Optimization of a Formula SAE Intake Manifold

(Technical Paper)

The Impacts of Passenger Vehicle Fuel Economy on a Global Scale

(STS Paper)

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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

Fuel efficiency has an enormous impact on the world around us, socially, economically, and environmentally. It is common knowledge that when fuel prices go up, the price of everything else goes up with it (citation). This is due to transportation costs, as most household goods manufactured now are shipped from distant places, relying on tractor trailers and airplanes to bring their products to customers. This means that rising fuel prices impact all people, from the working class to both small and large businesses. Consequently, developing technologies to increase fuel efficiency, thereby decreasing fuel consumption helps everybody while also helping to reduce global carbon emissions. This leads me to my technical discussion. I am a member of the University of Virginia's Formula SAE team. Formula SAE is a point based collegiate automotive design competition. Teams from around the world come to Michigan to race cars that were built entirely in house by students. These are not ordinary cars though, they have unique components that includes: extremely high power to weight ratios; weigh under 500lbs; have active aerodynamic wings; carbon fiber suspensions; and a space frame chassis. Additionally, if the teams are lucky, they have world class drivers. As the competition has modernized, the event organizers have started to give points for fuel efficiency to push young engineers to design more environmentally conscious cars. One of the most important aspects of these vehicles for both performance and fuel efficiency is the power trainand the air intake system which leaves a lot of room for development. This has the potential to improve both fuel efficiency and power output simultaneously. .

Technical Discussion

Our team is aiming to increase the power output capabilities of our engine while also reducing fuel consumption by optimizing our Formula SAE car's intake system. Last year's design did not have enough fluid flow analysis performed t, and we believe there are substantial improvements left to be made , particularly in smoothing out airflow through the components. The new system will feature a carbon fiber 3d printed nylon plenum-restrictor combo. It is standard for these components to be made separately and fixed together. We believe that by combining the two we can reduce and the weight and improve the fluid flow through the components. The system will first be designed using a CAD software, the team has chosen Fusion 360 for its collaborative team environment. Then, after a rudimentary design has been made, it will be iterated upon using CFD analysis techniques. We will be looking to optimize fluid flow, during dynamic operation, namely engine operation. To do this, we will use an advanced engine simulation package to validate our designs.

Engine output power can be simplified down to the air fuel mixture. To burn fuel most efficiently the fuel within the combustion chamber must have the right ratio of fuel to air. Too much fuel, and not all of it will combust, which is referred to as running rich. Too much air and a reduced amount of power will be made from the fuel, resulting in losses which is referred to as running lean. For each fuel there is a stoichiometric air-fuel-ratio, AFR, at which it chemically burns the most efficiently. For unleaded gasoline, this ratio is 14.7, meaning 14.7 parts air to one part gasoline. For simplification most tuning is done using Lambda, which is a variable weight based on the fuel used, where one means the fuel is burning stoichiometrically (at stoich), less than 1 means it is rich, more than one means it is lean (Magda). Modern cars and racing vehicles have O2 sensors in their exhaust system to measure the amount of oxygen coming out of the engine, using these sensors the ECU (Engine Control Unit) can use a closed feedback loop to reduce or increase the amount of fuel being injected at certain stages and modify the AFR at will while the car is running (Hooshmand). Using O2 sensors we can specify what AFR we would like the engine to run at, and given a good base tune, the computer can adjust on the fly for changing weather conditions, temperature or even fuel quality to ensure the engine is always burning at the programmed ratio.

For internal combustion engines burning at stoichiometric combustion is not technically possible as there is not enough time during an engine cycle for the combustion process to fully occur, with only about 90% of the air-fuel mixture being used in a typical passenger vehicle. Furthermore, a richer mixture burns cooler due to fuel evaporation helping to cool the cylinder walls. This increase in cooling allows for an increase in peak power output from an engine, with the drawback of reduced theoretical fuel economy. Through this research it can be determined that one method to increase fuel economy and thereby points in the competition is to run a leaner mixture than usual, with additional cooling capabilities on the car to prevent engine failure.

