Underbody Aerodynamics for Fuel Efficiency in Consumer Vehicles

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Abstract

The automotive industry is constantly innovating and changing. Many consumers are looking for cars that burn less gas, both for monetary and moral reasons. These consumers are often attracted to electric vehicles, but the pricing is often prohibitive. Many people can't afford a new car at all, but would still like to see their MPG increase. Automobile manufacturers invest large amounts of time and money into streamlining the bodies of their cars. The lower drag of these bodies increases efficiency, and many areas are explored in depth, with one exception. The effect of streamlining the underbody of the car is not deeply researched, and this what I aim to find. But just knowing the benefits isn't enough. A cost analysis will also be performed to find the price of such a modification, both from a mass manufacturing and aftermarket perspective, as different materials and processes are more convenient for each of the two options.

Background

The context of this research is the tumultuous and undergoing shift from gas to electric cars. Even as electric vehicles enter the market by the day, the average lifespan of a new vehicle is 16.58 years according to Auto Recycling World, meaning gas vehicles will be on the roads en masse through 2040. This means that new solutions are still being researched that may increase fuel efficiency. Powertrains are extremely complex and even more well researched, with new innovations like geared CVT transmissions few and far between. This is because the technology behind engines has become incredibly matured. Aerodynamics, on the other hand, are a much more recent topic of scrutiny. Up until the 80s, aerodynamic efficiency was either calculated by hand or guided by the designer's eye. The depth at which aerodynamic efficiency could be improved then became limited by computing power, which exploded over the next 40 years. But while the top of your average new vehicle is smooth and streamlined, the bottom features exposed underpinnings and machinery that can catch onto passing air and resist efficient travel. The NHTSA even disclosed a recall of Hyundai models because their undersides were exposed to the point of rusting out, which brings another potential advantage. Salt belt states, where roads are salted in winter to ward of ice, are notorious for killing cars by rusting out their frames. States like Vermont, New York, Rhode Island, and Delaware feature lifespans near or below 15 years. If there were a plate composed of a non-rusting substance between these cars and the salted roads, the 1.5+ year gap could be closed. An extra 1.5 years between purchases also allows more time for newer, more efficient models to enter the market. While doing background research, there were also no results in scholarly databases for underbody flow research for consumer vehicles, which led to a belief that a gap had been found. The only place that even surface-level analysis had been done was on hypermiling forums such as ecomodder.com, where on a number of threads both reliable calculations and credible insight from verified professionals could be found. Based on information from these sources, it appeared that the most important areas to cover were the front and rear cavities inboard of the wheel wells.

Portfolio

This portfolio includes annotated bibliographies, drafts, interviews, and literature reviews. Also included is the raw spreadsheet and 3D models used during data collection, and digital examples of any images used in the poster. Finally, and arguably most importantly, it contains the final draft of the research paper, which contains further detail on the topic than this poster.

Methods

Computational Flow Dynamics is an analysis tool through which computers are able to make reliable conclusions on aerodynamic properties of a provided shape under a provided set of conditions including direction, ambient pressure, speed, and fluid density. The CFD tool I plan to use is Solidworks' built in Simulations feature, titled SolidWorks Flow Simulation. It provides results in the form of 3-D path structures, animated air particle movements, pressure shading, and an exportable writeup that includes the force applied by drag and drag coefficient. The control model will be a high quality, 3-D asset from the game BeamNG.drive. test runs will be with a control car and one with the underbody panel modification. Drag forces are the most important output figures and thus will be most prominently featured in the results section of the paper. The force applied will be compared to that of the control to determine whether there is any improvement and the magnitude of that improvement. Solidworks CAM can then be used to determine manufacturing costs, and observing market rates will allow me to gauge material costs. Once a design is tested, and its price is known, a market analysis will take place to determine whether consumers will pay the price tag for the improvement in gas mileage.

