

University of Wales Trinity Saint David

Wales Institute of Science & Art



Prifysgol Cymru

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Comparison of Different Displacements in Modern Engineering

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Joshua Billings-Evans

2506256

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1 Introduction

As automotive engineering continues to progress, the reliance on larger displacement engines to create more performance has declined as advancements allow us to create more efficient engines, allowing us to maintain performance with a smaller powertrain. This report will explore and compare the differences in why, across the automotive world, there are numerous different displacements used, and delve into the popular trends of modern performance cars in the endless pursuit of extracting as much power out of an engine whilst maintaining a smaller package. And to understand and provide insight into the application of downsizing in the modern automotive designs.

2 Background

2.1 Drivers of Downsizing

Manufacturers are in a constant race with technology with rivals but also the constant development in global economy and regulations imparted by governments. This has led to a trend of downsizing engines to account for rising fuel costs and also in a battle to reduce CO₂ emissions. As technology continues to advance, it creates new opportunities to push the boundaries further as alluded to in Ultra Boost for Economy: Extending the Limits of Extreme Engine Downsizing (Turner et al.) Lowering the displacement of an engine leads to a reduction in fuel consumption, evident in smaller vehicles for general usage. It is further mentioned that a result of downsizing engines results in an increase in mechanical efficiency as the engine operates at an increased load. The concept of Engine downsizing and efficiency has been further explored in An Investigation into the Effects of Engine Displacement and Geometric Compression Ratio on Downsizing of a Direct-Injection Spark-Ignition Engine Turner, N. (Author). 16 Jun 2021. Whereby he cites a Test carried out by Land Rover Jaguar, to which they tested the efficiency of their 8-cylinder engine and concluded that there is a threshold to where when an engine reaches an efficiency rating it becomes feasible to replace the engine with a smaller displacement engine. Turner N. proceeds to then provide data that shows that at an output of 200% of its original output, there is data to show that an engine originally providing that output was an 8-cylinder, it is then viable to replace the engine with a 4-cylinder engine.

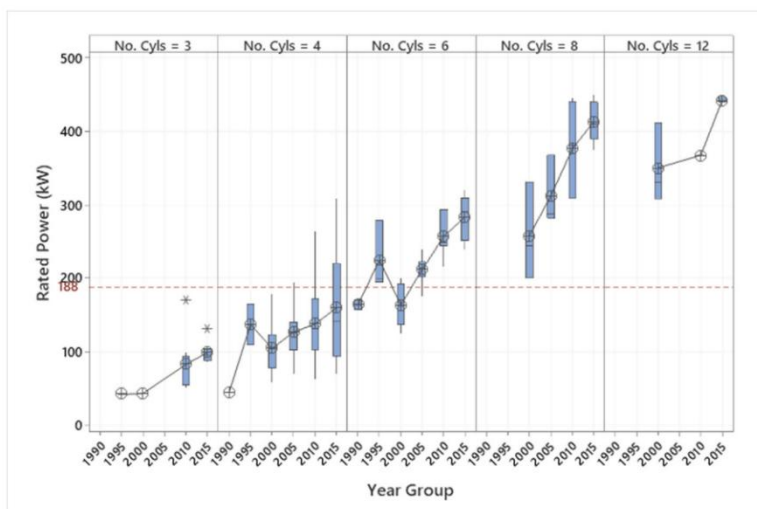


Figure 1.1 - Power against year

The above Figure, comparing the power produced by varying engines of differing cylinders show that over time engine efficiency has increased as evident by simply looking at the data of the 6 cylinders. In 2015 engines were able to achieve power nearing 300Kw however in decades prior they were not even breaking the 200Kw threshold.

