Research on the Application of Eucalyptus Oil and Ethanol Blended Fuels to Spark Ignition Engine

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1. Purpose of the research

Some results of engine tests using the eucalyptus oil and it's blended fuel were reported previously[4]. For the eucalyptus oil mixed with gasoline the engine performance and fuel consumption were nearly equal to the case of 100% gasoline. One of the advantages of using eucalyptus oil and eucalyptus blended fuel was the reduction of carbon monoxide and hydrocarbon in emission.

This paper reports studies on the application of eucalyptus oil and ethanol blended fuel to a spark ignition engine. Experimental studies were made on the measurement of the excess air factor, engine performance, fuel consumption rate and analysis of emission. Table 1 shows the physical and chemical properties of the fuels used in the experiments.

Table 1. Physical and chemical Properties of fuels.

	Eucalyptus Oil	Ethanol	Gasoline
Molecular formula	$C_{10}H_8O$	C_2H_5OH	—
Molecular weight	154	46	—
Specific gravity (15/4°C)	0.918	0.796	0.731
Octane number (RON)	100.1～100.2	106	85
Flash point (°C)	54	14	Less than −40
Low calorific value (kcal/kg)	9500	6400	10500
Theoretical air-fuel ratio (kg/kg)	12.5	9.0	14.15
Calorific value of theoretical mixture (kcal/kg)	704	640	677

2. Theoretical air fuel ratio and lower calorific value of the blended fuels

The theoretical air fuel ratio to the 90 volume percent eucalyptus oil and 10 volume percent ethanol blended fuel were as follows.

$$C_lH_mO_n+\left(l+\frac{m}{4}-\frac{n}{2}\right)O_2+3.76\left(l+\frac{m}{4}-\frac{n}{2}\right)N_2$$
$$=lCO_2+\frac{m}{2}H_2O+3.76\left(l+\frac{m}{4}-\frac{n}{2}\right)N_2 \quad [5]$$

where l, m, n: number of atoms in the hydrocarbon and oxigen

$$0.912C_{10}H_{18}O+0.088C_2H_6O+13.033O_2+40.000N_2$$
$$=9.296CO_2+8.472H_2O+49.000N_2$$

$$Lo=\frac{32\left(1+\frac{m}{4}-\frac{n}{2}\right)+3.76*28\left(1+\frac{m}{4}-\frac{n}{2}\right)}{121+m+16n}=\frac{132.28}{121+m+16n}\left(1+\frac{m}{4}-\frac{n}{2}\right)\ (kg/kg)$$

Lo: theoretical air fuel ratio

$$\therefore\ R_{th}=Lo=12.38$$

Lower calorific value of the mixed fuels (Kcal/kg)

$$=\frac{\begin{pmatrix}\text{ethanol}\\ \text{volume percent}\end{pmatrix}\times\begin{pmatrix}\text{specific gravity}\\ \text{of ethanol}\end{pmatrix}\times\begin{pmatrix}\text{lower calorific}\\ \text{volume of ethanol}\end{pmatrix}+\begin{pmatrix}\text{eucalyptus}\\ \text{oil volume percent}\end{pmatrix}}{(\text{ethanol volume percent})*(\text{specific gravity of ethanol})}$$

$$\frac{\times\begin{pmatrix}\text{lower calorific value}\\ \text{of eucalyptus oil}\end{pmatrix}}{+(\text{eucalyptus oil volume percent})\times(\text{specific gravity of eucalyptus oil})}$$

Table 2 shows the lower calorific value, theoretical air-fuel ratio and the calorific value of theoretical mixture of the blended fuels.

Table 2. Low calorific value, theoretical air-fuel ratio and calorific value of theoretical mixture of blended fuels.