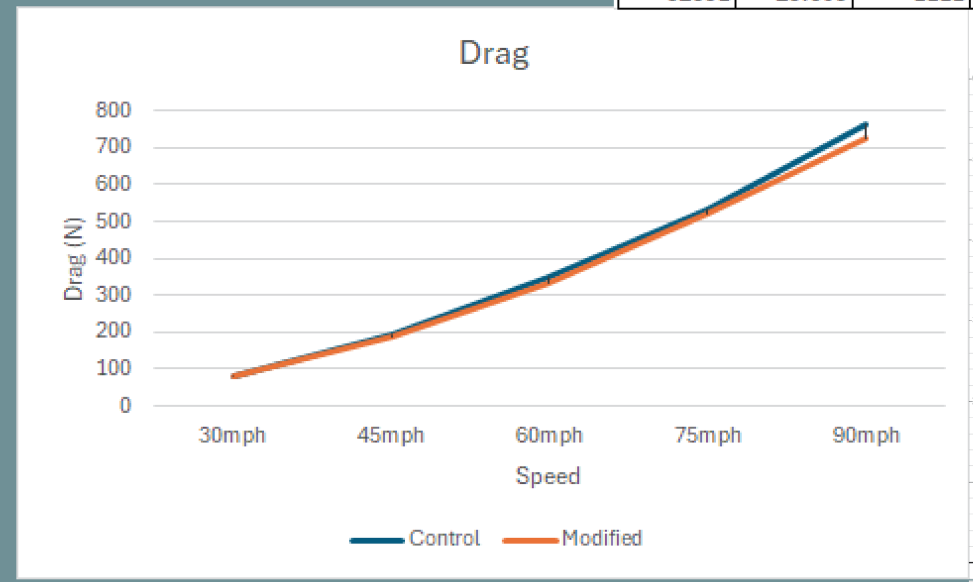
Average Price	Average MPG	Average $/MPG	Average Drag Reduction Factor	New MPG	$ Value	Total Cost (Unit #5000)	Break Even (Days)	Lifetime Dividend (16.58 Years)
32891	29.603	1111	3.28%	30.57398	1078.757	$72.12	1133	$625.90