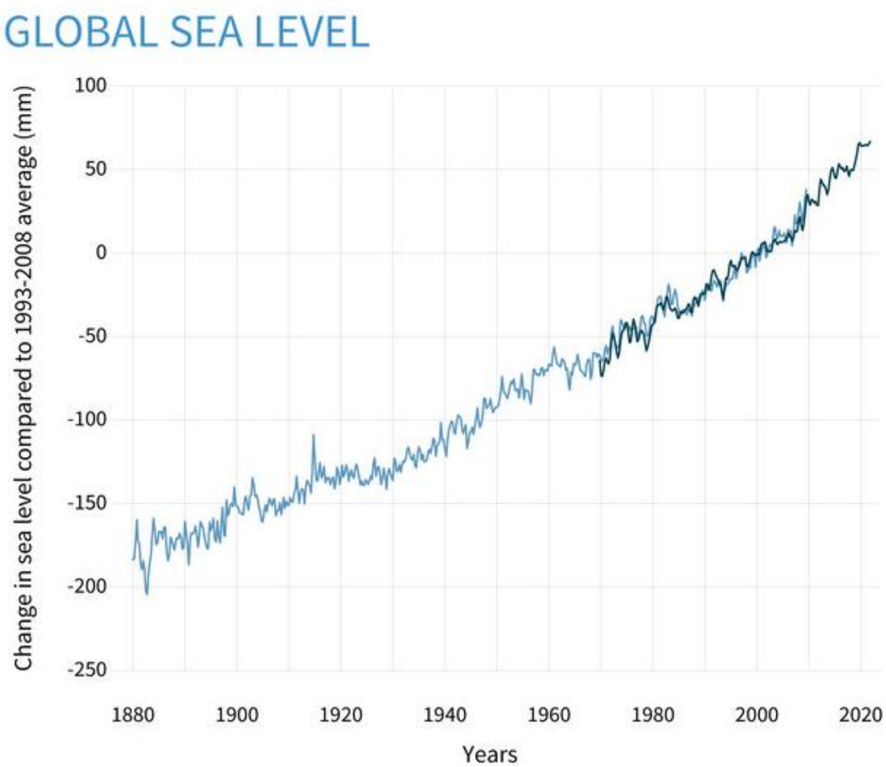
This is just one of the many different aspects of engine design and tuning that can increase fuel economy. There are still many other methods to be looked into in the development process, that includes increasing cylinder pressure, changes in ignition timing, injection timing, injector sizing and spray pattern, intake and exhaust valve sizing, changing the duration and timing of valve events within the motor, forced induction, and reducing losses due to friction, and weight.

This project is projected to be completed in a period of five months; however, it has been broken down into stages such as design, validation, manufacture, and testing to ensure proper deadlines are met. Our advisor for this project is Michael Momot from the Mechanical Engineering Department.

