Studies on the Citrus Oil utilization for Spark Ignition Engine Fuel (I)

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Preface

Citrus oil (Orange oil) has higher octane number enough to run the spark ignition engine. This paper presents the results of engine performance test and the specific fuel consumption of it in case of using various blend ratio of citrus oil into regular gasoline.

Citrus oil can be extracted generally from the peel of citrus, as a by-product through the process of In-line extracting at orange juice manufacturer.

There are sixteen in-line systems working in Japan, and about 600,000 tons of Orange (Tangerine) were processed in 1980.

The recovery of Citrus oil is about 0.2–0.5% of total weight of citrus. The main ingredient of Citrus oil (Orange oil) is d-limonen ($C_{10}H_{16}$) of which chemical structure is shown as follows.

Tab. 1. Constituent of Citrus oil.

Constituent	Unshu orange	Summer orange
d-limonen	87.06	84.51
γ-terpinene	5.01	7.31
myrcene	2.31	2.78
α-pinene	1.21	0.93

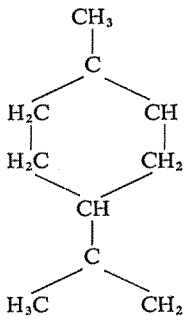

Fig. 1. Chemical structure of d-limonen.

1. Properties of Citrus oil and distillation curves of fuels with various blend ratio

Table 2 shows the physical properties of the orange oil tested. In general, citrus oil has a quite high octane mumber enough to run the CFR engine.

Tab. 2 Properties of Citrus oil

Item \ Sample No.	Citrus oil No. 1	Citrus oil No. 2	Citrus oil No. 3	Citrus oil No. 4
Specific gravity 15/4°C	0.8467	0.8450	0.854	0.845
Flash point by P. M. Method	56°C	54	56	56
Calorific volue Cal/kg	—	10814	—	—
Viscosity 30°C/cst	0.99	0.95 (25°C/cst)	1.05	0.939
Octane Value (R. O. N.)	137.7	140	106	135

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Tab. 3. Kind of fuels used.

FUEL	Gasoline	Unshu orange	Summer orange	Ethanol
G 100*	100	0	0	0
G 90,O10*	90	10	0	0
G 70,030	70	30	0	0
G 50,050	50	50	0	0
G 30,070	30	70	0	0
G 10,090	10	90	0	0
O 100	0	0	50	0
G 50,O(s)50*	50	0	50	0
O(s)100	0	0	100	0
G 34, O 33, Et 33	34	33	0	33
G 34, O(s)33, Et 33	34	0	33	33

* G: Gasoline O: Unshu orange O(s): Summer orange (%)

The flash point of the citrus oil measured by the Pensky Martens method was in the range of 54–56°C.

Some difficulty was found in engine startability, especialy under the low temperature condition. Fig. 2–1 shows the distillation curves of the Citrus oil (Unshu orange, Summer orange), gasoline and ethanol. Both citrus oil, Unshu orange and Summer orange show the similar tendency.

Fig. 2–2 shows the distillation curves of citrus oil blended with gasoline. The distillation characteristics of 10% citrus oil blended with gasoline showed almost the same value nearly equal to the regular gasoline.

The blended fuel of 10% orange oil into regular gasoline can be expected to have good startability,

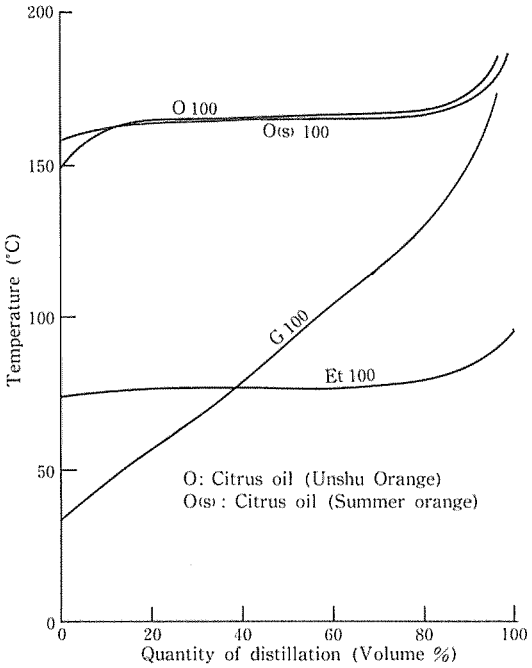

Fig. 2–1. Distillation curve.

