COMPARATIVE PERFORMANCE TEST OF A "DUCATI IS-11" DIESEL ENGINE USING CRUDE COCONUT OIL

by

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A comparative test of the "Ducati-IS-11" single cylinder diesel engine showed no significant change in its performance when using either crude coconut oil or diesel fuel. In 18 runs using coconut oil, the average brake thermal efficiency was 23.7 percent at an average power output of 5.6 Bhp, compared with an average thermal efficiency of 23.4 percent in another 18 runs using diesel fuel at the same power output.

Introduction

Crude coconut oil (unrefined) has a potential as a better fuel for diesel engines than diesel oil. It is at present about twice as expensive as diesel fuel based on urban prices. However, in remote villages where transportation costs add greatly to the price of diesel fuel, and where coconut oil can be milled in place, the cost of coconut oil could in fact be less than diesel oil. Add to this the argument that coconut oil is a renewable source of energy, whereas petroleum is a depletable commodity whose price, from all indications, can only go up, then one has sufficient justification to pursue research in the direction of the development of this indigenous source.

One of the early studies (1976) on the use of crude coconut oil as fuel in a laboratory ASTM-CFR test engine showed that the performance of the engine when using coconut oil compared well with the engine performance when using diesel fuel.[2] In 75 experimental runs using coconut oil, the over-all average indicated thermal efficiency was 33 percent at an average indicated horsepower output of 6.8. This is compared with an over-all average indicated thermal efficiency of 32 percent at the same indicated horsepower output in another 75 experimental runs using diesel fuel.

Experimental Procedures

The "Ducatis IS-11" was a vertical, single-cylinder, 4-stroke cycle diesel engine with a rated engine speed of 3000 RPM. The engine horsepower rating was not stated in the engine manual although the number 11 in the code "Ducatis IS-11" could mean a rating of 11 brake horsepower (Bhp). Subsequent results showed that the normal load attained at 3000 RPM was about 7 Bhp.

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[2]"Comparative Performance of a CFR Diesel Engine When Using (1) Crude Natural (Coconut) Oil and (2) Ordinary Diesel Fuel" – by I.E. Cruz, U.P. Industrial Research Center Report to the Philippine Coconut Authority (PCA), May 1976.

Since the engine was new, it was run without load for at least 50 hours in order to break it in.

Loading of the engine was accomplished by means of a water-cooled prony brake attached to the power take-off shaft. The power take-off shaft rotated at half the speed of the engine crank shaft. The torque on the take-off shaft was therefore twice the torque on the engine crank shaft.

A 6-inch brake-drum with a deep rim to accommodate cooling water was fabricated and attached to the power take-off shaft. The brakes, made of wood cleats attached to a steel frame with a 12-inch lever arm, could be tightened or loosened against the drum to vary the load torque applied on the power take-off shaft. The resisting force on the brake lever arm was measured by means of a "Detecto" platform balance with a minimum scale reading of 0.2 pound.

Since the lever arm was 12 inches, the scale reading in pounds minus the tare weight gave directly the load torque in foot-pounds. The tare weight was the average of two scale readings when the engine was manually rotated slowly in one direction to obtain a scale reading, and then in the opposite direction to get another scale reading. Since the brakes were loosely riding on the brake drum when these readings were being taken, the tare weight approximated the weight of the vertical wooden post which rested on the platform balance and supported one end of the prony brake lever arm. The average of several tare weight measurements was 4.7 pounds.

Aside from measuring the power output, the exhaust gas temperatures and gas analysis for 30 out of the 41 runs were determined. Each run lasted for 30 minutes. Fuel consumption was measured by placing the fuel supply tank on a weighing scale. The higher value of the diesel oil and two batches of crude coconut oil from two different suppliers were determined by means of the Paar oxygen bomb calorimeter. Thus, the brake specific fuel consumption and the brake thermal efficiency for each run could be calculated.

Discussion of Results

Table 1 gives a summary of the experimental results. There were 20 runs in which crude coconut oil was used and 21 runs in which diesel oil was used in the engine at varying loads and speeds. The engine operating conditions were maintained practically the same when comparing the performance of crude coconut oil with that of diesel. Thus the average load when using crude coconut oil was 5.57 Bhp at 2803 RPM compared with 5.62 Bhp at 2920 for diesel oil.[1] The corresponding average brake thermal efficiency was 23.7 percent for crude coconut oil as against 23.4 percent for diesel oil. The average exhaust temperature was 980°F for crude coconut oil and 975°F for diesel oil. Paired statistical t-tests showed no significant differences in the averages of the performance parameters. The brake specific fuel consumption for crude coconut oil was higher due to its lower calorific value, however.

