

Science as a Human Endeavour Investigation

How have developments in particulate matter detection, battery degradation analysis, and neutron imaging revealed new evidence relating to technology and benefits of future hybrid locomotives?

The SHE concept is **Development**.

Introduction

Diesel-powered locomotives are engines which use the energy provided by diesel fuel to pull any number of train cars on a railway. In one sense diesel locomotives are already hybrid because the diesel fuel powers an electricity generator rather than more mechanically turning the wheels (Chabilan, O 2018), but this report focuses on diesel locomotives which are described as a hybrid because they also use high-capacity batteries to increase efficiency.

Explanation of relevant science

The main components of a typical modern diesel locomotive are: a diesel engine which burns the fuel, an alternator which converts the motion of the diesel engine into electricity, and electric motors which provide a force to the wheels so that the train can accelerate.

A diesel engine works by burning diesel fuel in a hollow *cylinder* in rapidly repeating controlled explosions. These provide pushing and pulling forces which are then converted into a turning force. The number of *revolutions* (turns) in the cycle of pushing and pulling varies from place to place but is generally between one and two thousand revolutions per minute (Connors, P 2019).

An alternator is an *electrical generator*; it relies on the way electric charges are pushed by magnetic fields during motion. A coil of wire, wound many times, is spun in a *magnetic field* (a place where magnetic objects can be affected). This causes the charged particles (electrons) in the wire to experience a force, moving them along the wire, creating electricity.

Electric motors are essentially electrical generators in reverse. Electricity is run through a coil of wire in a magnetic field, which causes a force to be experienced by the wire. This force spins the motor, which in this case turns the wheels of the train against the rails of the track, causing the track to push the train, accelerating it.

In the future, diesel-electric locomotives might commonly include energy storage, such as a battery or a capacitor. This could potentially increase efficiency, for example by storing the train's kinetic

Commented [TB1]: The focus sentence does not need to be a question, and its wording is likely to change as you continue with your investigation.

Commented [TB2]: Choose one or more SHE concepts that will be focused on in this report.

Commented [TB3]: A suggested layout for a max. 1000-word report (with approximate word counts) is:

- Introduction (75)
- Explanation of relevant science (225)
- Connections to SHE (450)
- Potential impact (150)
- Conclusion (100)

Commented [TB4]: Relevant concepts or background. This must include use of scientific terminology.

Commented [TB5]: Keep the order of ideas consistent. For example, these components are discussed in the following paragraphs in the same order as listed here.

Commented [TB6]: Each paragraph should have a theme or purpose which is made clear by the first sentence.

Commented [TB7]: Include a reference for facts, figures, or any other information that you would not know if you had not found them in your research. Even if you already knew it, a reference supports your point with evidence.

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energy as potential energy when it is slowing down, rather than converting it into waste heat using brakes.

Connections to Science as a Human Endeavour

This report will focus on three recent scientific developments which are relevant to diesel-electric hybrid trains. These include technologies for collecting data about pollution from diesel engines, a process for identifying causes of battery aging, and instruments for viewing inside the batteries without opening them.

New portable technologies for measuring the pollution produced by diesel engines allowed scientists from the Southern Ontario Centre for Atmospheric Aerosol Research to build on past research about exposure of commuters to exhaust. The types of pollution focused on in these research studies are black carbon (BC) and ultrafine particles (UFP) because they have possible negative health effects. The past research showed that commuting to and from work leads to high exposure to BC and UFP, but did not provide data measuring exposure passengers receive while in-transit on a diesel-powered train. In the new research, portable instruments to detect BC and UFP were carried onboard the train and took measurements every ten seconds. The new evidence revealed during this study could lead to further studies to evaluate methods for reducing exposure (Jeong, C et al. 2017).

Mechanical engineering researchers from Penn State University in the United States analysed the charging and discharging cycle of a lead-acid battery and design a charging algorithm to improve it. They used a process called *electroimpedance spectroscopy*, which is non-destructive, simple, and cheap, so they were able to identify the main aging mechanisms in the battery. This data was then used to design an algorithm to reverse some of the damage that happens inside the battery when it is frequently charged and discharged. The researchers were able to increase battery capacity this way but an alternative to the electroimpedance spectroscopy model could lead to even further development in this area. (Penn State 2013).