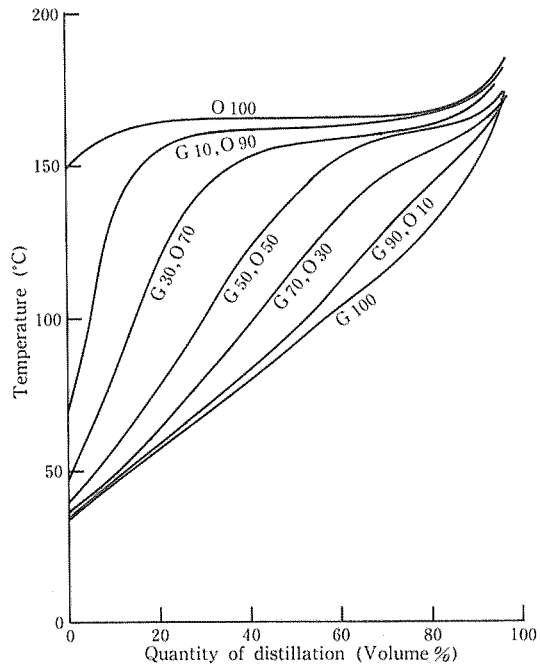

Fig. 2–2. Distillation curve.

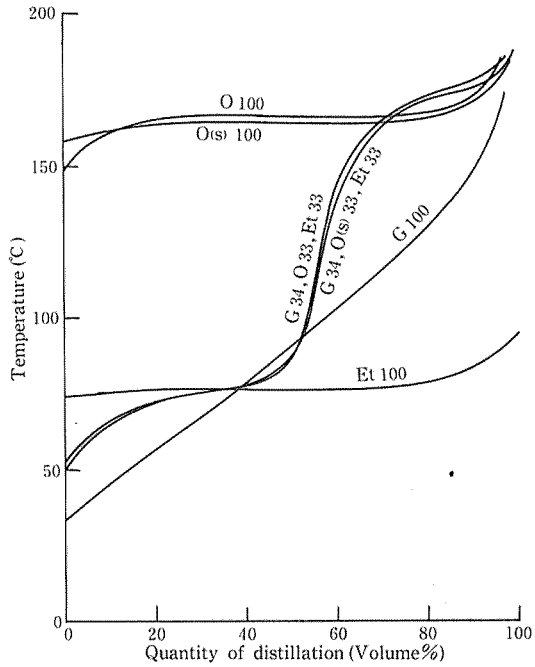

Fig. 2-3. Distillation curve.

Tab. 4-1. Property of various fuels.

Fuel	GASOLINE	ORANGE OIL	SUMMER ORANGE OIL	ETHANOL
Molecular formula	—	$C_{10}H_{16}$	$C_{10}H_{16}$	C_2H_5OH
Molecular weight	—	136	136	46
Specific gravity (15/4°C)	0.74	0.85	0.85	0.79
Octane number (RON)	80~90	106	135	110
Flash point (°C)	−40	56	56	13
Low calorific value (kcal/kg)	10500	10560	10560	6500
Theoretical air-fuel ratio (kg/kg)	14.9	14.1	14.1	9.0
Calorific value of theoretical mixture (kcal/kg)	660	699	699	650

Tab. 4-2. Property of blended fuels.

	Specific gravity (15/4°C)	Low calorific value (kcal/kg)	Theoretical air-fuel ratio (kg/kg)	Calorific value of theoretical mixture (kcal/kg)
G 90,010	0.75	10510	14.8	665
G 70,030	0.78	10520	14.6	674
G 50,050	0.80	10530	14.4	684
G 30,070	0.82	10540	14.3	689
G 10,090	0.84	10550	14.2	694
G 50,O(s)50	0.80	10530	14.4	684
G 34, O 33, Et 33	0.80	9200	13.5	634
G 34, O(s)33, Et 33	0.80	9200	13.5	634

Tab. 4-3. Distillation characteristics of blend fuels.

