WEAR STUDIES OF ENGINE COMPONENTS USING NEUTRON ACTIVATION TECHNIQUES

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ABSTRACT

This paper reports the results obtained in a series of tests for determining the wearing rate of some diesel engine components.

The pieces investigated were the needles of fuel injection nozzles, that were previously irradiated with a 10^{13} nv in the IEA-R1 nuclear reactor, and the wearing rate was established for different types of fuels. Total wear was calculated by measuring the specific activity of ^{51}Cr present in the fuel and originated by metal particles worn from the needle.

Wear tests were performed using a device that simulated the actual working conditions of the injection nozzles. The system was run during 350 hours and, along that period, 36 fuel samples of 10 ml each, were collected and analysed for cumulative wear calculation.

A metal concentration as low as 10^{-6} g in 10 ml of fuel sample could be measured by this method.

At present time this procedure is being applied for measuring the wear-rate of other nozzle parts, using localized neutron activation techniques.

1.0 INTRODUCTION

From time to time motor engineers have discussed the fact that the conventional methods in use for measuring wear of specific components such as piston rings, injector nozzle, etc, are rather unsatisfactory. The classical methods involve extended operation of an engine, and gravimetric or volumetric measurement of the specific component before and after the operating test period.

Besides the limitation in accuracy of measurement, these methods are subjected to a number of critical drawbacks including:

a) the excessive time necessary for a single determination;

b) the low reliability resulting from the measured quantity being a small proportion of the total weight.

In addition, the differential weight or dimension methods do not account for the influences of the foreing material either solid or liquid, wich originates from the fuel and contributes to erroneus indication.

The use of radioisotopes offers a different approach to the development of a rapid and sensitive method for the measurement of engine wear tracing a specific element of the engine component or tagging a molecule group of the compound under study with a suitable radioisotope.

The promising advantages of the technique can be enumerated as below:

a) evaluation of transient behaviour e.g, the instantaneous effects of varying a single engine operation condition can be studied;

b) the great sensitivity of the radioactivity measuring equipment enables measurement of wear as small as 10^{-9}g;

c) reproducible tests can be carried out under identical operating condition without the engine after each test;

d) measurements can be precisely made for specific areas in the system;

e) multicomponent wear studies can also be made using a different for each component, with the help of multichannel analysers.

In order to determine the behaviour of injector nozzles in diesel-cycle-engines when biomass derived fuels are used a series of wearing tests were perfomed at IPEN's laboratories.

2.0 EXPERIMENTAL PROCEDURE

2.1 Tracer selection

Taking into consideration, the chemical composition of the needle (Table I), test time and the specific activity necessary for the accuracy required, ^{51}Cr, with its half-life of 27.8 days and gamma radiation with energy of 320 keV (9%), was selected.

2.2 Irradiation

Needles were irradiated in the research reactor IEA-R1 of IPEN-CNEN/SP with a flux of 10^{13} nv for 240 hours. In this way 16 mCi of ^{51}Cr per needle was obtained.

Depending on the different ways in which the specimens were tested, some needles were totaly irradiated whereas in other needles only selected areas were activated, using Cd foil as neutron absorver.

2.3 Standard samples

To prepare standard samples of known concentration small pieces of the test material were irradiated together with the needles. This activated was dissolved in acid solution and brought to concentration close to those used in the tests (μg of active material/ml). Using these reference samples the correlation mass/specific activity measurement conditions were obtained (Fig 1).

2.4 Wear test

Since the fuel contaning the radioactive metal particles would be burnt in the combustion chamber, it was not possible to conduct the test on the proper engine. To avoid this problem, a special system simulating the working conditions of the injection nozzles was designed and built (Fig 2).

The operational parameters of the simulator were:

- oil temperature: 80 ^{o}C
- fuel flow-rate of injector pumps (kg/h): 0.51; 0.85; 1.23 and 1.60
- pump rotation: 1735 rpm
- fuel used: diesel oil, soja bean ester and aditived alcohol
- effective fuel volume in the system: 100 ml

Initially, it was attempted to compare the needle wear rates for the three kinds of fuels mentioned above. For this purpose, whole irradiated needles were used and five 20 minutes runs for each type of fuel were performed with the simulator.

