

Friction and indicated power measurement for diesel engine by

(aerial dynamometer)

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Abstract:

The conventional methods - used for - measuring brake, friction, and indicated power are based on brake - off dynamometers which use hydraulic or electrical dynamometers .

The mentioned above methods use the measured torque to calculate the related power. The present method and instrument are characterized by measuring the amount of pressure opposed by a compressor joined to the engine and a reservoir for a compressed air, thus; the engine speed decelerates with the increasing pressure . For a specified pressure and engine speed, power could be calculated.

In addition, friction power in the engine could be estimated by measuring the consumed current and effective voltage on an electrical driving motor when the diesel engine at run – off situation; no fuel supply. The whole present dynamometer had been designed and performed by the researcher as explained.

قياس القدرة الاحتكاكية والبيانية لمحرك ديزل بواسطة (الداينوميتر الهوائي)

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الخلاصة

ان النظريات التقليدية المستخدمة في قياس القدرة الفرملية والاحتكاكية و البيانية للمحركات اعتمدت على داينوميتر التوقف الهيدروليكي أو الكهربائي . وهذه الطرق تستخدم العزم المضاد و المقاس لحساب القدرة المعنية بتلك المحركات.

أما الطريقة الحالية فقد تميزت بقياس مقدار الضغط المسلط بواسطة ضاغط هواء مرتبط بالمحرك بواسطة محور دوراني مع وجود خزان ضغط لإبقاء الحمل المسلط في حالة اتزان طيلة فترة الاختبار. وعليه فإن سرعة المحرك ستتناقص مع تزايد الضغط . وعند سرعة معينة وضغط معين يمكن حساب القدرة المطلوبة.

بالإضافة لذلك ، يمكن تقدير القدرة الاحتكاكية داخل المحرك بقياس التيار المستهلك والفولتية المسلطة على المحرك الكهربائي المستخدم في تدوير محرك الديزل في حين أن محرك الديزل في حالة عدم اشتغال .

ان الداينوميتر المستخدم مصمم ومنفذ بشكل كامل من قبل الباحث كما موضح من خلال البحث الحالي.

Introduction:

Dynamometers are useful in the development and refinement of modern day engine technology. The concept is to use an aerial dynamometer to measure and compare friction, brake power transferred at different loads and speeds, thus allowing the engine to be modified to get more efficient power transfer

An engine dynamometer measures power and torque directly from the engine's crankshaft (or flywheel), when the engine is removed from the vehicle. This dynamometer do not account for power losses in the driven parts, such as the gearbox, transmission or differential etc.

Arial - Dynamometers are aero-mechanical instrument used to place a controlled mechanical load on pressurized-producing device such as compressor. They are used to characterize pressure rise as a function of speed. The dynamometer is controlled by a mechanical and rotational load. It controls either speed or pressure and measures both. With this dynamometer the pressure-speed curves can be plotted, and the engine and motor can be tested over the intended operating range of speeds.

Speed and load control is done using a manual air pressure regulator. The speed at which the engine is running is measured by using a mechanical rotating string attached on the gear box.

Many advantages could be achieved from the present dynamometer:

- 1- The aerial dynamometer is easy to operate.
- 2- Provides repeatable and more accurate results.
- 3- Measures Friction, Brake and Indicated Power at the same time and conditions .
- 4- Clean and safe loading manner.
- 5- Easy to study thermodynamic properties

Basic theory of power calculation:

It is now necessary to describe the sequence of mathematical progress of calculations that leads to utilize of all parameters that could be measured to determine the properties of the engine and to represent the efficiency of the used dynamometer as shown below.

Friction power measurement and calculations:

friction power induced inside the diesel engine could be measured directly by running the diesel engine by an actuator with variable speed (electrical driving motor) with cutting – off fuel for the engine , so that the consumed current (I) and the effective voltage (V) by the motor give a good estimation about the friction power quantity.

so that friction power of diesel engine (F.P) \approx motor power (P) = $3 \times I \times V \times \cos\phi$ -Eqn. 1
where $\cos(\phi)$ is the power factor of the electric motor which is equal to 0.8 .

Work per minute, Brake power:

Let p = mean effective pressure, N/m^2 = pressure generated by compressor

D = diameter of cylinders of compressor , m.

