Educational 4-Stroke Internal Combustion Engine Model

The Future of Internal Combustion Engines in the Ocean Freight Industry

A Thesis Prospectus
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By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Internal combustion engines (ICEs) are a marvel of engineering and have been an integral part of everyday life since the early twentieth century. From over a century of infrastructure development, efficiency and power increases, and decreasing costs, ICE vehicles have radicalized the way and pace at which people live their lives and conduct their business. They power personal transportation, public transportation, shipping, and much more. That being said, their negative environmental impact–due to byproducts from combustible fuels–has been the source of much debate. Primarily beginning in the 1960s and becoming widespread in the 1990s, climate activists have been warning of adverse emission effects on public health and the environment (Skelton, 2023). The currently most favored alternative to ICEs, electric vehicles (EVs), aren't a new concept. However, their recent surge in popularity can likely be attributed to widespread scientific agreement on climate change and rapid development from EV companies like Tesla.

As EV technology is still in its infancy, many people are quick to point out the deficiencies of EVs such as range and charge times, as well as questioning whether the ecological impact of EVs is as low as touted. Regardless of these concerns, governments around the world have implemented or are considering implementing policies to speed up the transition from ICE vehicles to EVs. These policies typically come in the form of new ICE vehicle sales bans and EV tax credits. Much of the media attention surrounding the transition concerns personal transportation, with less attention on an unsung part of daily life: the shipping industry. For the sociotechnical portion of my project, I will use an actor network theory (ANT) approach like in Latour's 1992 essay "Where Are the Missing Masses? The Sociology of a Few Mundane

Artifacts" to analyze the current state and future of ICE engines in the shipping industry, specifically in ocean freight.

My technical project is targeted at creating a teaching tool for understanding the science and components behind how ICEs work. The function of ICEs is understated in the University of Virginia (UVA) Mechanical and Aerospace Engineering (MAE) department. Even as the transition to EVs is imminent, ICEs present a great untapped synthesis of many course topics in the curriculum. Currently, there is a used Rolls Royce jet engine sitting on display in the UVA MAE building. Although it is a fantastic display, it lacks interactive components and represents more of the Aerospace side of the MAE department. The primary goal of my project is to create a display–using a real, decommissioned engine–in the MAE building with interactive components to help students and visitors understand the function and importance of ICEs.

There isn't much connection between the pedagogy of internal combustion engines and the future of these engines in the ocean freight industry, yet each is important in their own regard. For the MAE department, ICEs represent a continually missed opportunity in how it raises its engineers. Teaching more about how these engines work more intentionally throughout the curriculum would provide much more context and application to the required science courses, and would also connect these courses to each other. Yet, in a broader context outside of UVA, the future of ICE vehicles is an important topic and is deserving of more research.

Technical Project Proposal

Like mentioned above, the importance and science behind internal combustion engines is not often discussed in the UVA MAE curriculum. Some of my peers believe that this is a missed opportunity, as all of the core disciplines heavily taught in the department–such as thermodynamics, heat transfer, dynamics, machine elements, et cetera–come together as key aspects in understanding the function and design of internal combustion engines.

Generally speaking, there are two forms of ICEs. One form is called a two-stroke. Two-stroke engines have exactly what it sounds like, two full extensions or strokes of the piston in the cylinder: scavenging/exhaust and compression/power. These engines are less common. Instead, four-stroke engines are used much more often in cars, utility equipment, motorbikes, generators, and more to generate rotational power. Four-stroke engines use four full extensions of the piston in the cylinder: intake, compression, power, exhaust (see figure 1; Encyclopedia Britannica). Due to their vastly spread adoption and technological intricacy, the capstone project will focus on these four-stroke engines.