Fuel	Low calorific value (kcal/kg)	Theoretical air-fuel ratio (kg/kg)	Calorific value of theoretical mixture (kcal/kg)
Gasoline	10500	14.5	677
Ethanol	6400	9.0	640
Eucalyptus oil	9500	12.5	704
Eucalyptus oil 90% +Ethanol 10%	9228	12.4	689
Eucalyptus oil 80% +Ethanol 20%	8948	12.3	673
Eucalyptus oil 70% +Ethanol 30%	8660	12.1	661
Eucalyptus oil 60% +Ethanol 40%	8364	12.0	643
Eucalyptus oil 50% +Ethanol 50%	8060	11.8	630

3. Materials and methods

(a) Engine used: Sibaura Model TEA0660 Air cooled single cylinder gasoline engine popularly used for the small power tiller in Japan. Table 3 shows the specifications of the engine.

(b) Fuel used: Fuel blended were
eucalyptus oil (principal contents; 1.8 cineol)
ethanol (99.5%)
gasoline (85 Research Octane Number)

(c) Experimental apparatus: Figure 1 shows the diagram of the experimental apparatus to measure

Table 3. Tested engine.

TEA0660 (SHIBAURA)

Type	Gasoline engine of air-cooled and 2 stroke cycle type
Number of cylinder-bore* stroke	1–45*38 (mm)
Total displacement	60 (cc)
Continuous rated horsepower	1.8/1,660 (ps/rpm)
Maximum horsepower	2.8/2,000 (ps/rpm)
Maximum torque	1.08/1,330 (kg·m/rpm)
Compression ratio	6.5
Ignition plug	B-6HS (NGK)
Reduction gear ratio	1/3
Standard main jet nozzle diameter	0.650 (mm)
Lublication system	Mixed lublication (Mixture ratio 25: 1)

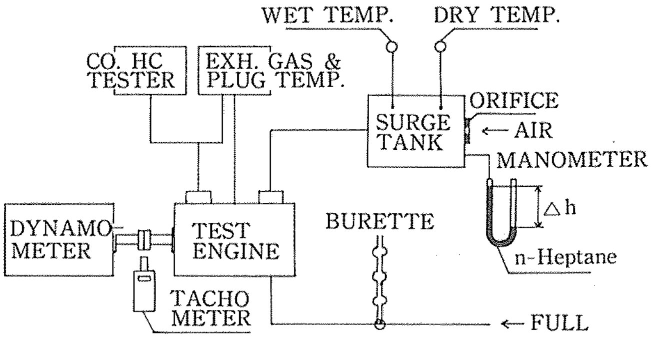

Fig. 1. Diagram of experimental apparatus.

Table 4. Fuel and main jet nozzle diameter.

Eucalyptus oil (%)	Ethanol (%)	Gasoline (%)	Main jet nozzle diameter (mm)
—	—	100	0.650, 0.675
100	—	—	0.700, 0.750, 0.800
90	10	—	0.700, 0.750, 0.800
80	20	—	0.700, 0.750, 0.800
70	30	—	0.700, 0.750, 0.800
60	40	—	0.700, 0.750, 0.800
50	50	—	0.700, 0.750, 0.800, 0.850

Mixed lublication (mixture ratio 40: 1)

the engine performance, fuel consumption rate and emission. The excess air factor was obtained by the following equation

$\lambda = R/Lo$

λ : excess air factor

$R = Ga/G_f$

Ga: weight of air, (kg/sec)

G_f : fuel consumption, (kg/sec)

(d) Combinations of the kind of fuels used and the diameter of carburetter main jet nozzle are showen in Table 4.

(e) Measurement of air quantity in suction system.
Figure 2 shows the measuring apparatus for air quantity.

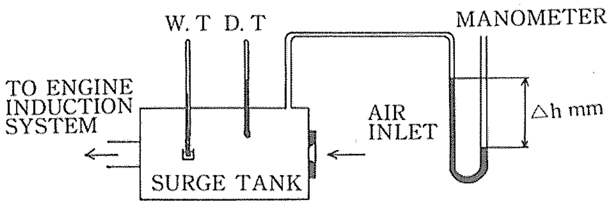

Fig. 2. Inflow of air measuring appratus.