Scientists working with neutron instruments at a University in Europe, the Technische Universitaet Muenchen, were able to determine reactant distribution inside a high-performance battery designed for hybrid locomotives. Developments in neutron imaging have produced non-destructive techniques such as neutron tomography, which these scientists used to visualise sodium levels, and stress and texture diffractometry, which they used to analyse the exact composition of the substances. The new evidence provided by these techniques allowed these scientists to develop a model of the distribution of chemicals inside the batteries, which will contribute to understanding

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Commented [TB10]: Keep using the wording of the SACE SHE concepts. It should be clear that this part of the report is showing how your focus illustrates SHE.

how often batteries can be charged and recharged. General Electric, the company that provided the batteries for the research, could gather even more precise data if these kinds of techniques can be used in real-time while batteries are recharging and discharging (Technische Universitaet Muenchen 2010).

Potential impact

The new evidence of commuter exposure to diesel exhaust during transit could provide both data and motivation for further research and application. The data and techniques could be used to evaluate technologies currently used, such as air filters. Applications and recommendations could include, for example, recommendations that passengers with health risks travel in a carriage further away from the engine (Jeong, C et al. 2017).

The models and techniques developed and used in the analyses of aging mechanisms and charging cycles of batteries could be used to design more efficient batteries, which would reduce running cost and emissions. In some cases, specific new technologies may become viable, providing better alternatives to existing technologies. For example, lithium is currently a common component of rechargeable batteries, but the batteries being studied with neutron imaging used sodium instead, and sodium is much more readily available.

Conclusion

Developments in particulate matter detection, specifically portable equipment, allowed for new evidence about the exposure of passengers to exhaust from diesel engines. Analysis and modelling of battery degradation led to the development of an algorithm to improve charging and discharging cycles. Neutron imaging provided non-destructive visualisation inside batteries designed for hybrid locomotives. Together, these developments contribute to the motivations and progress in the evaluation and design of efficient hybrid locomotive technologies.

987 words

Commented [TB11]: Include a discussion of the potential impact of the focus of the investigation, e.g. further development, effect on quality of life, environmental implications, economic impact, intrinsic interest.

Commented [TB12]: A conclusion that summarises the connection between your topic and the key concept(s) of science as a human endeavour.

Commented [TB13]: The report, which can be in a format of your choice, should be a **maximum** of 1000 words if written, or a maximum of 6 minutes for an oral presentation, or the equivalent in multimodal form. The word count includes in-text referencing but does not include the reference list at the end of the document.

References

Chabilan, O 2018, *Hybrid Locomotives, Ultracapacitors for the Railway Vehicles and Infrastructure*, <https://www.skeletontech.com/skeleton-blog/hybrid-locomotives-ultracapacitors-for-the-railway-vehicles-and-infrastructure>, accessed 26 April 2020

Connor, P 2019, *Diesel Locomotives*, <http://www.railway-technical.com/trains/rolling-stock-index/diesel-locomotives/>, accessed 25 April 2020

Jeong, C, Traub, A, Evans, G 2017, *Exposure to ultrafine particles and black carbon in diesel-powered commuter trains*, <https://www.sciencedirect.com/science/article/pii/S1352231017300857>, accessed 25 April 2020

Penn State 2013, 'Identification and remediation of sulfation in lead-acid batteries using cell voltage and pressure sensing', *ScienceDaily*, <https://www.sciencedaily.com/releases/2013/01/130104143654.htm>, accessed 25 April 2020

Technische Universitaet Muenchen 2010, 'Using neutrons to peer inside a battery designed for hybrid locomotives', *ScienceDaily*, <https://www.sciencedaily.com/releases/2010/04/100415143904.htm>, accessed 25 April 2020

Commented [TB14]: Remember to follow the reference formatting guidelines. Here is a brief outline:

1. Author (or responsible organisation)
2. Year of publication (or last update)
3. (if relevant) Published in/by, date published
4. (if Internet) web address, accessed date

Choose your sources carefully. Some advice:

- Avoid using people's opinions (such as on question-answer sites like Quora).
- Wikipedia is freely editable so rather than using information there, find out where the Wikipedia editors got their information from.
- Search engines like Google are useful for finding sources but are not a source of information themselves.
- Information should come from at least three different organisations (in this report, two are from ScienceDaily).