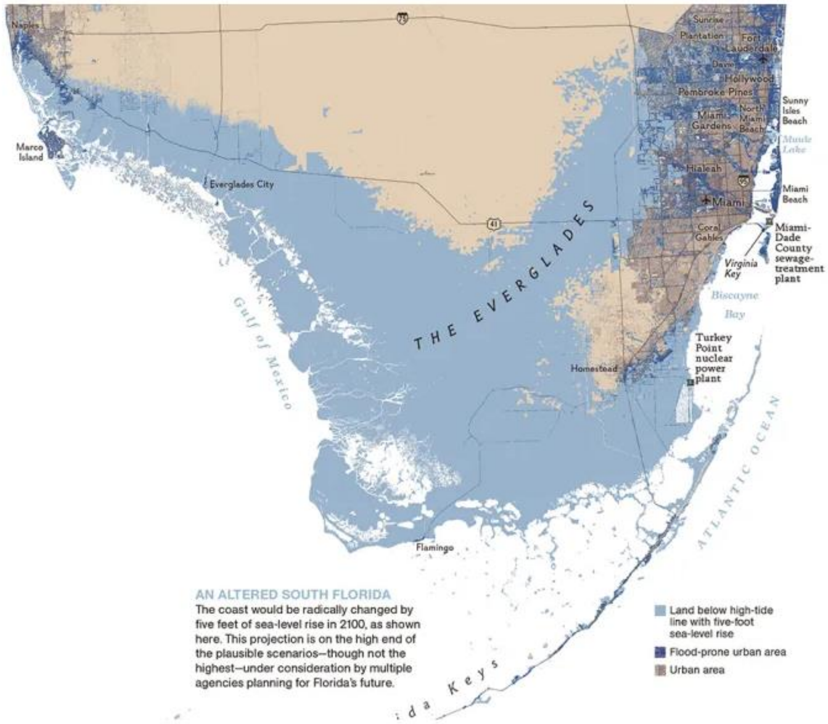
STS Discussion

One of the primary design goals for this new intake system is increased fuel efficiency. The Formula SAE competition motivates this by giving a substantial number of points to the team with the lowest fuel consumption (SAE). While the internal combustion engine is fading out, for the time being there are still two billion combustion engines still hard at work in the world (Internal). Improving the fuel economy of these numerous engines is vitally important to everyone in the competition. This is because in many cases it is not feasible to replace the aging technology with an entirely new more sustainable version. The manufacturing of any new vehicle produces as much carbon as the electricity used from an average home for three years. (Berners-Lee). Berners-Lee explains that the environmental issues of today cannot be solved with more consumption. As it stands it is more beneficial for the environment to continue using an old vehicle until it is completely unusable than to "upgrade" to a newer more efficient model, due to these manufacturing emissions. Issues created by overconsumption cannot be solved with "intelligent consumption." When a new vehicle is required, it is of course more beneficial to invest in a more sustainably designed car.

There are many factors to consider when attempting to solve this complex issue. Transportation emissions of course affect everyone, but pollution tends to have a larger impact in poorer communities. Affluent groups can afford to move to cleaner and healthier regions, leaving behind disadvantaged neighbors in areas with poor air quality (Failey). Kioumourtzoglou found that those who live in Black or African American communities had a much higher risk of premature death from airborne particle pollution than those living in communities which are predominately White (Kioumourtzoglou). This is particularly an issue as cities tend to both have higher levels of transportation pollution, and higher proportions of racial and ethnic minorities. This means that this issue is not only an environmental dilemma, but also one of social justice issue.



Rising temperatures across the globe have been primarily attributed to the burning of fossil fuels, and due to this, reducing our consumption of fossil fuels is necessary (NASA). Due to rising global temperatures we have also seen a rise in global sea levels (Lindsey). Average sea level has risen by nine inches since 1880 and it is projected that if we continue at this rate, by 2100, a substantial portion of Florida’s Everglades will be underwater, as well as other major coastal areas throughout the world (NatGeo).



Rising sea levels cause greater intensity of storm surge, flooding, and damage to coastal areas (NatGeo). Furthermore, we risk hitting a "point of no return" where the climate crisis triggers a self-sustaining feedback loop, from which no efforts will be able to stop a climate catastrophe (Lindsey). There are multiple positive feedback loops, but a common example is related to global sea levels rising. Ice reflects a substantial portion of sunlight that impacts it, whereas water absorbs heat. This means that as ice shelves deteriorate and melt, they no longer reflect heat back away from the earth and instead absorb it, which further causes ice to melt (Sea).

Research Question and Methods:

My research question is, **to what degree can fossil fuel efficiency be improved in an average passenger vehicle, and what impact that can have on greenhouse gas emissions?** The purpose of my question is to gain insight into whether this method is appropriate for addressing the global climate issue, or if other methods such as a a change in basic assumptions to electric vehicles are necessary in order to push our carbon footprint back to a reasonable level. To pursue this research question, I will first establish a baseline for a typical American passenger vehicle's carbon footprint through research. I I will also be researching various methods to improve the fuel economy within passenger vehicles including but not limited to, alternative fuels, reducing vehicle weight, and hybrid technology. From there an analysis can be made of the projected increase in fuel efficiency, and therefore carbon emissions. This can then be compared with other crucial factors like cost of implementation, or safety in a cost benefit analysis. Finally, I will compare these solutions with other alternative solutions that require more drastic social changes such as the consumer switch to electric vehicles, or more widespread use of public transportation.

Conclusion

In conclusion, the goal of my group's capstone is to design a more effective intake system for a Formula SAE vehicle. In doing this, we hope to improve fuel efficiency, and engine output power to score more points in our design competition. In a broader view however, improving the fuel efficiency of combustion engine vehicles would have a positive impact on people, global economies, and the environment. My research intends to make an assessment on to what degree improving fuel economy can help to solve our global environmental crisis in a way that is both sustainable and equitable.

Word Count: 1788

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