Afterwards, the tests were aimed towards obtaining the needle wear rates for its body and point, respectively (Fig 3), as a function of operating time and fuel flow. In this stage, two series of tests were made, using diesel oil as a fuel. Each series consisted of 36 operating runs.

Needles with activated body were employed in one of this series and just point irradiated needles in the other. In each run 100 ml fuel were used in the simulator and the operating time varied from 30 min for the first experiences up to 15 hours at the end of the test, summing up 350 hours for each series of runs.

2.5 Sample analysis

At the end of each run, 10 ml fuel samples were taken from the simulator and their specific activities determined with a well-type INa(Tl) scintillation crystal, associated to a multichannel analyzer.

The minimum concentration of worn mass in the fuel that could be measured with this system was 0,15 μg/ml.

3.0 RESULTS AND CONCLUSIONS

Total wear and wear rates are shown in Table II as a function of the different types of fuels used.

The accumulated wear of the whole needle, body and point have been represented in Fig 4, as a function of operating time and given flow of diesel.

Fig 5 shows the wear rates of the needle body and point as a function of diesel flow rate.

It can be concluded that the selection of ^{51}Cr as tracer was suited for the purpose of the tests since it gave coherent results and permitted obtain a high measurement sensibility. The worn mass determination was independent on the metal particle size.

Finally, the advantages of the radioisotope technique over classical methods, regarding to rapidity, repetibility of results and detection limit were confirmed.

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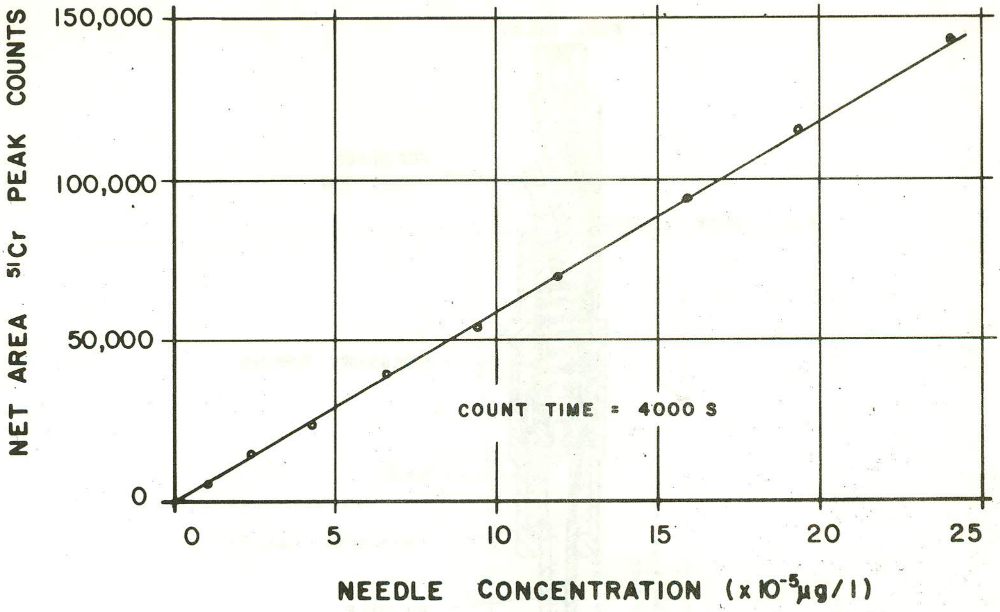
Table I - Needle composition (%)

C	0.86 - 0.94
Si	0.45 max
Mn	0.40 max
Ni	--------
Cr	3.80 - 4.50
Mo	4.70 - 5.50
W	6.00 - 6.70
V	1.70 - 2.0
S	0.030 max
P	0.030 max

Table II - Total wear and wear rates as a function of differents fuels.