	G 100	G 90 O 10	G 70 O 30	G 50 O 50	G 30 O 70	G 10 O 90	O 100	G 50 Os 50	Os 100	G 34 O 33 Et 33	G 34 Os 33 Et 33
Startability	○	○	○	△	×	×	×	△	×	△	△
Unti vapor lock	○	○	○	○	◎	◎	◎	○	◎	○	○
Warming up	○	○	○	×	×	×	×	×	×	△	△
Unti icing	○	○	○	◎	◎	◎	◎	◎	◎	○	○
Acceleration	○	○	○	×	×	×	×	×	×	△	△
Burnability	○	○	○	△	△	△	△	△	△	×	×
Unti fuel dilution	○	○	○	△	△	△	△	△	△	×	×

◎ best △ good Where O: Citrus oil (Unshu Orange)
○ better × unsuitable Os: Citrus oil (Summer Orange)

better acceleration and less vapor lock tendency, which are desirable for the spark ignition engine. Fig. 2-3 shows the distillation curves of the citrus oil, gasoline and ethanol blend fuels.

The kinetic viscosity shows 0.6 cst in gasoline, and 0.94-1.06 cst in the case of the citrus oil. For that reason, it might be difficult to use the citrus oil only as fuel.

When using the blended fuel of citrus oil with gasoline, the better effect can be expected. Table. 4-1 shows the property of various fuels, and Table. 4-2 shows the property of blended fuels respectively.

It can be therefore concluded from Table. 4-3 that the engine startability, until vapor lock resistance and other characteristics of using ten kinds of fuels.

2. Two cycle engine performance test

Table. 5 shows the specification of engine model TEA-0660. This type of engine is normally used for the garden tractor and the rice transplanter in Japan.

Figure. 3 illustrates the diagram of experimental apparatus.

The test were done on the engine performance, fuel consumption rate, air fuel ratio, and analysis of exhaust gas. Figure. 4-1, Figure. 4-2 shows the relationship between the excess air factor and the engine performance, fuel consumption rate and CO, HC density in emission gas at 5000 rpm engine speed.

Tab. 5. Tested engine.

TEA-0660 (SHIBAURA)

Type	Gasoline engine of air-cooled & 2 stroke cycle type
Number of cylinder−bore×stroke	1−45×38
Total displacement	60 (cc)
Continuous rated horsepower	1.8/1660 (ps/r. p. m.)
Maximum horsepower	2.8/2000 (ps/r. p. m.)
Maximum torque	1.08/1330 (kg•m/r. p. m.)
Compression ratio	6.5
Ignition plug	B-6HS (NGK)
Reduction gear ratio	1/3
Standard main jet nozzle diameter	0.650 (mm)
Lubricating system	Mixed lubrication (Mixture ratio 30: 1)

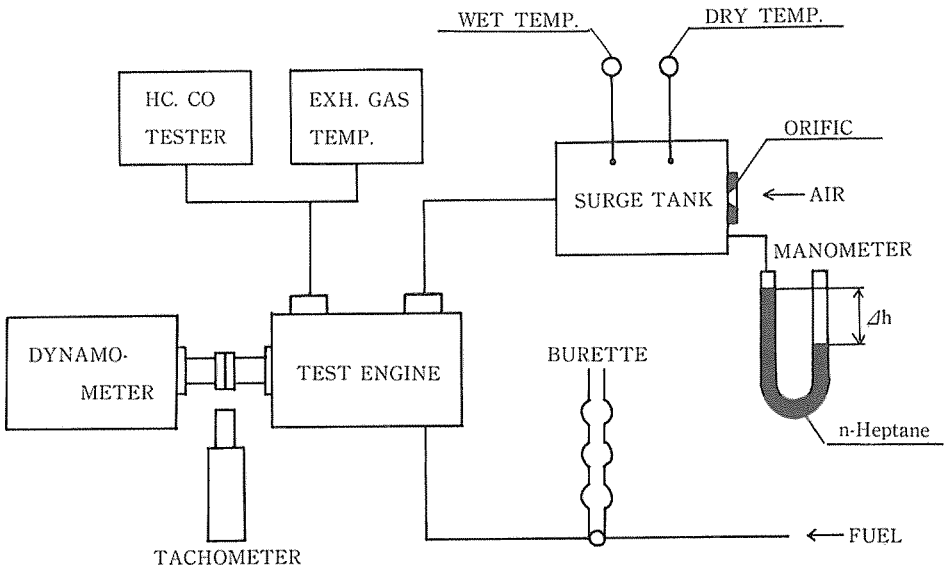

Fig. 3. DIAGRAM OF EXPERIMENTAL APPARATUS.