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[1] Runs 15 and 22 which did not have the same operating conditions, and Run 25 which did not have a matching run for coconut oil, were not included in the averaging.

Figures 1 and 2 compare brake thermal efficiencies and brake specific fuel consumption against engine load when using either fuel.

As observed from Table 1, the maximum load attained by the engine was 8.4 Bhp in Run 22 when the fuel filter was removed. Compared with Run 21 which immediately preceded Run 22, the engine output was 6.9 Bhp with the filter installed, indicating that the filter was introducing some resistance to fuel flow at full load. In the absence of a new filter element, the used filter was cleaned thoroughly and reinstalled in the succeeding runs. The maximum power attained subsequently was 7.2 Bhp in Run 37.

It was speculated above that in the engine code "Ducati IS-11", the number 11 could refer to the horsepower output. The reason for this is the high excess oxygen in the exhaust gas even as the maximum load reached (6.5% O_2 at 8.4 Bhp in Run 22). This means that there was still excess air available in the engine cylinder to burn additional fuel if it could be delivered to it, thereby increasing power output.

It has been observed that during cold days, solid particles formed in coconut oil which caused the fuel filter to become clogged, resulting in less fuel reaching the injector pump and consequently a reduction in maximum power output that the engine could deliver. Coconut oil would start to solidify in the temperature range of 68 to 78 degrees Fahrenheit and since many of the experiments were performed in late November when such temperatures prevail, fuel starvation of the engine could have been caused by such clogging of the filter. Later experiments showed that blending 20 percent by weight of diesel oil with coconut oil (80 per cent by weight) eliminated the problem of oil solidification during the coldest days of the year.

It has been observed also that starting the engine during cold days was a little difficult, and it was sometimes necessary to prime the engine with a little gasoline thru the air intake manifold in order to start it. Once the engine became hot, however, there was no further problem in stopping and re-starting it.

Conclusion and Recommendations

1. There was no significant change in the brake thermal efficiency of the engine (about 23 per cent) when using either crude coconut oil or diesel fuel.

2. Because of the higher viscosity of coconut oil, its passage thru the fuel filter was met with greater resistance and starvation of fuel by the engine resulted when the fuel filter became slightly dirty.

3. It is recommended that coconut oil used fuel be kept completely free from solid dirt or suspended particles by pre-filtering it before pouring into the fuel tank.

4. Fuel filters in the engine likewise should be regularly cleaned to prevent fuel starvation by the engine.

5. Diesel fuel oil (about 20 per cent by weight) blended with coconut oil (80 per cent by weight) prevented solidification of the oil during the coldest days of the year and thus solved filter clogging by solidified fuel particles.