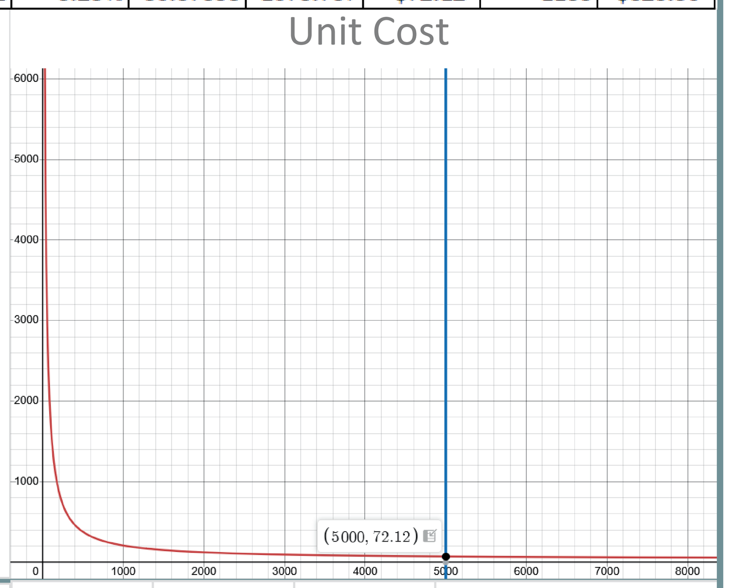
PessimaCONTROL

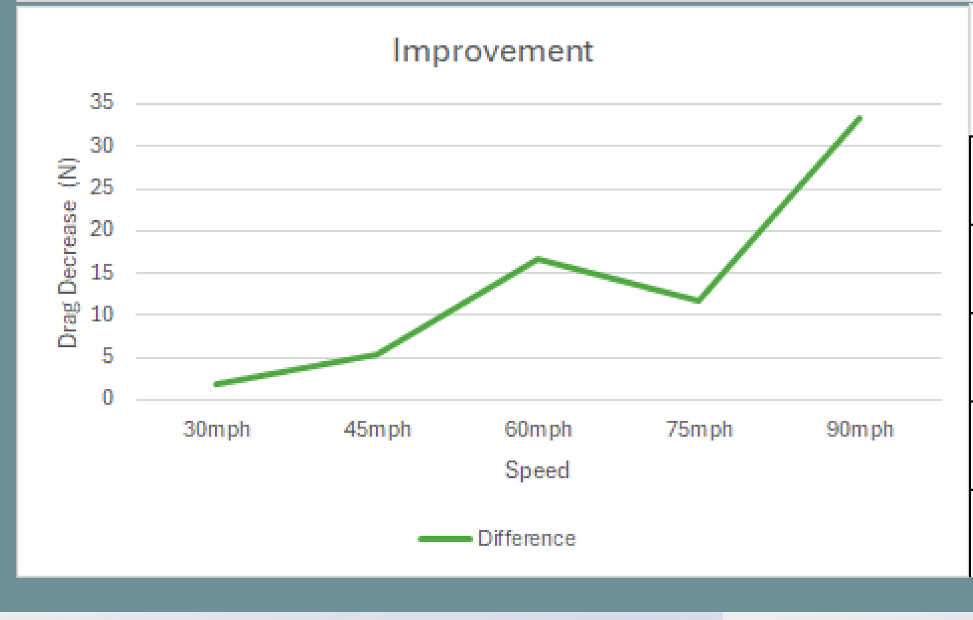
Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
GG Force (Y) 1	[N]	71.69881	80.37018	71.69881	99.04891	100	Yes	27.3501	30mph
GG Force (Y) 1	[N]	169.921	191.4006	169.921	237.9456	100	Yes	68.02457	45mph
GG Force (Y) 1	[N]	313.0335	352.1064	313.0335	437.0566	100	Yes	124.0231	60mph
GG Force (Y) 1	[N]	480.6922	532.6653	480.6922	652.079	100	Yes	171.3868	75mph
GG Force (Y) 1	[N]	684.5328	761.0114	684.5328	932.2833	100	Yes	247.7505	90mph

PessimaModified

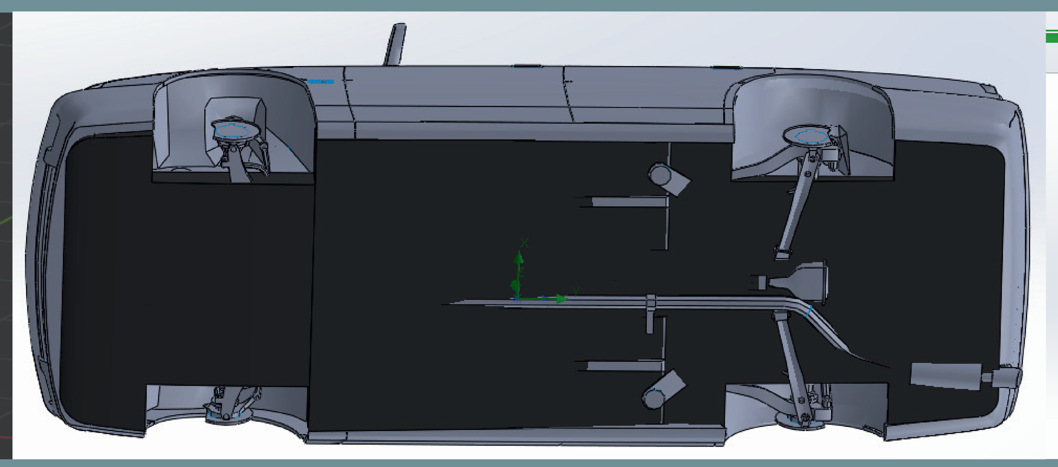
Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
GG Force (Y) 1	[N]	71.13687	78.57229	71.13687	94.51205	100	Yes	23.37518	30mph
GG Force (Y) 1	[N]	167.7975	185.9727	167.7975	223.8479	100	Yes	56.05038	45mph
GG Force (Y) 1	[N]	300.8357	335.485	300.8357	406.1039	100	Yes	105.2682	60mph
GG Force (Y) 1	[N]	467.2111	520.8354	467.2111	632.157	100	Yes	164.9459	75mph
GG Force (Y) 1	[N]	660.193	727.7352	660.193	866.8235	100	Yes	206.6305	90mph