Citrus oil and blended fuel of it could show the better performance than regular gasoline only, because the carolific value of citrus oil is 60 kcal/kg higher than gasoline. The engine performance showed maximum value at 0.9~1.0 of the excess air factor.

The blended fuels of which the ratio of 30% of citrus oil and 70% of gasoline can be expected to

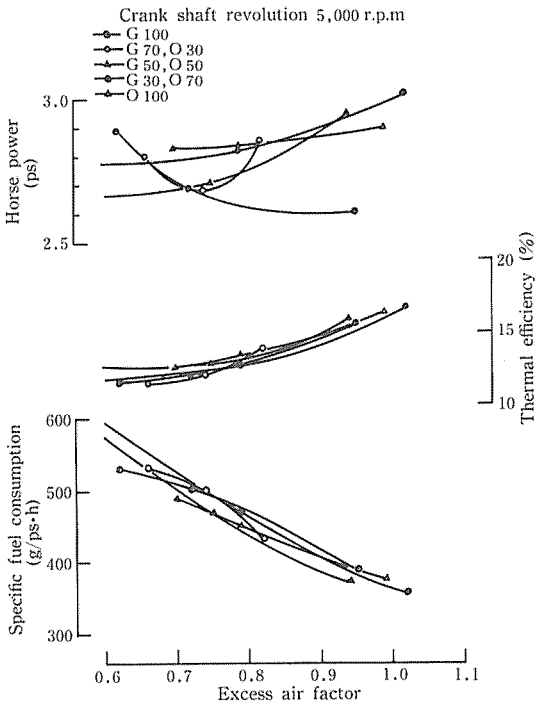

Fig. 4-1. Engine performance test.

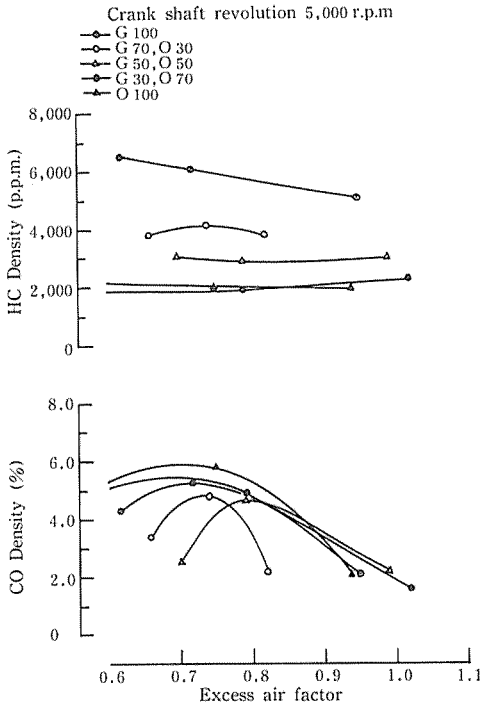

Fig. 4-2. Analysis of exhaust gas.

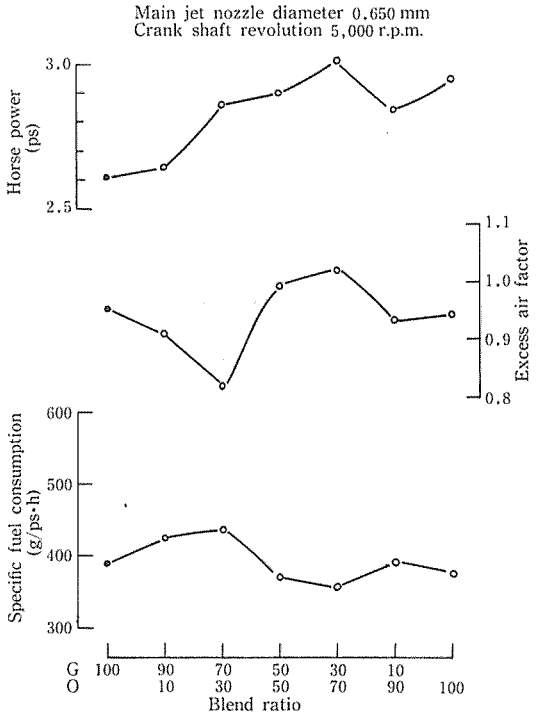

Fig. 4-3. Engine performance test.