Fuel	Total wear (g)	Wear rate (g/min)
Diesel oil	1.9×10^{-6}	0.05×10^{-6}
Aditived alcohol	9.5×10^{-4}	19.1×10^{-6}
Soja bean ester	9.0×10^{-5}	1.65×10^{-6}

FIG. I - CALIBRATION CURVE



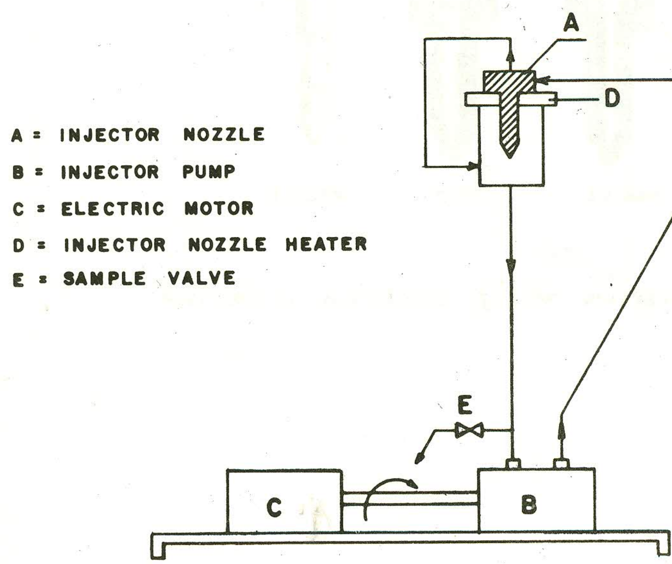


FIG. 2 - EXPERIMENTAL SYSTEM TO SIMULATE WORKING CONDITIONS OF INJECTION NOZZLES.