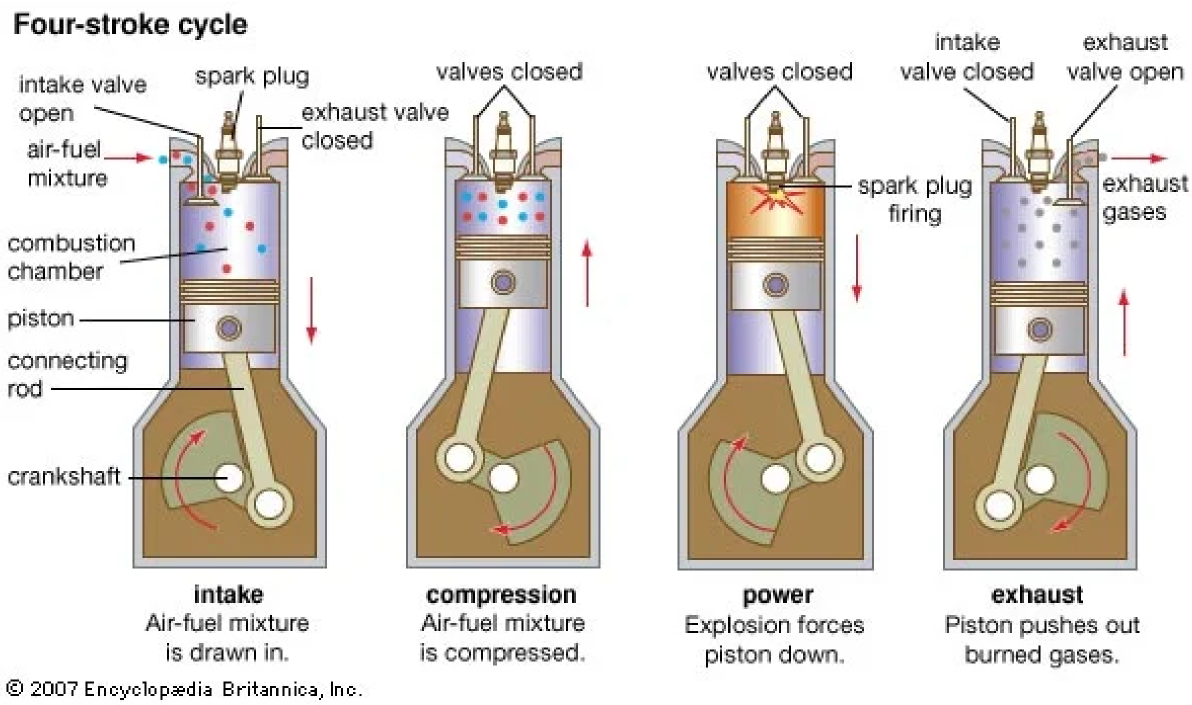

Fig.1. Schematic of four-stroke cycle of internal combustion engine ("Four stroke-cycle").

In order to properly convey the functions and technologies in a four-stroke engine, the goal of the project is to deliver an educational model of one of these engines for display in the

UVA MAE building. To accomplish this, the model will use a decommissioned small engine. The engine will be cleaned, then cut in such a way that the user will be able to see the entirety of the engine's inside, while keeping the internal components intact and secure. The crankshaft will be rotated via an electric motor, and lights (LEDs) will be used to draw the users attention to different areas of the engine during the cycle to highlight what is happening during each stroke. These electrical elements will be powered from a wall outlet and controlled with a microcontroller. Additionally, a display screen will be attached adjacent to the model to provide key information and show animations when desired by the user.

The model's main use case is as a self-explorable (interactive) feature in the MAE building. It will be something that anyone–whether they be a curious current student in between classes, a mechanical engineer studying for a test, or someone on a tour of the building–is able to use for as little or as long as they want without previous instruction. An additional use case of the model will be as a teaching aid. It should be portable enough that a professor who wants to use it as part of a class lecture can easily move it to a classroom in the building and use it as a physical model to contextualize the information they are teaching. It may be useful as an aid in the "Intro to Mechanical Engineering" course everyone in the mechanical engineering program already needs to take, typically in their second year at the University.

