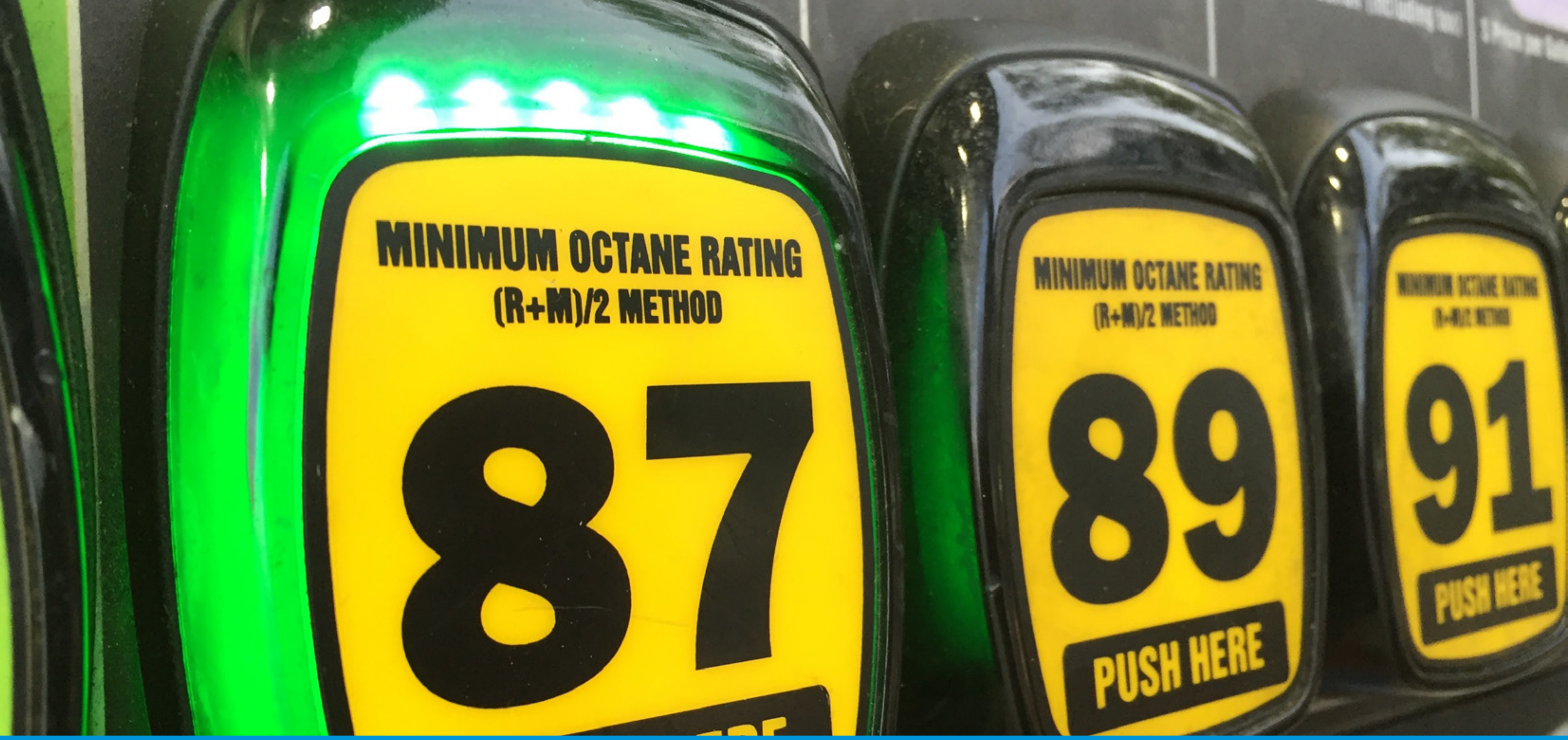

WHY ARE RON AND MON IMPORTANT ?