3 Comparing use of Different Displacements

3.1 Characteristics and Application of Small displacement engines

As briefly addressed in the introduction, the modern emphasis on downsizing in everyday cars is in a pursuit of efficiency and constantly changing regulations and legislations. Advancements in technology have allowed engines to gain substantial gains in efficiency which has aided in achieving greater fuel consumption efficiency. However, there will always be a limit to how efficient and how much power can be made from an engine that remains naturally aspirated. There becomes a tipping point where the gains in efficiency and power fall off. At this threshold is when the availability of forced induction becomes the option to continue to increase the metrics. The most popular form of forced induction in modern cars is the use of turbochargers. It has become common for small displacement engines such as those found in modern hatchbacks such as the Ford fiesta, VW polo, etc to be turbocharged to improve the efficiency and output of the engine whilst maintaining a relatively small power package and maintaining the efficiency of the 1-2l engines they use. Again, in the 'Ultra Boost of Economy' (Turner et al., 2014) paper and aided by figure 1.1 it is shown that engines in the displacement range of 2.5-3.0l can feasibly be replaced by 1.0-1.5l engines which are now aided by turbochargers and have better efficiency. This is then visible as modern hatchbacks that are popular for their efficiency are most commonly powered by a package within that 1.0-1.5l range. Discussed in the article 'Technical research on improving engine thermal efficiency' (Mu et al., 2022) engines have only recently in the last decade been able to achieve a thermal efficiency of over 40% and Hybrids have pushed past the conventional engines range of 37-40% to upward of 43% thermal efficiency as supported by figure 2.1

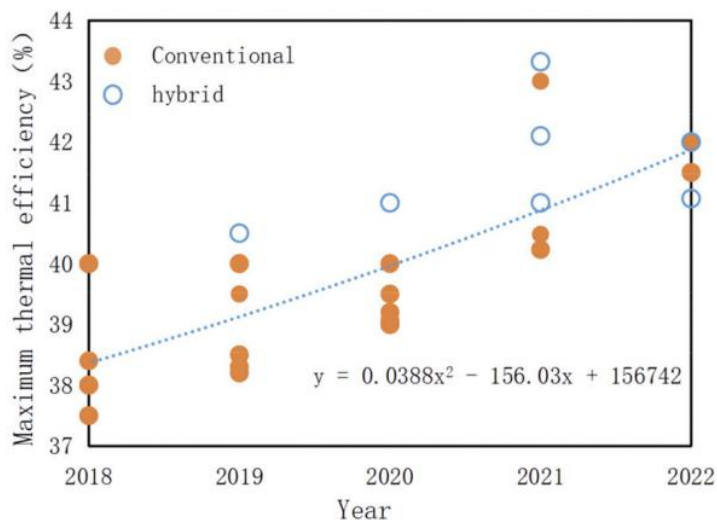


Figure 2.1 - Trend of thermal efficiency in small engine cars.

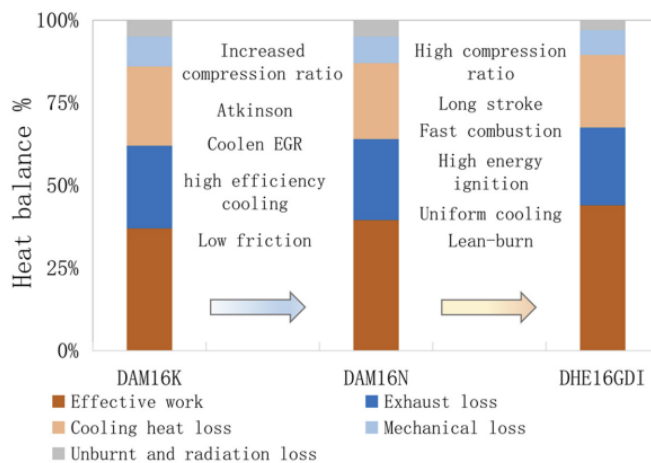


Figure 2.2 - Thermal Improvements of Engine Designs.

Due to the smaller size, there is less mechanical friction which aids the increase in thermal efficiency. In (Mu et al.) paper, figure 3.1.2 was provided which shows the result of a study of using different technologies to find ways to increase the thermal efficiency. Of note was a technology called cooled EGR which caused for lower friction and increased cooling efficiency allowing for a thermal efficiency of 39.5%.