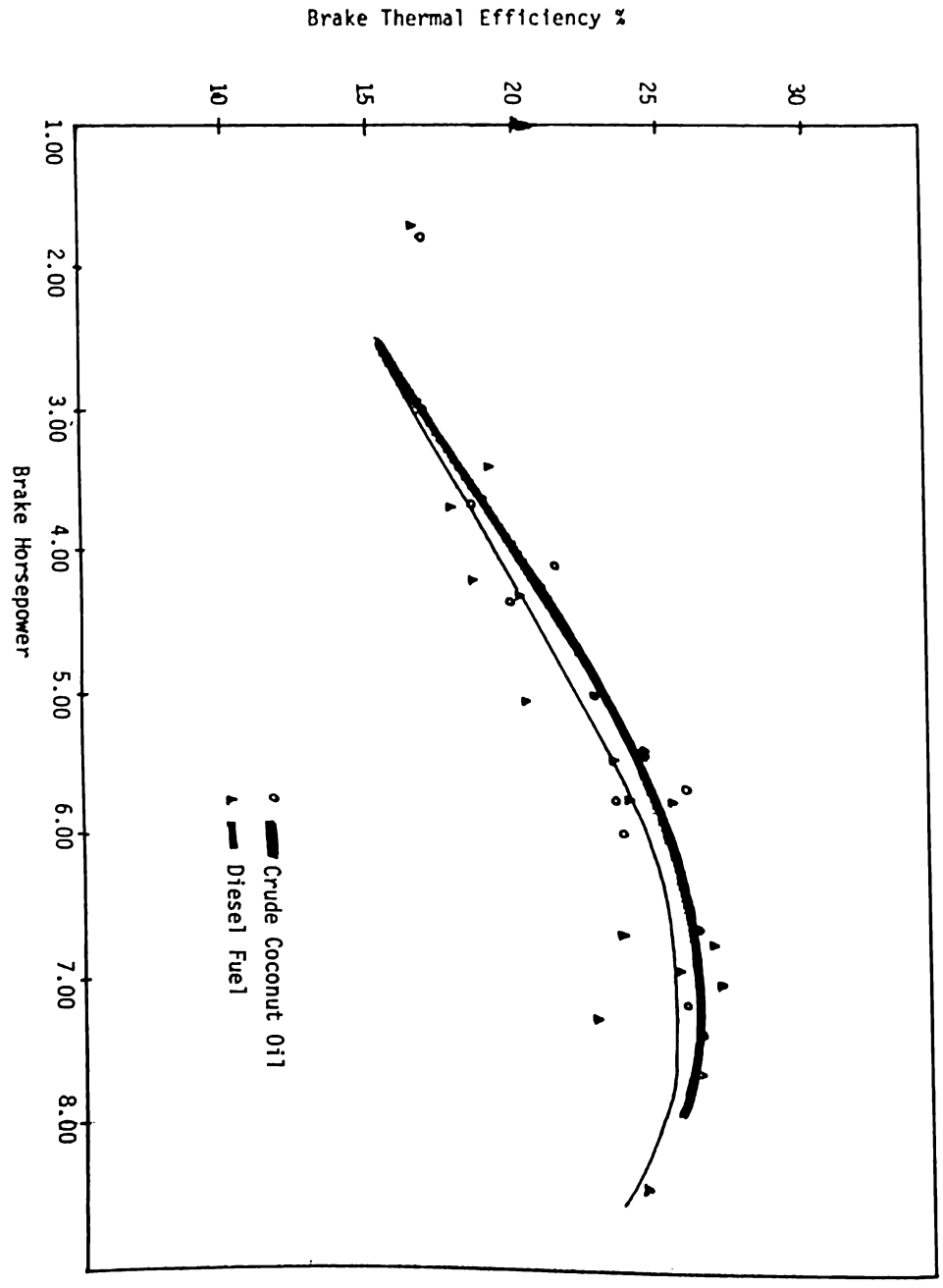

Fig. 1 Comparison of Brake Thermal Efficiency Variation With Engine Load

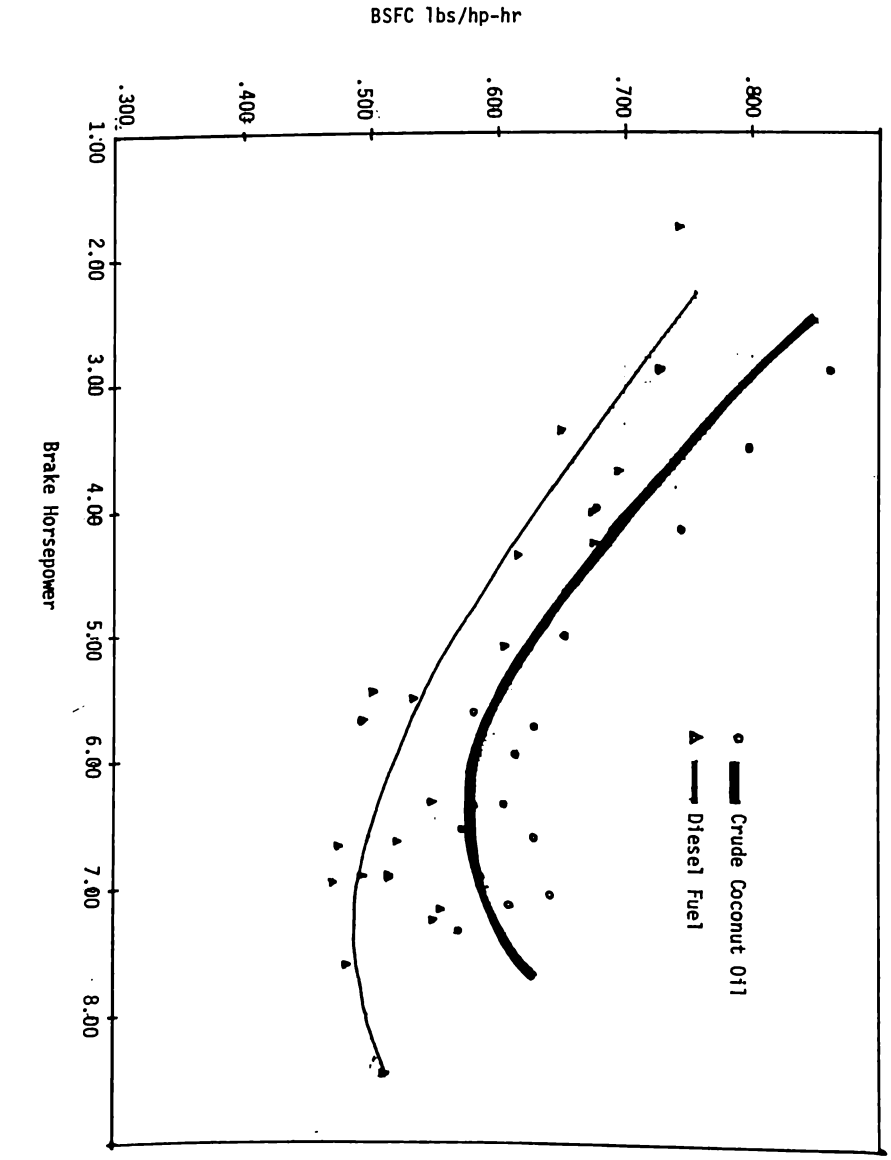

Fig. 2 Comparison of the Variation of Brake Specific Fuel Consumption with Engine Load

Table 1

Summary of results, comparative performance test of Ducati IS-11 diesel engine when using diesel fuel versus crude coconut oil

1. Run No.	1	2	3	4	5	6	7	8	9	10	11	12
2. Fuel	Diesel	Diesel	Diesel	Coco Oil A	Coco Oil A	Coco Oil A	Diesel	Coco Oil B	Coco Oil B	Diesel	Diesel	Diesel
3. Higher HV Btu/lb	19,523	19,523	19,523	16,775	16,775	16,775	19,523	16,342	16,342	19,523	19,523	19,523
4. Running Time, Min.	30.083	30.067	30.067	30.07	30.050	30.047	30.011	30.106	30.167	30.017	30.189	30.083
5. Engine RPM	2245	2904	2850	2229	2814	3060	2796	2774	2730	2770	2818	2754
6. Engine Torque, ft-lb. x 2	8.11	15.20	20.3	8.4	15.4	20.5	21.3	21.3	25.3	25.3	20.3	25.3
7. BHP Output	1.73	4.20	5.51	1.78	4.13	5.97	5.67	5.63	6.58	6.67	5.45	6.63
8. BSFC, lb/Bhp-h	0.741	0.673	0.539	0.848	0.675	0.616	0.494	0.582	0.577	0.470	0.510	0.531
9. Brake Thermal Efficiency, eb, %	17.6	19.4	24.2	17.9	22.5	24.6	26.4	26.8	27.0	27.7	25.5	24.5
10. Exhaust Temp., °F											864	1013
11. Exhaust Gas Anal.												
$\%CO_2$											9.8	9.8
$\%O_2$											10.0	9.0
%CO											0.2	0.4
$\%H_2$											0.4	0.4

