CHAPTER III

EXPERIMENTAL METHODS

The experiment compares the performance and vibration characteristics of two 4-cyclo 4-cylinder in line engines where one is conventional type and the other is equipped with second mode vibration balancer system.

Objectives

The objectives of this experiment can be classified into 5 topics as follws :

(1) Determination of mode of vibration

Any engines with many moving parts such as piston, connecting rod, crankshaft, inlet and exhaust valves, oil pump, fuel pump etc. could produce very complex vibration. Consequently, it is a good practice to determine first what mode of vibration exist. hence, the modes of vibration of engine is recorded. This is done by running the engine at constant speed namely 1600, 2000, 2500 rpm. and then the acceleration is measured employing octave filter set by varying the centre frequencies covering the whole spectrum. With these data any vibration of significant level can be determined and further investigation could limit to those modes only.

(2) Determination of vibration at different locations of the engine

Engine is built up from many parts put together by fasteners mainly nuts and bolts with washers or gaskets. Each component exhibits different damping and spring effects so it is thought that different components of the engine may subject to different vibration levels. Consequently, vibration levels at different locations are measured concurrently with above procedure.

(3) Determination of the effect of load on vibration

Automotive engines in driving conditions face many types of loads namely no load when idle, full load when throttle is fully open and in between with part load at road load condition. Consequently, it is quite interesting to determine the effect of loads on vibration. It can be done easily by adjusting the loads with dynamometer. Theoretically, the loads have no effect upon the inertia force and inertia moment which depend on speed only. However, when the gas-pressure force varies the engine torque varies accordingly. The procedure of experiment is similar to previous experiments but the loads vary from no load to some part loads.

(4) Determination of vibration at no load and full load

As loads on engine may effect the vibration level hence for comparison of vibration of different engines, the loads must be well defined. In this study, for comparison purpose, vibration levels are measured at no load and full load only since other intermediate loads are difficult to set equally on two dynamometers.

(5) Determination of performance of engines

Engine performances taken at full load yeild useful results such as maximum horsepower, maximum torque, fuel consumption per unit time per unit horsepower etc. The purposes of obtaining these data are twofold, firstly the results can be compared to manufacturer's published data and secondly the results may suggest modification of testing set up as existing in the laboratory.

Fig. 3-1 shows the conventional engine. Fig. 3-2 shows second mode counter balancing shaft engine. Fig. 3-3 shows counter balancing shafts and Fig. 3-4 shows counter balancing shafts as equipped on engine.