$Ga = \alpha \cdot \varepsilon \cdot A\sqrt{2g\,\gamma\,(P_1 - P_2)}$ (kgf/sec)

Ga : weight of air to intake (kgf/sec)

α : : coeficient of velocity

ε : air expantion factor

$\varepsilon = 1 - 0.54 \frac{p_1 - p_2}{p_1}$

A : sectional area of orifice

γ : specific gravity of air $= \frac{p_2}{RaT}$ (kgf/m³)

Ra : gas constant of air (Ra = 29.27 [kgfm/kgf⁰k])

T : absolute temperature of air (⁰k)

P_1 : absolute atmospheric pressure in front of orifice (kgf/m²)

P_2 : absolute pressure in the tank behind the orifice (kgf/m²)

$P_1 - P_2$: pressure difference between P_1 and P_2

$P_1 - P_2$ = (specific grauity of n-pentane) × (reading of manometer)

Ra : gas constant of air (Ra = 29.27)

T : absolute temperature of air (⁰K)

4. Experimental results and discussion

Figure 3, 4 and 5 show the engine performance, torque and fuel consumption rate in case of using the three kinds of fuels.

For the different sizes of the main jet nozzle, almost the same engine performance as the normal 100% gasoline was obtained.

The fuel consumption was increased for the case of using 0.8 mm main jet nozzle.

Figure 6 shows the engine performance for the various blended fuels.

Similar engine performance was obtained using various blending ratio of alcohol and eucalyptus oil.

Fuel consumption was increased for the case of ethanol blended fuels.

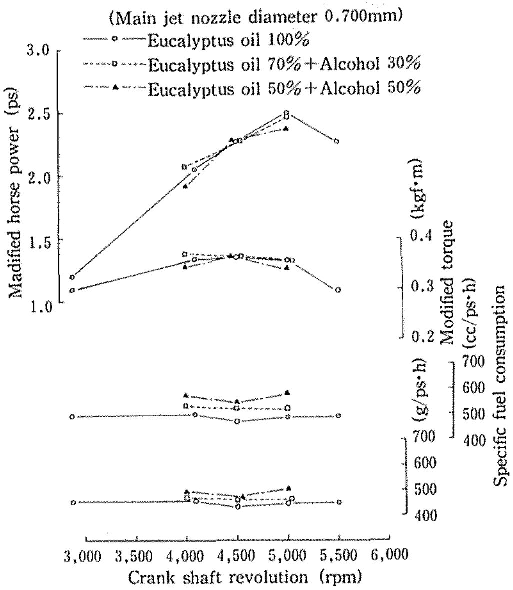

Fig. 3. Engine performance with various blended fuels.

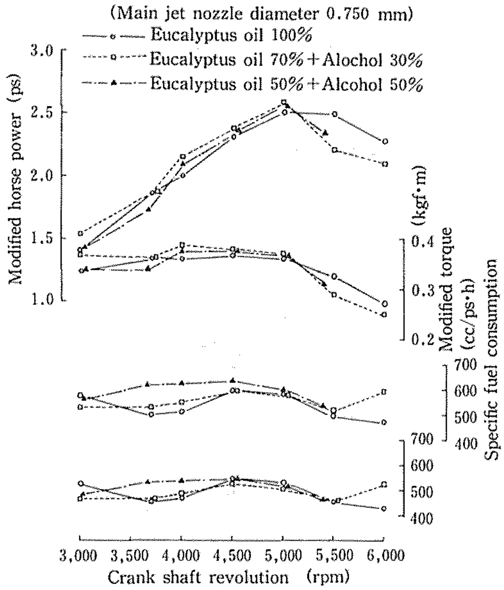

Fig. 4. Engine performance with various blended fuels.

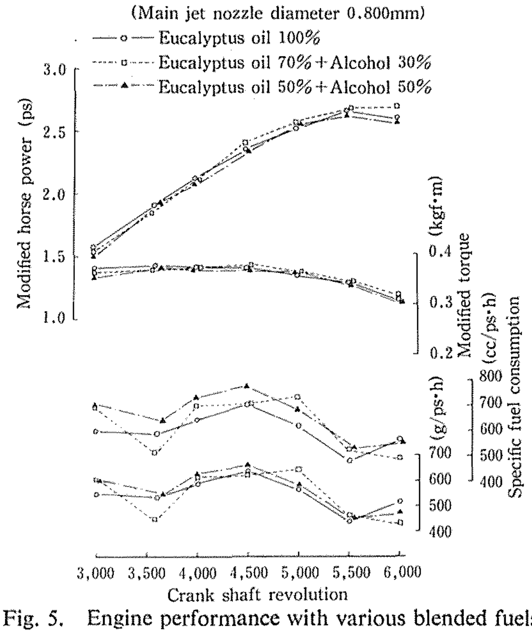

Fig. 5. Engine performance with various blended fuels.

