. Adapted.[F4]

What About Sustainability?

- A good maintenance program can save 5 - 20% of total energy usage annually.[9]
- In 2017, the US industrial sector consumed 21.9 quadrillion Btu in grid energy.[10]
- The average greenhouse gas emissions of electricity is 1,559 lbs. of CO_2 equivilent per MWh in the US.[11]

On the low end, country-wide implementation would save over 200 million metric tons of CO_2 per year.

That's 3% of US annual emissions!

*This is an order of magnitude calculation. A much more advanced model is necessary for any further analysis.

Total Money Savings

Smart maintenance can save $1.2 - 3.7 trillion over 10 years.[12]

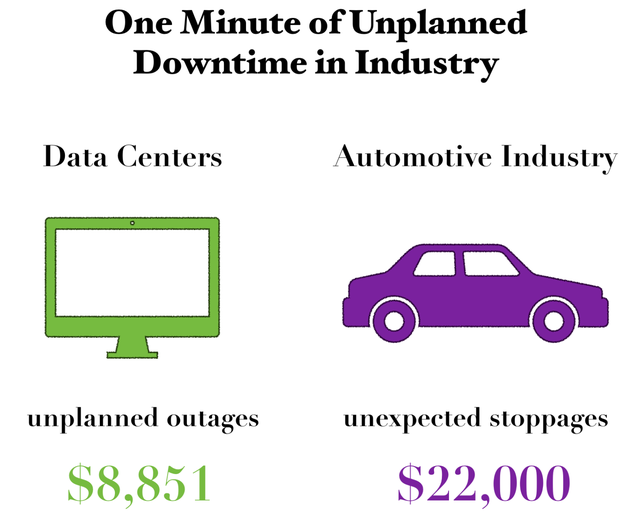


Fig 6: Average cost of unexpected downtime for different industries. Adapted.[F5]

Other Avoided Emissions

These impacts are widely acknowledged,[13] but have yet to be properly quantified. Due to the proliferation of large scale equipment as well as the growth of smart technology, even small savings per unit can have a large impact.

Extended lifespan of equipment

Self-powered sensors avoid batteries

Future Work

Research surrounding piezoelectrics – and even preventative maintenance – is deeply lacking in regards to sustainability. Smart maintenance systems have been established to significantly impact climate change issues. The exact extent of that role is still being discovered.

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Citations

For a full list of the references used in this poster, see attached document.