(TESTING FOR RON/MON USING AN OCTANE ENGINE)

The maximum performance and efficiency of modern gasoline engines are limited by a phenomenon called knock. Knock is an engine noise related to the autoignition of fuel in the cylinder, resulting in a characteristic knocking sound. The propensity of a fuel to knock is characterized by its chemistry; given the complex chemistry of modern fuels, a simpler metric – the octane rating – quantifies the propensity of a fuel to result in a knocking sound. The octane rating has been used since 1928 and has become embedded in American society. In this article, we will provide some background on octane testing, why it is done, and some of the test methods that have been developed for this purpose.

Autoignition of a fuel is primarily determined by two factors: temperature and compression. Both of these are specified for a given engine as the operating temperature and compression ratio, respectively. A combustion reaction takes place in engines that ignite the fuel and produce work and combustion reactions result in high temperatures. It is thus very hard to try and decrease the operating temperature inside the engine to prevent autoignition, so that has led to a focus on the compression ratio. The compression ratio of an engine is tied to the maximum efficiency of the engine, such that engines with higher compression ratios produce more work for a given amount of fuel. Compression ratios have increased over time going from a value of 4 in the Model T to 12 in modern engines. The problem with higher compression ratios is that they can produce more knocking than usual, which led to a focus on designing fuels to resist knock. Note that knock not only produces an irritating sound, but heavy knock can result in engine damage. This is where the octane rating and octane testing proves very useful.

It is generally seen that as the octane number of a fuel increases, the fuel has less propensity to knock, therefore increasing its anti-knock capabilities. This led to many developments in fuel formulation. Early fuels were very prone to knock, resulting in a need for very low compression ratios. The development of catalytic cracking resulted in fuel blends that were much less likely to knock. The octane rating of a fuel could be further increased through anti-knock additives. From the early 1920s to the 1970s, the most popular anti-knock additive added to fuel was tetraethyl lead. Tetraethyl lead was phased out due to tighter restrictions on emissions, and aromatics became a popular anti-knock additive. Eventually aromatics were deemed too toxic so now ethanol is added to gasoline to help boost the octane rating because ethanol burns cleaner [1].

Standardized test methods

There are two different octane numbers that are tested for. They include the research octane number (RON) and the motor octane number (MON). These numbers differ in the test methods used to determine them. The RON is found using test methods specified by ASTM D2699 and the MON is specified by ASTM D2700. Both of these tests use essentially the same engine, which is a single cylinder, four-stroke cycle, carbureted, variable compression ratio, originally developed by the Cooperative Fuels Research group. They both give octane ratings for fuels up to 25% v/v of ethanol. ASTM D2699 has a working range of RON from 40 to 120 and ASTM D2700 has a working range of MON from 40 to 120. The primary difference in the two testing methods is that the RON method is determined from relatively mild engine conditions, while the MON method is determined from more harsh engine conditions. The MON method was developed to test fuel samples under conditions that are more similar to actual driving conditions. ASTM D2699 (RON) uses an engine speed of 600 rpm and an intake temperature of 52°C. ASTM D2700 (MON) uses an engine speed of 900 rpm with an intake temperature of 149°C [2,3].

To measure a fuel's octane number, the engine is set to run on that fuel at one of the above conditions. The compression ratio is then increased until the engine starts to knock at a given intensity. This compression ratio is then compared to a reference fuel, consisting of iso-octane and n-heptane. As the percentage of iso-octane in the reference fuel blend increases, the fuel is less likely to auto ignite. So, if a fuel has a RON of 92, it implies that at the RON engine conditions, the CFR engine knocks with that fuel at the same intensity as a reference fuel that consists of 92 percent iso-octane, 8 percent n-heptane.