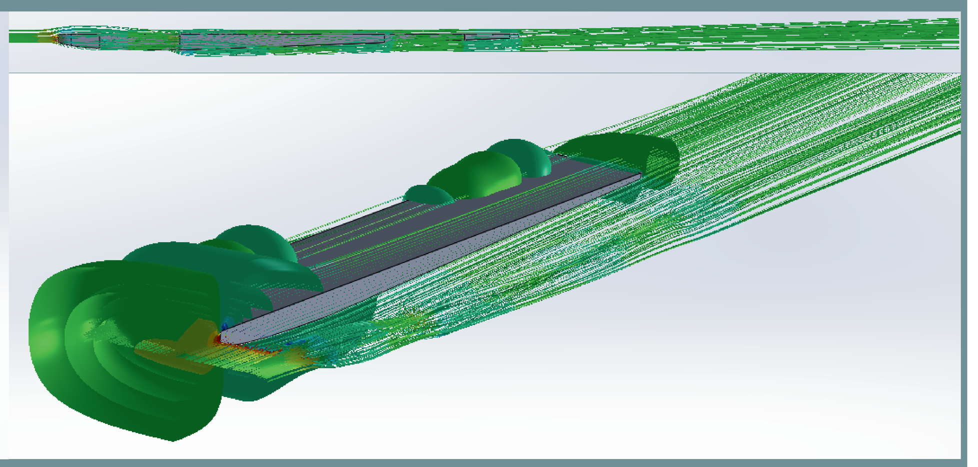






Control	Modified	Speed	Difference
80.37018	78.57229	30mph	1.7978893379984
191.4006	185.9727	45mph	5.42795064277701
352.1064	335.485	60mph	16.621448171435
532.6653	520.8354	75mph	11.829878892712
761.0114	727.7352	90mph	33.276196250918





Results

At the average price of a mid-size car in February 2025 was $32,891. (Johnson, 2025) The average fuel efficiency of this same type of vehicle was 29.603 miles per gallon. (EPA) Cost was assessed at the 5000th unit by dividing the 75th percentile cost of an injection molding machine by the number of units, added to the material cost of a mass of Polypropylene (PP) equivalent to the mass of the part used for simulations. The cost of such a machine would be in the ballpark of $170,000 per unit, (FormLabs) including both injection equipment and mold. While operator wages are also a real world factor, they are not being accounted for by this figure or the calculations in this paper. Material cost of a thermoplastic like PP is fairly low, as the 78.532 pounds of it in the 3d model equate to a value of just $38.12 or $0.49 per pound. With this equation, the cost of the 5000th part to manufacture will be only $72.12.
This far undercuts the added MPG value of $1078.76, meaning even if it were sold at a 200% margin ($144.24) the modification can be expected to easily break even. In fact, taking into account the average yearly commute distance, gas usage, and gas price of an American, they can expect to break even in 1133 days. Just over 3 years, and the owner of a vehicle equipped with such a modification could already be making a profit compared to people who bought an identical vehicle without it. By the time the vehicle is off the road, the owner can expect to have saved $625.90.

Conclusion

It can be concluded that the average consumer would likely have an interest in this modification. Not many things offer such a simple pitch for a salesman or a buyer as being able to truthfully say they might as well be putting more than $500 into their pocket by checking a box. In fact, the savings will likely increase over time with the price of gas, as each gallon saved becomes more valuable. The modification would also be good for the environment, as despite the use of plastics, it would save over 200 gallons of gas per example. The modifications could be made even cheaper with incentives to consumers, such as tax discounts on vehicles above a certain fuel economy threshold.

References and Acknowledgements

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