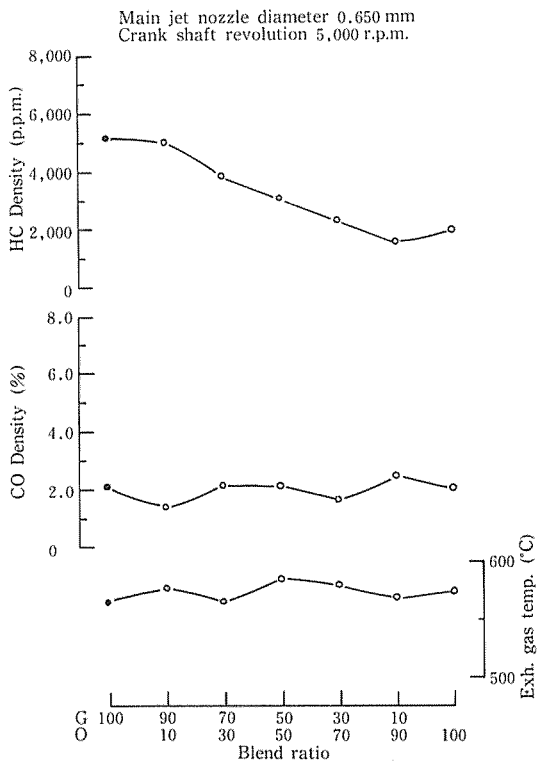

Fig. 4-4. Analysis of exhaust gas.

show the better operation. Fuel consumption rate showed almost the same tendency in case of using various blended fuels.

HC density in emission gas was decreased 30% in case of using the citrus oil fuel, but CO content involved in the exhaust gas was increased when using the citrus oil.

Figure. 4-3 and Figure. 4-4 show the relationship between the engine performance variation due to the blend ratio at 5000 rpm. The blend ratio 30% of citrus oil and 70% of gasoline showed the maximum performance, fuel consumption rate and HC density in exhaust gas showed satisfactory result respectively.

3. Discussion and conclusion

Citrus oil fuel showed the better performance than the case of using the gasoline only, due to the higher carolific value of it. The fuel consumption rate showed almost the same tendency for the fuels with various blend ratio.

HC and CO density in exhaust gas was decreased, for the case of using citrus oil. The suitable blend ratio, 30% of citrus oil and 70% of gasoline can be recommended, for the better operation of the spark ignition engine.

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梗　　概

かんきつ油の火花点火機関用燃料としての研究（第1報）

竹　田　策　三・服　部　　弘

かんきつ類果皮の黄色表層部（フラベド）には油胞が存在し，それに精油が内蔵されている。その含有量は，温州みかんで果皮に対し0.6～1.2%，夏みかんでは1.3～2.4%，バレンシアオレンジで0.6～1.7%程度である[5]。

これらのかんきつ油は，インライン搾汁システムを装備する大型ジュース工場における，ジュース濃縮工程および果皮よりモラセスを製造する工程で分離回収される。

かんきつ油の主成分はd-リモネン（$C_{10}H_{16}$）で，CFR 機関による測定の結果リサーチオクタン価106～140と極めて高く火花点火機関に適している。

本研究は，かんきつ油の内燃機関燃料としての有効性を確める目的で，かんきつ油100%および，かんきつ油とガソリンを任意の割合に混合し，農用2サイクル火花点火機関を供試機関とし，電気動力計により機関出力を測定した。また燃費率，排気分析を行なった。その結果，ガソリンにかんきつ油を混合したとき，同一条件において，かんきつ油およびかんきつ油混合燃料は機関出力が増加した。その理由は，かんきつ油はガソリンより容量あたり発熱量が大きいことによる。燃費率は，空燃費0.9前後で，かんきつ油，ガソリンの間に差はなかった。排ガス濃度は，HC, COともガソリンの場合より低下し，かんきつ油混入割合の増加に伴ない，その傾向は顕著となった。

かんきつ油の粘度は0.9～1.0 cstである。これはガソリンの粘度より高いが，気化器メインゼットの口径は，ガソリン仕様でその性能が発揮できた。以上のように，かんきつ油は，火花点火機関燃料として実用化できる。