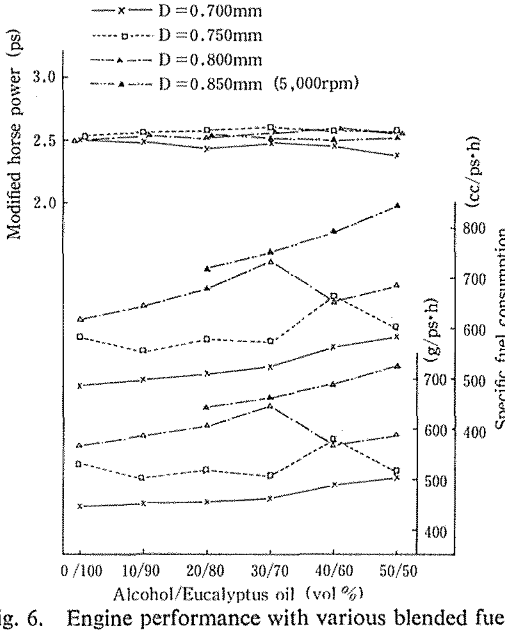

Fig. 6. Engine performance with various blended fuels.

This was due to less calorific value of the ethanol than the eucalyptus oil.

Figure 7 shows the effects of excess air factor upon the engine performance, fuel consumption rate. The engine performance showed almost the same tendency for the case of the six kinds of fuel. The fuel consumption rate was minimum at the excess air factor of 1.0.

Figure 8 shows the analysis of emission. The carbon monoxide in emission was minimum for the the blended fuel of 50% eucalyptus oil and 50% ethanol.

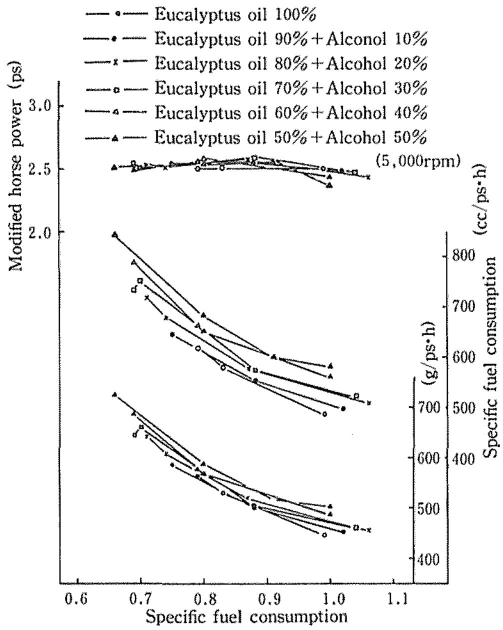

Fig. 7. Engine performance with various blended fuels.

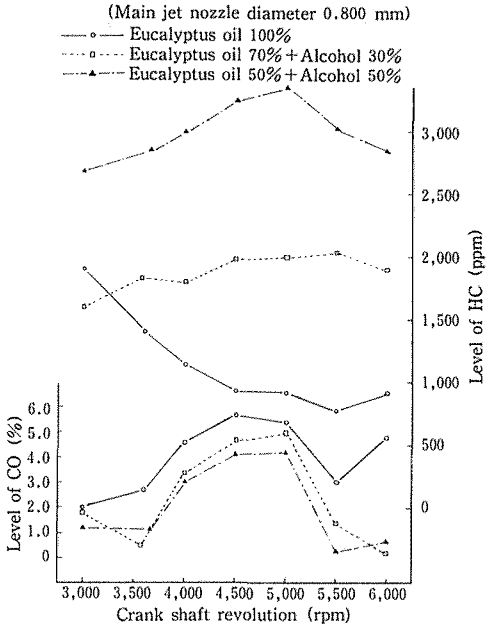

Fig. 8. Analysis of exhaust gas.