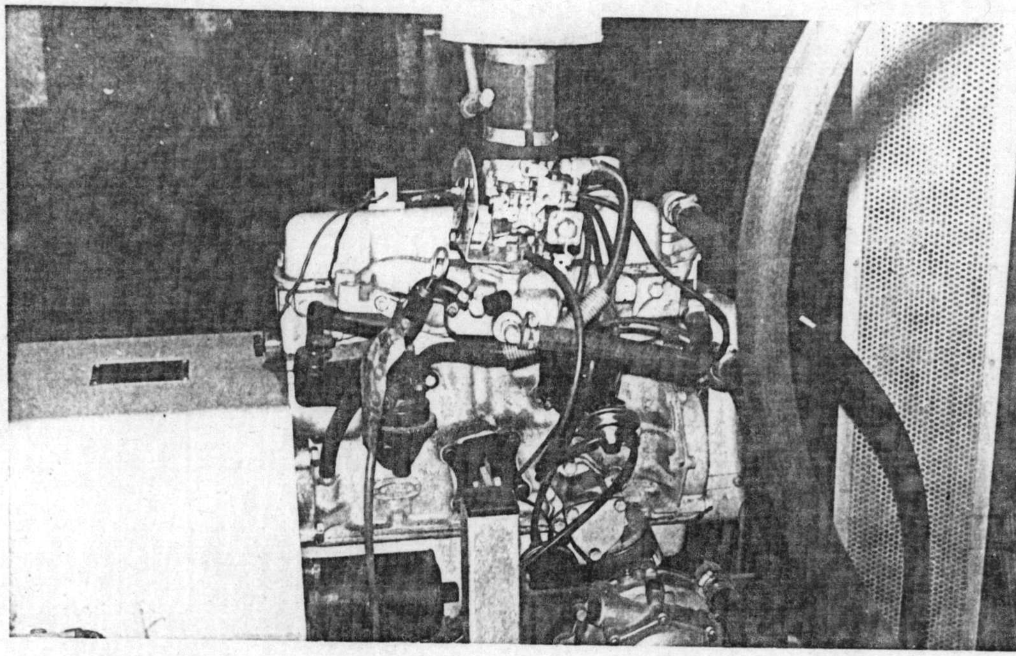

Fig.3-1 Conventional engine

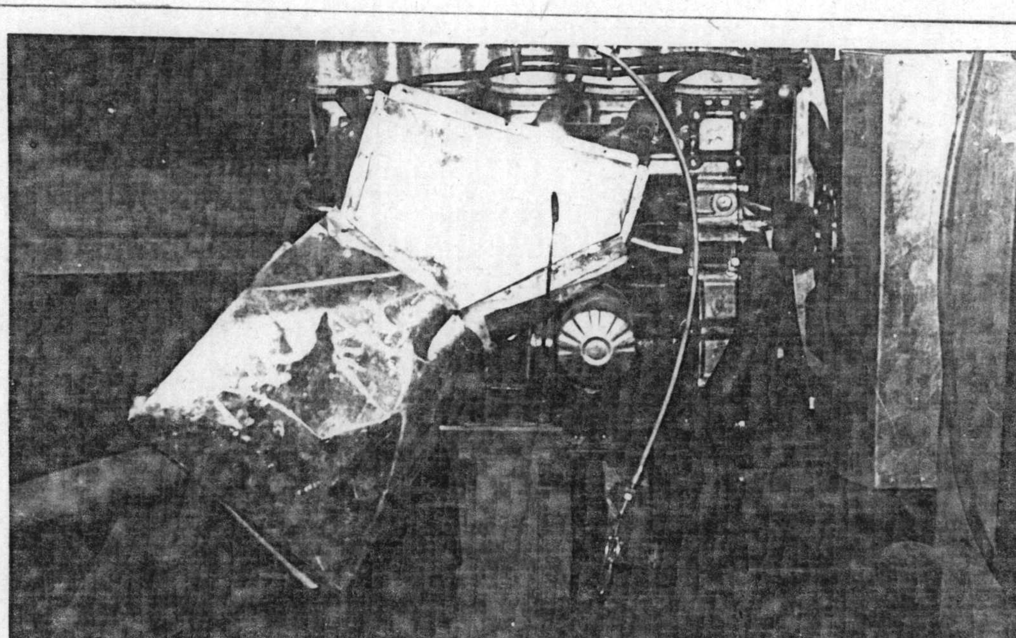

Fig.3-2 Second mode counter balancing shaft engine

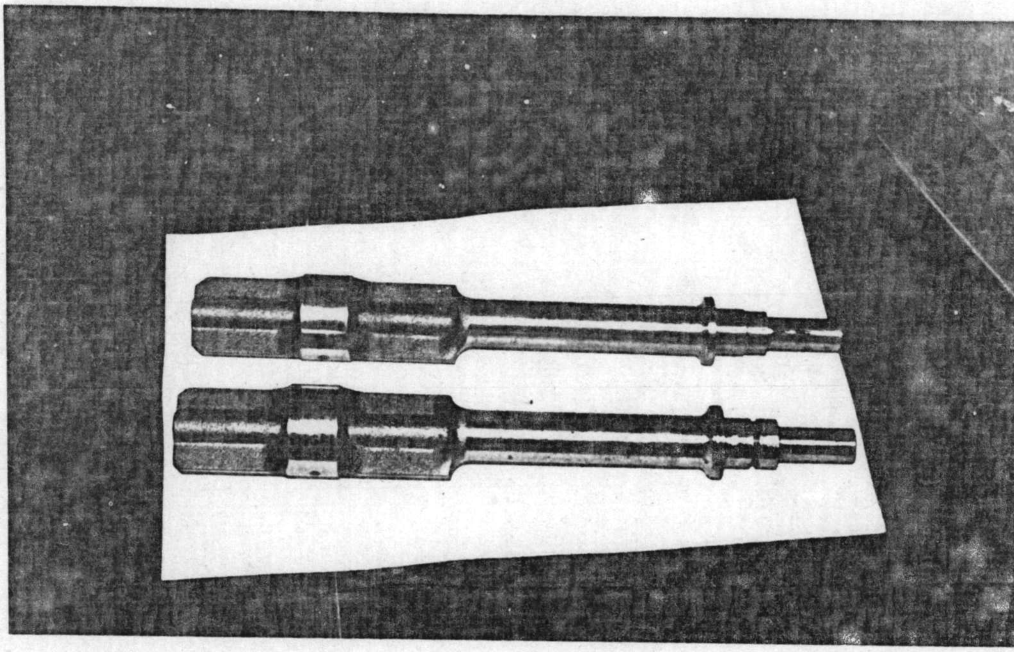

Fig.3-3 Counter balancing shafts

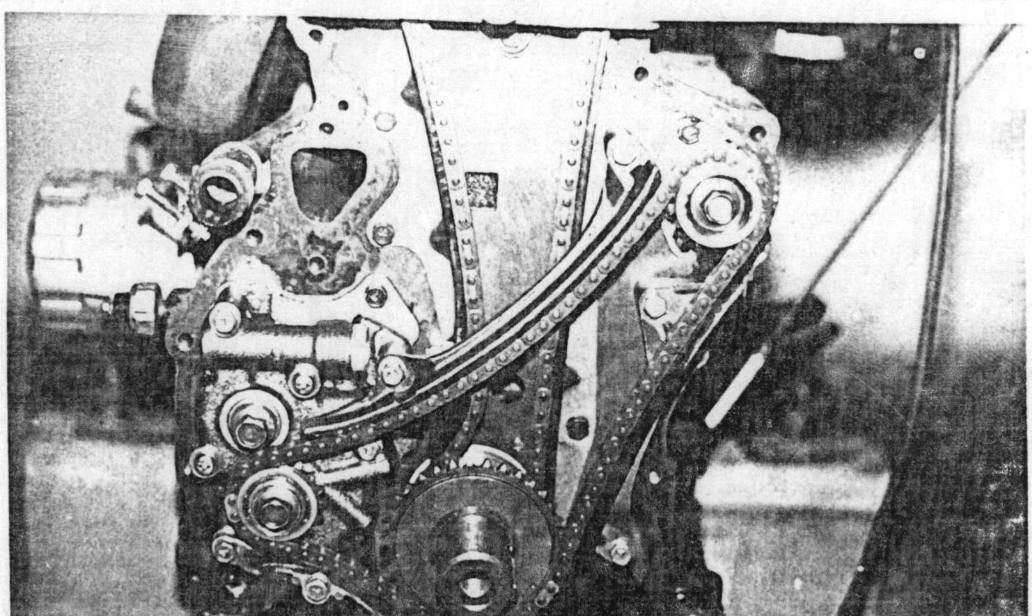

Fig.3-4 Counter balancing shafts as equipped on engine

Major Specification of Engines

	Engine with second-mode balancer	Conventional engine
Name	Mitsu "80"	Ford
Model	4G52	2261 E
Type	4-cycle, 4-cylinder in-line	←
Cooling	Water cooled	←
Displacement(cc)	1995	1098
Bore × stroke(mm)	84 × 90	80.98 × 53.29
Compression ratio	8.5 : 1	8 : 1

Apparatus

Dynamometer

Loads on counter-balancing engine are regulated through Froude Dynamometer Model DPX-2 capable of testing up to 150 hp. while conventional engine is connected to Froude Dynamometer Model DPX 1 with maximum rating of 100 hp.

Vibration Measurement

Vibration level in unit of acceleration of vibration g is measured by Bruel & Kjaer instrument consisting of

1. Impulse Precision Sound Level Meter Type 2209
2. Octave Filter Set Type 1613
3. Integrator Type ZR 0020
4. Accelerometer Type 4332S as shown in Fig. 3-5.

In order to pursue with the experiment, it is essential to agree upon the term 'mode of vibration'. It can be described as vibration at a particular frequency which is the multiple of engine speed. For example, an engine running at 3000 rpm. corresponds to a frequency of 50 Hz. then vibration at 50 Hz. is called first mode vibration, similarly vibration measured at 100 Hz. which is twice the frequency of the engine speed is called second mode vibration and so forth. Table 3-1 indicates modes of vibration when employing Octave Filter Set Type 1613.