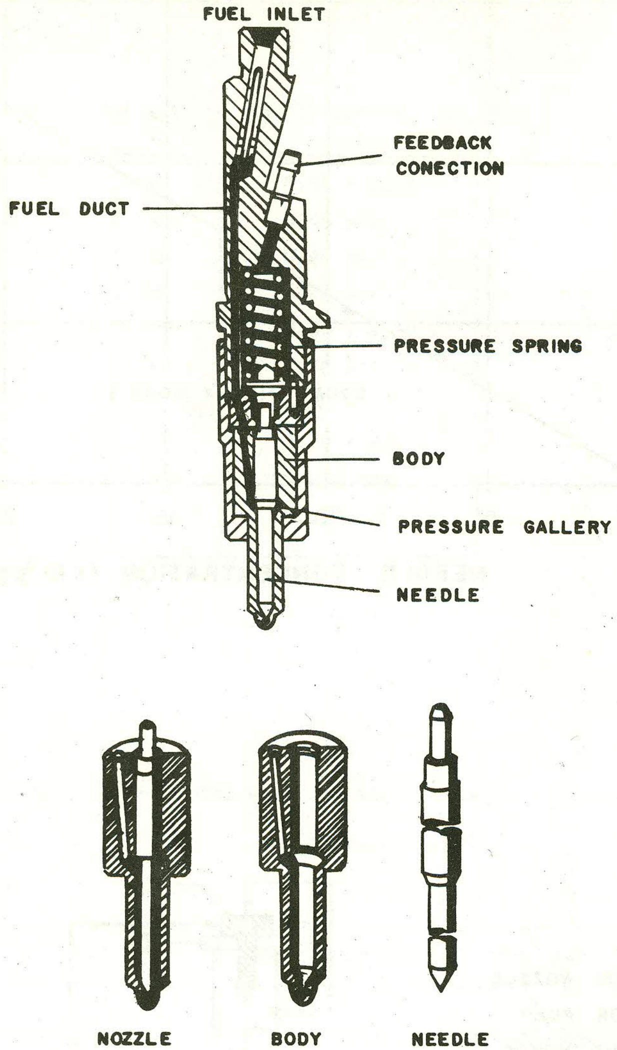


FIG. 3 - INJECTION NOZZLE MECHANICAL DESCRIPTION

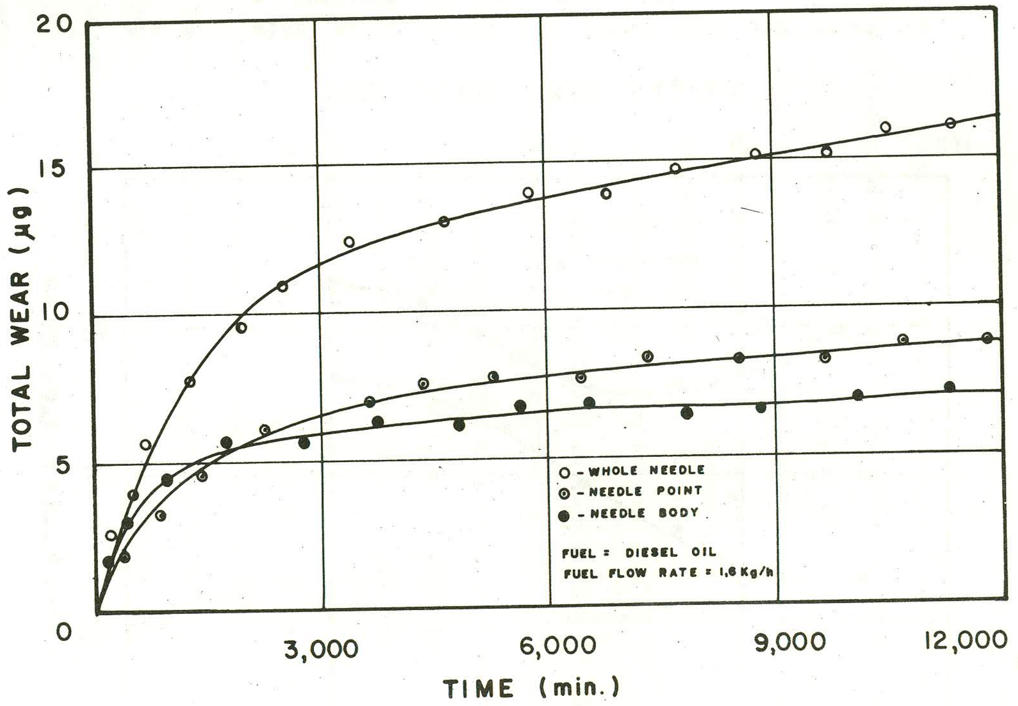


FIG. 4 - WEAR CURVES FOR NEEDLE BODY AND POINT, AS A FUNCTION OF OPERATING TIME.

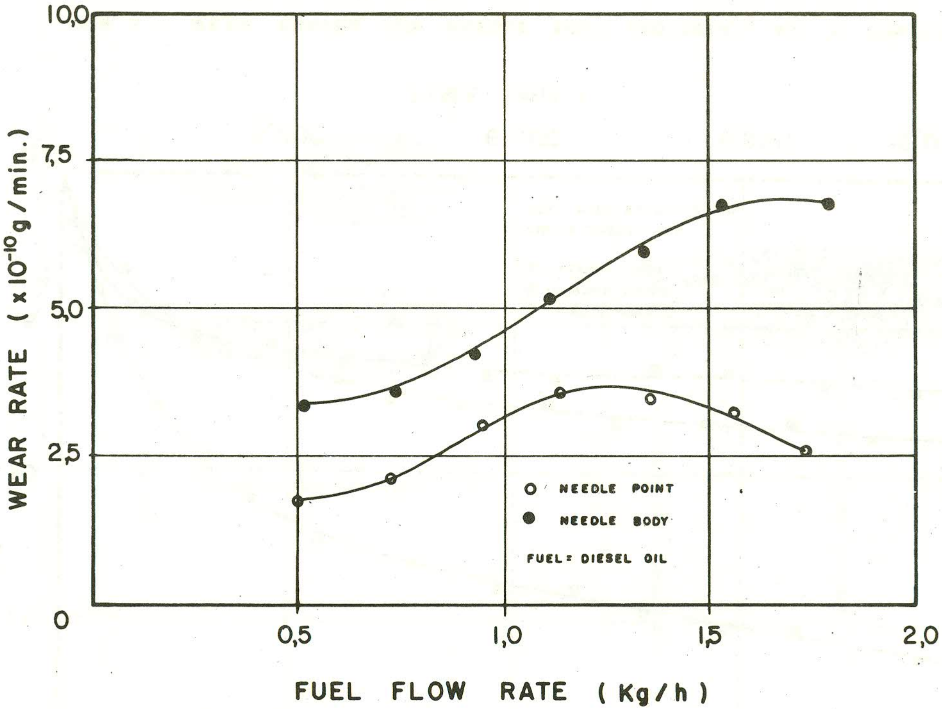


FIG. 5 - WEAR RATES CURVES FOR NEEDLE BODY AND POINT, AS A FUNCTION OF FUEL FLOW RATE.