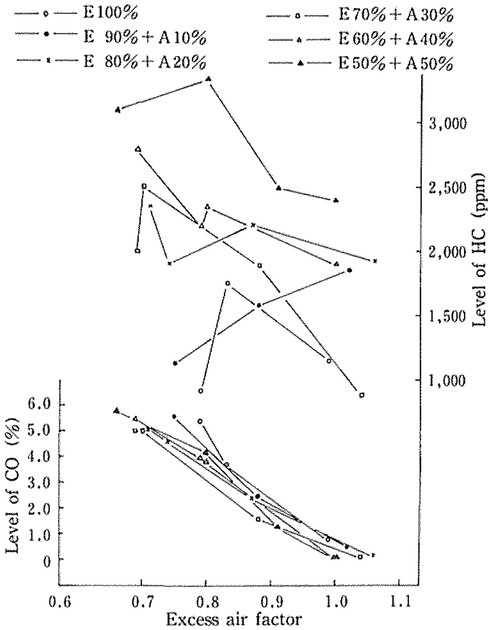

Fig. 9. Analysis of exhaust gas.

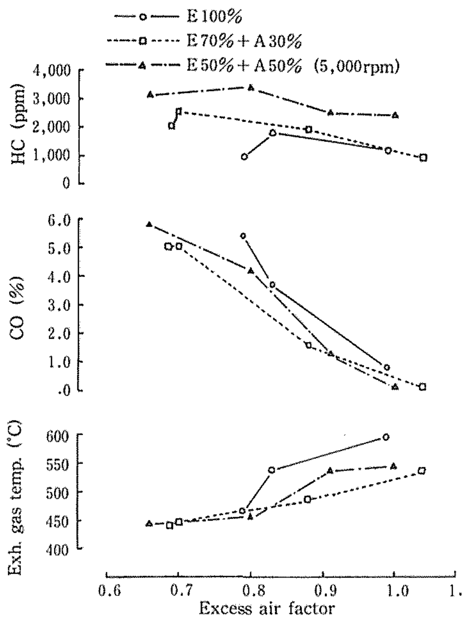

Fig. 10. Analysis of exhaust gas.

Figure 9 shows the analysis of emission using six kinds of fuels. The carbon monoxide in emission was reduced with the increase of excess air factor. At the excess air factor of 1.0, the carbon monoxide showed the minimum value.

Figure 10 shows the analysis of emission for the case of using three kinds of fuels. At the exess air factor of 1.0 the hydrocarbon and carbon monoxide showed the minimum value.

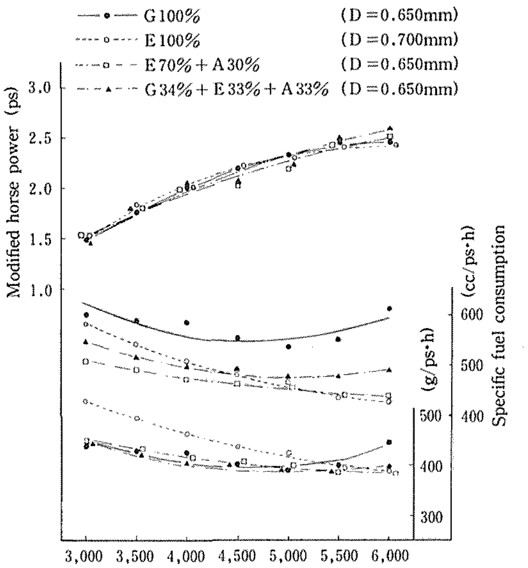

Fig. 11. Engine performance with various blended fuels.