Engine RPM	1st Mode Hz	2nd Mode Hz	4th Mode Hz
1000	-	31.5	63
1500	31.5	63	125
2000	31.5	63	125
2500	31.5	63	125
3000	63	125	250
3500	63	125	250
4000	63	125	250
4500	63	125	250
5000	63	125	250
5500	63	125	250

Table 3-1 Octave Filter Centre Frequency Setting for Measuring Engine Vibration Mode

In measuring vibration, a proper mounting of the accelerometer to the specimen is of utmost important especially at higher frequencies.[7] There are many possible ways of applying the accelerometer to the vibrating specimen such as using steel stud, magnet and wax so that accelerometer is in contact with vibrating surface. All mentioned mounting required close contact of accelerometer at all time to hot vibrating surfaces, therefore, they are not suitable for this experiment due to too high temperature. It is afraid that possible damage may occur to the accelerometer as well as the cable insulated by Polyethylene and PVC which will not withstand more than 100 c. However, there is a method of mounting by attaching the accelerometer to the probe with handheld measurement. This method is applicable for this experiment but the natural resonance frequency is very low.

Trial Run on Engine Equipped with Second Mode Balancer

Trial run on engine indicated many precautions which must be taken seriously taken before actual experiment is performed.

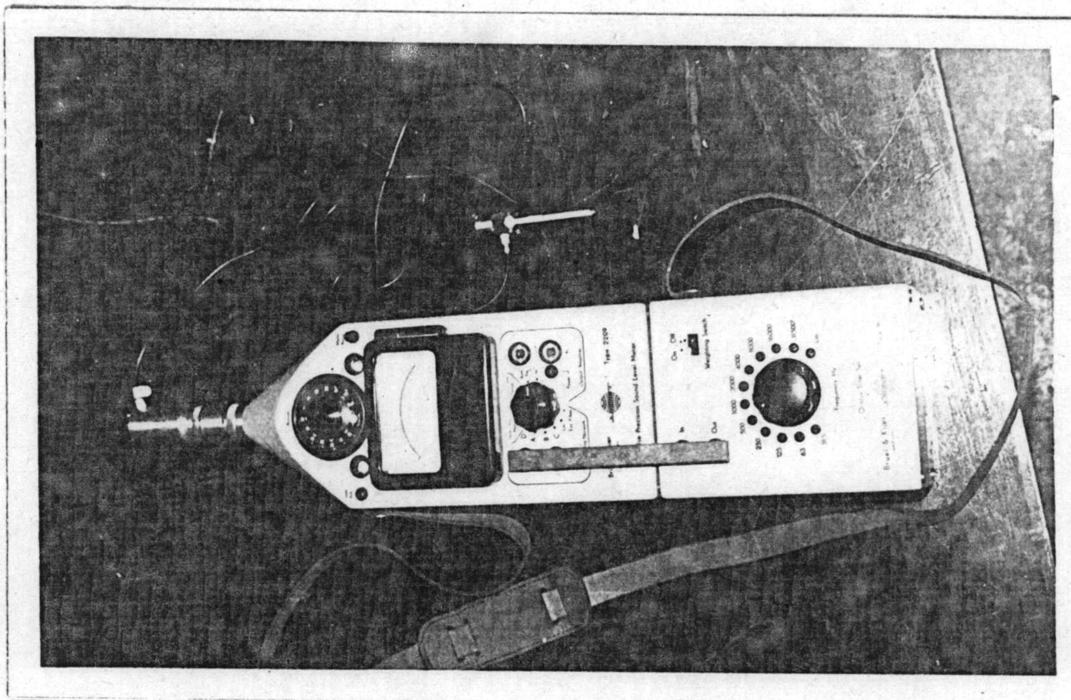

Fig. 3-5 Vibration measuring instrument

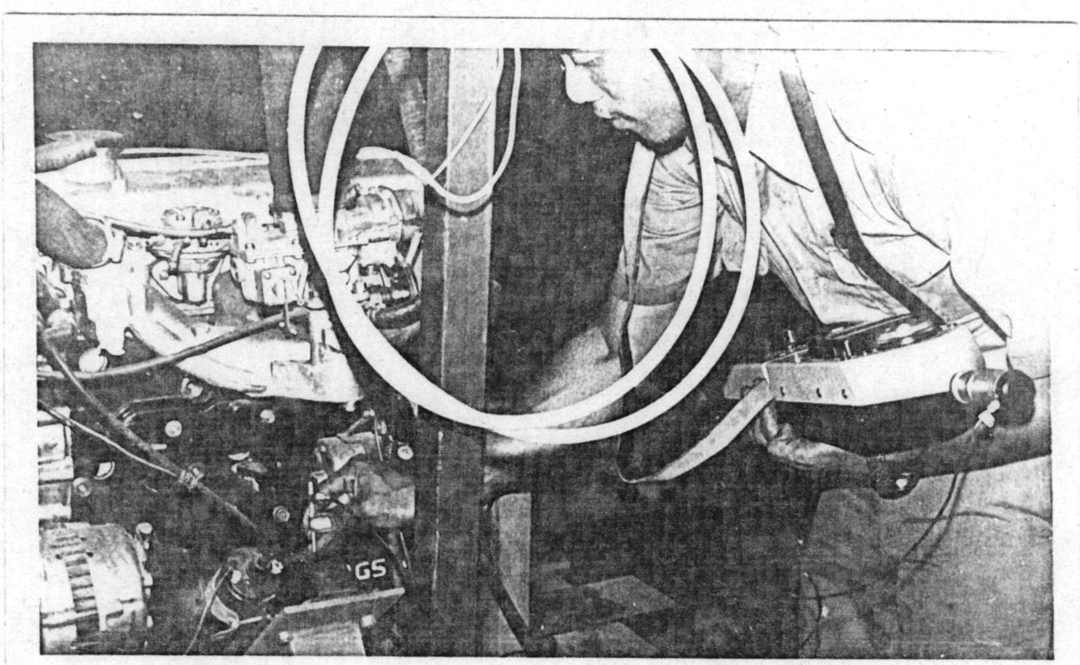

Fig. 3-6 Vibration measurement

The item listed here have been adopted in actual test after trial run.

1. Exhaust pipe has been installed with heat barrier making from galvanized sheet fabricated into a box shape with 2 inches thick Fibre Glass insert. It is found that heat radiation from exhaust pipe to the surrounding is much reduced and making the test possible.

2. Thick glove must be worn by the investigator when taking vibration measurement since heat radiation at all surface of the engine is very high. Even with thick glove, the author found that taking vibration measurement at any point more than 30 seconds is unbearable.

3. Blower must be used to cool the radiator when engine is operating at sustained full load in order to keep temperature variation of cooling water down to acceptable limit.