Another key design feature of this project is repairability and longevity. It would not be ideal for this model to break a few months after graduation and become a heavy piece of trash in the hallway. In order to avoid this fate, the model should come with lots of documentation including well commented microcontroller code, any computer aided design (CAD) files, and potentially assembly guides. Another method will be to thoroughly test the model with conditions like what it will see on display, such as being constantly touched, moved, and stressed.

STS Project Proposal

The transition from ICE vehicles to EVs is a topic of mass debate relevance in the modern political, social, and technological climate. This debate stems from growing climate change concerns, and the generally favored shift from fossil fuels to renewable energies. With many governments putting restrictions on new ICE vehicle sales and EV infrastructure growing, the topic is of great everyday importance. Across the United States and the world, EVs have shifted from a sight to see on the road to being very common.

For many people, however, the electrification movement is largely only discussed concerning personal transportation. The shipping industry–both land and sea–is a large driver of daily life and the global economy. It currently produces roughly 3% of global carbon emissions, which is expected to reach 10% by 2050 (Transport & Environment). The lack of discussion and media coverage on this issue–over personal transportation–led me to wonder about the future of ICEs in the shipping industry, which led me to my research question: What is the future of the internal combustion engine in ocean freight applications? Is electrification technologically and economically feasible?

To analyze this problem, I will employ an actor-network theory (ANT) approach like Bruno Latour in his essay "Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts." In this essay, Latour analyzes the actors relevant in the simple artifact of the door. It will also be useful to read works from other authors who study actor-network theory, such as John Law or Wiebe Bijker. I believe that this approach will be valuable because of the many different actors–both human and non-human–involved in climate change related problems. In this topic, human actors may include (but are not limited to) governments, shipping companies, ship manufacturers, and climate activists. On the other hand, non-human actors may include electric infrastructure, battery technologies, roads, railways, and the ocean. Actor-network theory is particularly valuable in cases when the evolution of technologies is heavily affected by societal pressures and environmental/scientific limits. In the case of this topic, I will be analyzing how electric motors and electric infrastructure can replace actors such as the internal combustion engine and its relevant infrastructure in the context of the ocean freight industry.

In pursuing this topic, evidence will be gathered from many sources. For background on the history of the ocean freight industry, tertiary sources such as encyclopedias will be useful. Additionally, primary sources such as laws issued by governments, emissions data, and claims from companies in the industry will be good supporting evidence and context for analysis. However, secondary sources like journal articles will be best for analyzing the current state of the technology, its economic viability, and what professionals in the technology and ocean freight research field are predicting for the future.

In preliminary research, I have found that I am not alone in my question. The push for sustainability has prompted researchers to examine current technologies for their viability in different sea shipping applications and their economic viability. Additionally, players in the shipping industry have acknowledged their role in emissions and climate pressure. Generally speaking, the industry is in relatively early stages of transition, but development is rapid. Researchers have proposed pathways forward both in new, sustainable fleets of ships as well as how to modify current infrastructure to be more climate conscious; they offer solutions such as carbon capture and storage systems (Bei et al., 2024; Raźniewska et al., 2024).

Conclusion

For my STS thesis, I am pursuing the study of the future of internal combustion engines in the ocean freight industry. I will employ an actor-network theory approach to tackle my research question: What is the future of the internal combustion engine in shipping applications? Is electrification technologically and economically feasible? As climate change concerns grow and governments are pushing society towards sustainable technologies, the current function of the world will have to change. Whether it is through everyday transportation or through the global supply chain, it will be important to understand how our society will adapt and what technologies will make adaptation possible. I expect to find that this adaptation is not only possible but that it is feasible. As battery, electric infrastructure, and alternative fuel technologies improve, the shipping industry will be able to remain functional under transition and in the new era. It may entail large initial investments, but sustainable technologies will be economically viable and benefit society.

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