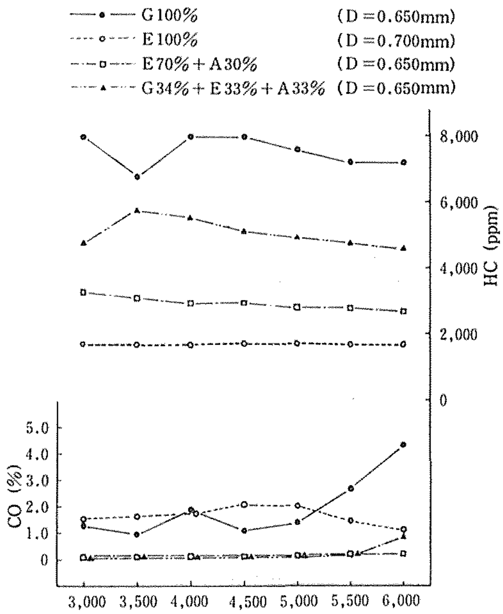

Fig. 12. Analysis of exhaust gas.

Figure 11 shows the engine performance for the various blended fuels.

In the case of using the four kinds of fuels, the engine performance obtained was almost the same. The fuel consumption rate was nearly equal to the gasoline.

Figure 12 shows the analysis of emission in case of using four kinds of fuels. The phenomenon found in this analysis is interesting. When the fuel of 70% eucalyptus oil and 30% ethanol was used the hydrocarbon in emission was greatly reduced as compared to gasoline.

The carbon monoxide in emission was reduced drasticly in the case of using the gasoline, encalyptus oil and ethanol blended fuels.

5. Conclusions

a. Eucalyptus oil and ethanol blended fuel can be used to operate the spark ignition engine.

b. Since the calorific value of ethanol was less than eucalyptus oil the fuel consumption was high in case of alcohol blended with eucalyptus oil.

c. For the case of using eucalyptus oil and ethanol blended fuels the maximum engine output was obtained with the excess air factor of 0.8～0.9.

d. The emission of eucalyptus oil and ethanol blended fuel was quite clean as compared with gasoline.

e. The engine output performance for the blended fuels (eucalyptus oil, ethanol and gasoline) was quite simillar to the gasoline.

The emission was clean too.

Above results indcate that eucalyptus oil and ethanol blended fuel will be one of the hopeful alternatives in the future.

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References

1) FUJIO NAGAO; Internal combustion engine, Sankaido, 1967, p. 90–91 (in Japanese)
2) A. B. Greene and G. G. Lucas; The Testing of Internal Combustion Engine, The English Universities Press Ltd. 1969.
3) SAKUZO Takeda and others; Farm Power and Machinery, Asakura-shoten.
4) Sakuzo TAKEDA and others; Studies of Eucalyptus Oil and Its Application to Spark Ignition Engine (III), The Bulletin of Faculty of Agricutre, Mie University, No. 62 pp. 163–169, March, 1981.
5) H. Hiroyasu, Internal Combustion Engine, Nisshin Shuppan. 1979. pp. 34～35 (in Japanese)

摘　　要

ユーカリ油・エタノール混合燃料の火花点火機関への利用に関する研究

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ユーカリ油，ガソリン混合燃料を火花点火機関へ使用したとき，機関出力，燃費率は，ガソリンに比らべ殆んど同等であるのみならず，排気中の CO, HC は，ユーカリ油混入に比例して減少することがわかった。今回の研究は，ユーカリ油，エタノール混合燃料による実験で，とくに空気過剰率を測定，これと機関出力，燃費率，排ガス分析などの関係を，各種燃料毎に明らかにした。空気過剰率の測定には次式を用いた。

$\lambda = R/Lo$

R: 実測空燃比

Lo: 理論空燃比

今回の実験で，注目される現象は，排気中の未燃焼炭化水素 (HC ppm) は，ガソリンに比較し，ユーカリ油，エタノール混合燃料の場合は非常に少なかった。また排気中の CO 成分は，ガソリンに比較し，混合燃料 (E 70%＋A 30%, および G 34%＋E 33%＋A 33%) では極端に減少した。以上により

(1) ユーカリ油，エタノール混合燃料は火花点火機関燃料として適当である。

(2) エタノールはユーカリ油より発熱量が少なく，エタノール混合の増加とともに燃費率は増加する。

(3) 上記エタノール・ユーカリ油混合の場合，空気過剰率0.8～0.9で混合燃料による機関出力は最高となる。