4. At least 3 persons are required to conduct the experiment. First person controls the load and takes measurement of fuel consumption, air inlet volume, engine torque, engine speed. Second person takes vibration readings and third person records all the data.

Experimental Procedure

1. Preparation work before experiment
    1. Tune up the engine
    2. Calibrate Impulse Precision Sound Level Meter for vibration measurement by using the built-in reference voltage method[8]
2. To achieve objectives (1), (2) and (3). They can be done concurrently as follows:

Step 1 Operate the engine at no load and set it to run at desired speed.

Step 2 Handheld the accelerometer at a location.

Step 3 Set centre frequency on octave filter set at 31.5 Hz.

Step 4 Record data

Step 5 Repeat steps (3) and (4) until whole octave filter centre frequencies are coverod.

Step 6 Remove the accelerometer to new location and repeat steps (3) to (5).

Step 7 Apply load on engine by dynamometer then open engine throttle to reach the same speed as in step (1) and repeat steps (2) to (6).

3. To achieve objective (4) at no load

Step 1 Set dynamometer at no load.

Step 2 Open throttle until engine runs at 1000 rpm.

Step 3 Handheld the accelerometer at engine support bracket.

Step 4 Select centre frequencies on octave filter set to measure first, second and fourth modes respectively.

Step 5 Remove the accelerometer to carburetor.

Step 6 Repeat step (4).

Step 7 Open throttle until engine runs at 1500 rpm. and repeat steps (3) to (6). With speed increment of 500 rpm, repeat appropriate steps until speed reaches 5000 rpm.

4. To achieve objective (4) at full load and objective (5) which can be performed concurrently as follows:

Step 1 Slowly open the throttle while imposing greater load on the engine until the throttle is fully open then adjust the load to keep engine running at 1000 rpm.

Step 2 Wait until steady state is attained. Record the following data: speed, torque, fuel consumption, air inlet volume, water temperature and vibration level.

Step 3 Reduce the load letting the engine gain 500 rpm. Repeat steps (2) and (3) until the engine reaches its maximum speed.

Step 4 Repeat the experiment with speed reduced from maximum to minimum.