3.2 Characteristics and Application of Large displacement engines

Even with the trend of downsizing to conform to certain regulations and the demand for more efficient and practical engines for the large majority of consumers. There is still a place for larger engines, whether it be for performance vehicles looking to produce higher power figures or for heavy-duty vehicles that require more torque and power for the vehicle to satisfy its intended usage. Larger engines are proven to produce greater levels of torque at lower RPMs, thus leading to them being more beneficial for application in lorries and off-road vehicles. The lower torque is beneficial in the prior applications as it creates a greater towing force as well as it provides greater driving force to the wheels, enabling the lorry or off-road vehicle to gain the traction needed to move.

There is a theoretical cap to the performance of an engine of its respective displacement. Thus, cars that are built for performance such as supercars and high-end sports cars are powered by a package that reflects the desired power the manufacturer desires. Commonly found in super cars such as McLarens and Ferraris are V8 engines. 'Navigating the Evolution of McLaren Road Car Engines: Triumphs and Trials' (SBR Engineering) discusses how modern McLarens are powered by a twin-turbocharged V8 which originated in their MP4-12C which was a 3.8l engine. However, in the more modern 720s it is powered by a 4.0l V8 twin-turbocharged engine which not only provides a package with a greater potential for higher power figures but also with technology advancements it generates the power with higher efficiency. An alternative to achieving those higher power figures that seem to be a contention point for the sport and super car market can also be achieved by the introduction of electric motors, providing a large boost to the figures. For example, in the (SBR Engineering) article the P1 is referenced as it shares the same 3.8l twin-turbocharged platform of the MP4-12C, however the introduction of the electric motor enables the P1 to achieve a power figure of a combined 903hp. The drive to increase power in modern cars does come with the drawback where a sacrifice is needed somewhere. In the case of these high-power super cars needing a larger power package and displacement, the sacrifice comes in the fuel efficiency as larger quantities of fuel are needed to be burned to produce the desired figures.

4 Conclusion

Comparing the different applications of both larger and smaller displacement engines and the benefits and drawbacks of both. The trend of downsizing engines is practical for both manufacturers and consumers, as the increase in efficiency provides a more reliable and economical solution for the increasing cost of fuel as well as the constant change in regulations. Due to the changing state of the world and economy, the desire to increase efficiency and retain as small a package as possible only further. without sacrificing the performance will only continue to increase. And with the continued development of technologies, it is realistic to see the boundaries only be pushed farther with how efficient and small we can create engines.

However, there is always a demand for larger displacement engines for heavy-duty purposes such as towing where the comparatively high low-range torque is required. Large machinery and utility vehicles will continue to require large engines in order to maintain their function. Until a development is made whereby it makes the current combustion engines obsolete, the large engines will persist. There is also a demand for them from the performance enthusiast market where the competition for increasing the power figures is a large selling point. There is also less of an emphasis on efficiency as the emotions and experience provided by the car and engine are more of the focus than the fuel economy and efficiency.

As a result, the criteria needed to be achieved is too vast for there to be one singular option to fulfil. Thus, there will be continued usage and development of both large and small displacement engines, as they have different uses. However, the development within each category will be dictated by the developments of technology and changes in the regulations issued as time carries on.

5 References

Turner, J., Popplewell, A., Patel, R., Johnson, T. et al., "Ultra Boost for Economy: Extending the Limits of Extreme Engine Downsizing," SAE Int. J. Engines 7(1):387-417, 2014, <https://doi.org/10.4271/2014-01-1185>.

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5.1 Figures

Figure 1.1: Power Against Year (3 – 12 cylinder engines) - Turner, J., Popplewell, A., Patel, R., Johnson, T. et al., "Ultra Boost for Economy: Extending the Limits of Extreme Engine Downsizing," SAE Int. J. Engines 7(1):387-417, 2014, <https://doi.org/10.4271/2014-01-1185>

Figure 2.1: Trend of Efficiency in Small Engine Cars. - Mu, H., Wang, Y., Yang, C. et al., "Technical research on improving engine thermal efficiency" Advances in Mechanical Engineering 2022, Vol. 14(9) 1–15

Figure 2.2: Thermal Improvements of Engine Designs. - Mu, H., Wang, Y., Yang, C. et al., "Technical research on improving engine thermal efficiency" Advances in Mechanical Engineering 2022, Vol. 14(9) 1–15