RESEARCH NOTE

INFLUENCE OF ALTITUDE/ATMOSPHERIC PRESSURE ON OCTANE REQUIREMENT

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Abstract The normal specifications of motor gasolines as well as their combustion characteristics in internal combustion engines are reviewed in this paper. The effective factors influencing the fuel performance, such as the molecular structure of the fuel constituents, the operating conditions and the atmospheric pressure and temperature are also discussed. A relationship between the optimum octane number and local altitude has been formulated and plotted for a certain range of elevations. While these studies pertain only to normal compression spark-ignition engines, it is however, possible to obtain similar correlations for high compression engines by applying a different set of data.

چکیده دراین مقاله خواص معمولی و رفتار احتراقی سوختهای موتوری در موتورهای درون‌سوز مرور شده است. عوامل مؤثر در بهبود کیفیت رفتار، مانند ساختمان مولکولی اجزاء سازنده سوخت، شرائط کار سیستم، دما و فشار محیط بررسی شده است. رابطه بین شماره اکتان سوختهای موتوری جرقه‌ای و ارتفاع محل از سطح دریا بصورت معادله تنظیم گردیده است. مطالعات مزبور برای موتورهای با نسبت تراکم معمولی بوده و می‌توان با بکاربردن اطلاعات کیفیت اکتان و فشار اتمسفر در مورد موتورهای با نسبت تراکم بالا نیز روابط مشابه دیگری بدست آورد.

INTRODUCTION

The motor gasolines used in different countries possess practically very close chemical composition and quality. The high octane stable components present in gasolines provide satisfactory combustion behavior leading to the production of mechanical energy in the internal combustion engines. The important effective properties of gasolines are: vapor pressure, octane quality and their freedom from corrosive and undesired matters such as sulfur, water, gum compounds and so on.

There is a general correlation between the burning properties of fuels and critical compression ratio (C.C.R) in the engine. The critical compression ratio in the engine cylinder is directly related to the chemical structure of the fuel molecule. The higher the C.C.R. value, the higher the knock resistance for a certain fuel and a lower C.C.R. value indicates the tendency of the fuel to knock. The octane requirement for motor fuels is progressively increased with severity of physical conditions under which they are combusted, i.e. the temperature, pressure and compositions of the fuel-air mixture. To obtain a satisfactory efficiency at a certain engine power a minimized fuel consumption is required which in turn depends on the compression ratio of the system. An inccrease of the C.C.R. value will raise the thermal efficiency that affects the maximum internal pressure of the engine. Thus, a designated final compression pressure limits the critical compression ratio "a function of the octane requirement for engine fuel".

The intake air to the cylinder obeys the ideal gas law where the mole numbers of the fuel vapor can be calculated from the following relations:

$$(1)\quad P_o V_o = n_{air}(RT)$$

$$(2)\quad n_{air} / n_{fuel} = r$$

$$(3)\quad n_{fuel} = \frac{P_o V_o}{r(RT)}$$

where P_o and V_o are the initial pressure and volume of the cylinder and r is the air to fuel ratio. Therefore, at constant temperature and volume, for a certain fuel-air mixture, the number of moles of the fuel is proportional to the intake air pressure. As the atmospheric pressure decreases, the final compression pressure and temperature fall in the cylinder and thus, the carburetor system provides a lower mass of the fuel-air mixture for burning in the combustion chamber. In this case a lower octane quality gasoline may be used without encountering any difficulty, hence the less severe conditions will reduce the octane requirement. With a lower octane fuel, less energy will be obtained and presumably the engine becomes less efficient. Table 1 indicates the compression pressure, the C.C.R. value and the octane number for sevevral typical fuels [1].

Table1.Octane Numbers for Various C.C.R.Values

Fuel	Compression Pressure (psia)	C.C.R.	Octane number
Benzene	520	20	100
Isooctane	470	18	100
Premium gasoline	350	14	80
Nonpremium gasoline	230	10	
Normal heptane	175	8	0

The Optimized Octane Quality for Gasolines

The knock intensity increases with any rise in temperature and pressure of the gases in the system; since the tendency of a fuel to knock increases with a rise in compression ratio of the engine, the use of a high octane fuel is thus required to eliminate this problem. The discussion can be elaborated on by applying the thermal efficiency equation of internal combustion engines [2]:

$$E = \frac{T_2 - T_1}{T_2} 1 - T_1 / T_2 = 1 - (P_2 / P_1)^{1/\gamma - 1}$$

$$= 1 - (V_1 / V_2)^{1-\gamma} = 1 - (C.R)^{1-\gamma}$$

Where E=thermal efficiency, C.R.=compression ratio, P_2 and P_1 are the final and initial pressures of the cyli ler respectively and

$$\gamma = C_P / C_V = 1.4$$

For a certain air/fuel ration, any reduction in atmospheric pressure influences the final compression pressure P_2 in the system and therefore the compression ratio is partially altered according to relation:

$$\frac{1}{C.R.} = \left(\frac{P_2}{P_1}\right)^{-1/\gamma} = \left(\frac{P_1}{P_2}\right)^{0.714}$$

Under such conditions a lower octane grade fuel is required to obtain a certain output efficiency.