12. Notes: Runs 1-6 were performed on Oct. 29, 1977. Fuel filter problem (clogging) occurred after Run 6, Runs 7-10 were done on Nov. 5, 1977, and Runs 11-18 on Nov. 12, 1977.

TABLE 1. (Continued)

1. Run No.	13	14	15	16	17	18	19	20	21	22	23	24
2. Fuel	Coco Oil B	Coco Oil B	Coco Oil B	Coco Oil B	Coco Oil B	Diesel	Diesel	Diesel	Diesel	Diesel	Coco Oil A	Coco Oil A
3. Higher HV Btu/lb	16,342	16,342	16,342	16,342	16,342	19,523	19,523	19,523	19,523	19,523	16,775	16,775
4. Running Time, Min.	30.083	30.037	30.006	30.167	30.067	15.133	30.250	30.017	30.067	30.061	30.183	30.017
5. Engine RPM	2789	2943	3058	2200	2503	2538	2910	2878	2377	2960	2977	2705
6. Engine Torque, ft-lb, x 2	20.3	25.3	25.3	30.3	30.0	30.0	25.2	27.8	30.4	29.9	24.6	27.8
7. BHP Output	5.39	7.09	7.37	6.35	7.15	7.25	6.98	7.62	6.88	8.43	6.97	7.16
8. BSFC, lb/Bhp-h	0.615	0.641	0.574	0.581	0.590	0.549	0.467	0.481	0.495	0.514	0.727	0.612
9. Brake Thermal Efficiency, e_b, %	25.3	24.3	27.1	26.8	26.4	23.7	27.9	27.1	26.3	25.4	20.9	24.8
10. Exhaust Temp., °F	840	1079	1126	940	1027	1068	995	1099	1073	1087	1233	1114
11. Exhaust Gas Anal.												
$\%CO_2$	9.0	11.4	12.5	9.1	11.2	10.4	9.0	11.2	11.2	11.5	11.8	11.8
$\%O_2$	10.5	9.6	5.5	9.9	9.2	12.6	9.0	8.2	7.8	6.5	6.5	6.3
%CO	0.2	0.4	0.4	0.7	0.4	0.4	0.2	0.6	0.6	0.4	0.4	0.6
$\%H_2$	0.4	0.4		0.4	0.4	0.8	0.3	0.5	0.4	0.4	0.6	0.4