Importance of accurate octane testing

Octane testing became important in the early 20th century as a way to quantify the anti-knock characteristics of a certain fuel. Even today, standardized octane test methods are used to determine the number that appears on the fuel pumps. These numbers are usually taken to be the average between the RON and the MON of the fuel. Octane testing also becomes very important as more studies are done to see what kinds of fuel formulations affect the octane rating of a fuel. Recording an accurate octane rating for a sample of fuel is very important to ensure that these studies done are accurate and so that they can further improve the design of fuels. There was also a recent study done by Prakash et. al. where they reported that the fuel sensitivity can have an impact on engine efficiency [4]. The sensitivity is defined as the difference between the RON and the MON. In the study they found that increasing both the RON and sensitivity had a positive effect on engine efficiency and fuel consumption. The amount of improvement of these parameters was usually between 1-5%. They also found that at a higher RON (e.g., 98), the RON itself has a more significant effect on the engine efficiency while at a lower RON (e.g., 92), the sensitivity has more control over the engine efficiency. Studies and results like these cannot be achieved without the accurate measurement of octane ratings.

Description of a typical octane testing engine

Figure 1 shows an image of a typical octane testing engine (combination engine) which means it can test for both RON and MON and this engine conforms to both ASTM D2699 and ASTM D2700. In the engine here, the parameters can be adjusted according to the standards very simply through the operating panel. There is a dual speed motor which allows for constant engine speeds according to the standards and allows for quick change between RON and MON testing. The electric motor assembly adjusts the cylinder height to change the compression ratio based on user input. The combustion knock is converted to an

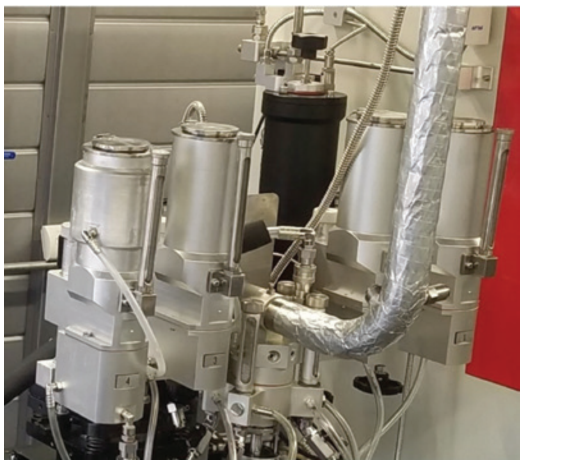

Figure 1: Combination Octane Rating Unit Engine produced by Koehler Instrument Company.

analog signal which improves accuracy. The intake air humidity technology maintains the moisture content of the intake air based on the standards. Resonance pulses and back pressure are mitigated by the exhaust surge tank system. The engine also has a safety system which will automatically halt engine operation if different fault indications are present.

A primary advantage of such a system is the ability to switch seamlessly between the RON and MON testing methods. This is done by shutting the engine down, changing the carburetor jets, and then restarting the engine. The RON test can be run without the removal of the mixture heating manifold. Also, the ignition timing is set automatically and the drive belt configuration does not need to be changed when switching between RON and MON. Usually changing between RON and MON in the past could take hours but in this case, it is only done in a matter of minutes.

Conclusion

There has been much development in octane testing and enhancement over time and a lot of folks have contributed to the growth in this field. It has been seen that octane rating has an effect on engine efficiency and performance. It is very important that the octane numbers are measured accurately and efficiently, so that research on fuel design may continue to progress.

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https://www.astm.org/DIGITAL_LIBRARY/MNL/SOURCE_PAGES/MNL37-2ND_foreword.pdf

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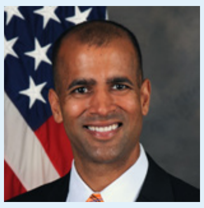
More information on Raj can be found at https://www.che.psu.edu/news-archive/2018/Alumni-Spotlight-Raj-Shah.aspx



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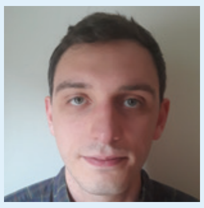

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