CONCLUSIONS

As the burning conditions are often normalized to produce as much heat and mechanical energy as possible in the industrial systems, then the effects of altitude/barometric pressure on the quality of the gasoline should be considered. The adjustment of the operating conditions for an engine is based upon the fuel nature and its capability for a proper combustion system. In selecting a particular gasoline the influence of altitude [3,4,5] on the antiknock behavior is to be taken into account. With a decrease in atmospheric pressure and temperature due to an increase in altitude, the final pressure established in the combustion chamber is reduced to a value that necessitates the use of lower octane gasolines at normal efficiency.

The octane requirements for gasolines applied in the universal spark ignition engines have already been reported [6,7,8,9] and among the influencing factors such as the engine design, the ignition quality and the type of gasoline, the octane number and altitude may be correlated by the expression:

$$O.N. = \left(\frac{h+1}{1000}\right) A^2 . ex \left(\frac{-h}{100A}\right)$$

where O.N. = optimized octane number, h =altitude from sea level (feet), and A is a constant which depends upon the altitude for a designed engine. The equivalent barometric pressures and altitudes are plotted in Figure 1 while the constant A is read from Figure 2 by plotting the h value. With the knowledge of A and h values the octane number is computed from the above equation. The typical octane requirements for normal spark ignition engines are plotted against the altitude/barometric pressure in the form of nomogram (Figure 3). This mathematical expression may be used by both producers and consumers of gasolines at a wide range of atmospheric pressure.

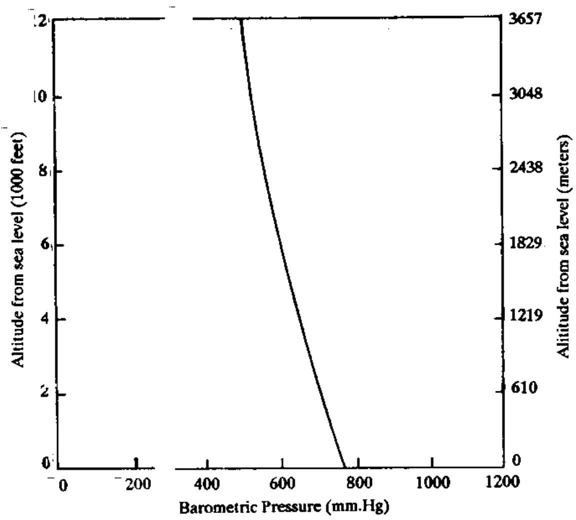

Figure 1. Equivalent barometric pressure at various altitudes from sea level

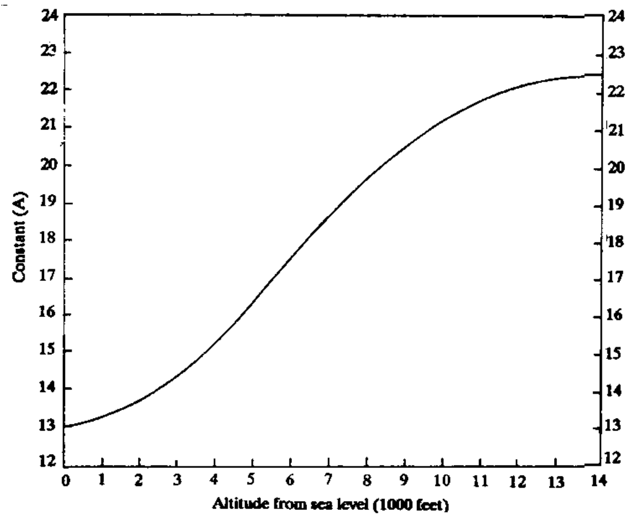

Figure 2. Calculated values of constant."A" at various altitudes

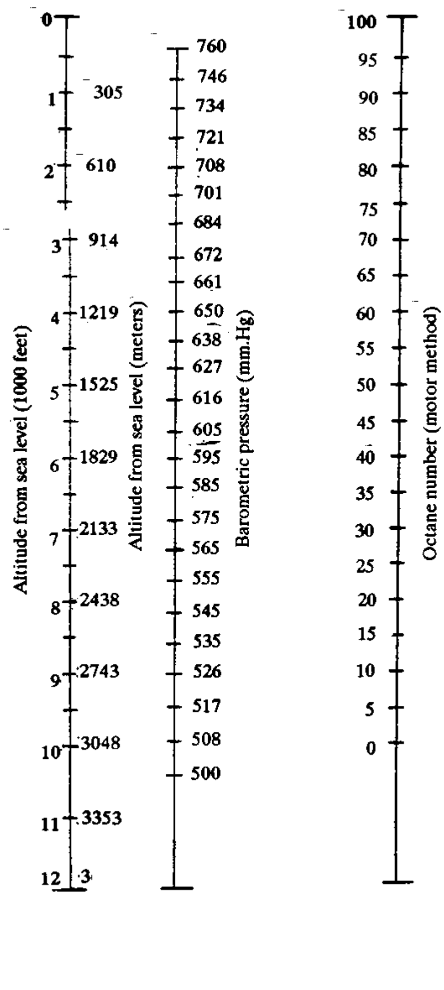

Figure 3. The octane requirement for normal spark ignition engines

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