12. Notes: Runs 19-24 were done on Nov. 18, 1977. In Run 22, the engine was run without the fuel filter. Increase in RPM compared to Run 21 at about the same torque could indicate filter clogging.

TABLE 1. (Continued)

1.	Run No.	25	26	27	28	29	30	31	32	33	34	35	36
2.	Fuel	Diesel	Diesel	Diesel	Diesel	Diesel	Coco Oil B	Coco Oil B	Coco Oil B	Coco Oil B	Diesel	Diesel	Diesel
3.	Higher HV Btu/lb	19,523	19,523	19,523	19,523	19,523	16,342	16,342	16,342	16,342	19,523	19,523	19,523
4.	Running Time, Min.	27	30.247	30.083	30.531	30.083	30.067	29.917	30.083	30.072	30.128	30.189	30.017
5.	Engine RPM	3130	3043	2994	2744	2863	3076	2995	2974	2631	3043	3043	3016
6.	Engine Torque, ft-lb, x 2	12.3	17.5	22.4	27.4	12.4	12.5	17.5	22.5	27.5	10.4	15.4	20.4
7.	BHP Output	3.67	5.07	6.38	7.16	3.38	3.66	4.99	6.37	6.89	2.90	4.33	5.74
8.	BSFC, lb/Bhp-h	0.693	0.609	0.548	0.554	0.650	0.797	0.653	0.610	0.586	0.730	0.617	0.527
9.	Brake Thermal Efficiency, e_b, %	18.8	21.4	23.8	23.5	20.1	19.5	23.8	25.5	26.6	17.9	21.1	24.7
10.	Exhaust Temp., °F	728		1054	1100	674	829	885	1024	989	716	873	945
11.	Exhaust Gas Anal.												
	$\%CO_2$	7.0	11.0	9.8	11.5		7.0	10.0	10.0	10.0	5.6	7.0	8.0
	$\%O_2$	12.0	9.5	11.2	8.5		13.5	11.0	10.5	11.0	15.2	13.6	12.5
	%CO	0.2	0.6	0.5	0.6		0.3	0.3	0.4	0.5	0.2	0.3	0.4
	$\%H_2$	0.3	0.7	0.6	0.7		0.5	0.5	0.6	0.6	0.4	0.5	0.6

12. Notes: Runs 25-33 were performed on Nov. 22, 1977; Runs 34-41 on Nov. 24, 1977.

TABLE 1. (Continued)

1.	Run No.	37	38	39	40	41
2.	Fuel	Diesel	Coco Oil B	Coco Oil B	Coco Oil B	Coco Oil B
3.	Higher HV Btu/lb	19,523	16,342	16,342	16,342	16,342
4.	Running Time, Min.	30.089	30.028	30.139	30.106	30.083
5.	Engine RPM	2997	3015	3057	3011	2776
6.	Engine Torque, ft-lb, x 2	25.6	10.5	15.4	20.5	25.4
7.	BHP Output	7.19	2.90	4.37	5.76	6.61
8.	BSFC, lb/Bhp-h	0.591	0.868	0.745	0.649	0.647
9.	Brake Thermal Efficiency, e_b, %	22.0	17.9	20.9	24.0	24.1
10.	Exhaust Temp., °F	1200	726	894	974	1067
11.	Exhaust Gas Anal.					
	$\%CO_2$	9.0	5.5	7.0	8.0	8.8
	$\%O_2$	11.8	15.3	13.5	12.3	12.0
	%CO	0.5	0.2	0.2	0.3	0.5
	$\%H_2$	0.7	0.5	0.5	0.6	0.6

12. Notes: Runs 25-33 were performed on Nov. 22, 1977; Runs 34-41 on Nov. 24, 1977.