L = length of stroke, m.

N = revolutions per minute.

f = number of effective strokes, per revolution per cylinder minute second constant

n = number of cylinders.

$F.P$ = friction power inside the engine (watt)

$$\text{Force acting on one cylinder} = p \frac{\pi D^2}{4} \text{ newtons}$$

$$\text{Work done per effective stroke} = p \frac{\pi D^2 L}{4} \text{ newton} \cdot \text{meter} = \text{joules}$$

$$\text{Work done per revolution} = p \frac{\pi D^2}{4} L f \text{ joules}$$

$$\text{Work done per min} = p \frac{\pi D^2}{4} L f N \text{ joules}$$

Since the SI unit of power is the watt (W), or one joule per second

$$\text{the power per cylinder in SI unit is} = \frac{p \pi D^2 L f N}{4 \times 60} \text{ Watt}$$

$$\text{and the whole engine brake power B.P (or compressor power)} = \frac{p \pi D^2 L f n N}{4 \times 60} \text{ Watt}$$

it is known that $\frac{\pi D^2 L f n}{4 \times 60}$ is a constant value for a specified engine or compressor

thus the whole brake power (B.P) = $p \times N \times \text{constant}$ ----- Eqn .2

so that the formula is similar to $(T \times N \times \text{constant})$ as in the hydraulic brake dynamometer

From equation (1) & equation (2) :

$$B.P + F.P = I.P \text{ (indicated power)} ----- \text{Eqn} \cdot 3$$

for a compressor of the following specifications :

$$D = 14 \text{ cm} \quad f = 1$$

$$L = 15 \text{ cm} \quad n = 2$$

$$\text{the constant} = 7.6969 \times 10^{-5} \text{ m}^3$$

for a pressure measured by bar should be compensated by $\frac{N}{m^2}$ (pascal)

$$\text{where } 1 \text{ bar} = 10^5 \frac{N}{m^2}$$

$$\text{thus the whole power} = 7.6969 p (\text{bar}) \times N \text{ Watt}$$

$$\text{or} \quad = 7.6969 \times 10^{-5} p \left(\frac{N}{m^2} \right) \times N \text{ Watt}$$

DYNAMOMETER DESIGN: (Dynamometer System)

Considering the purpose of this instrument design, we have to choose the proper devices to simulate the actual conditions to get the best fit model parameters.

So it is needed a large electrical actuator with wide range variable speed, to run the diesel engine in a reasonably efficient way (while the engine is cut-off ; no fuel supply) , in order to measure the consumed current and the effective voltage which give an accurate indication about the power consumed to overcome the friction inside the driven engine in addition to some unaccounted losses in the driven parts such as gearbox . The driver actuator in the dynamometer must simulate various loads, in addition to act with desired values. This allows to choose the simulated friction load acting between the rotating parts inside the engine.

The dynamometer that has been developed in this paper will be discussed in this section. The dynamometer system has two major component assemblies. The first part is 10 HP DC motor with variable speed between 600-3000 RPM fastened by belt to a pulley which is in turns mounted on a flywheel to the (diesel engine under test) for measuring the friction power by determining the current and voltage of D.C motor at a specified speed as shown in Fig 1 . The diesel engine with four cylinders and 2 Liters capacity is shown in Fig 2.



Fig 1 The D.C motor (actuator)



Fig 2 The tested diesel engine

The second major component assembly in the dynamometer is a clutch Fig3 and a gear box Fig4 to simplify the transmission of power to the air compressor with 13 HP Fig 5 .



Fig 3 The clutch and pulley



Fig 4 The gearbox



Fig 5 the compressor



Fig 6 the air reservoir

The gearbox is connected to the compressor by a rotating shaft - with two universal joint to keep a flexible mounting - and connected by a hose to a high pressure air reservoir with 500 liter volume (The reservoir is capable to withstand a pressure up to 12 bar) as shown in Fig 6 .

A single board motor control is the mini controller used to control the driving motor Fig 7a& b.

The controller enables the motor to work either as a starting motor at the beginning of diesel engine working when the brake power is needed to be measured, or as main rotating motor to drive diesel engine for long time when friction power is needed to be measured .



Fig 7a controller of driving motor



Fig 7b contents of controller

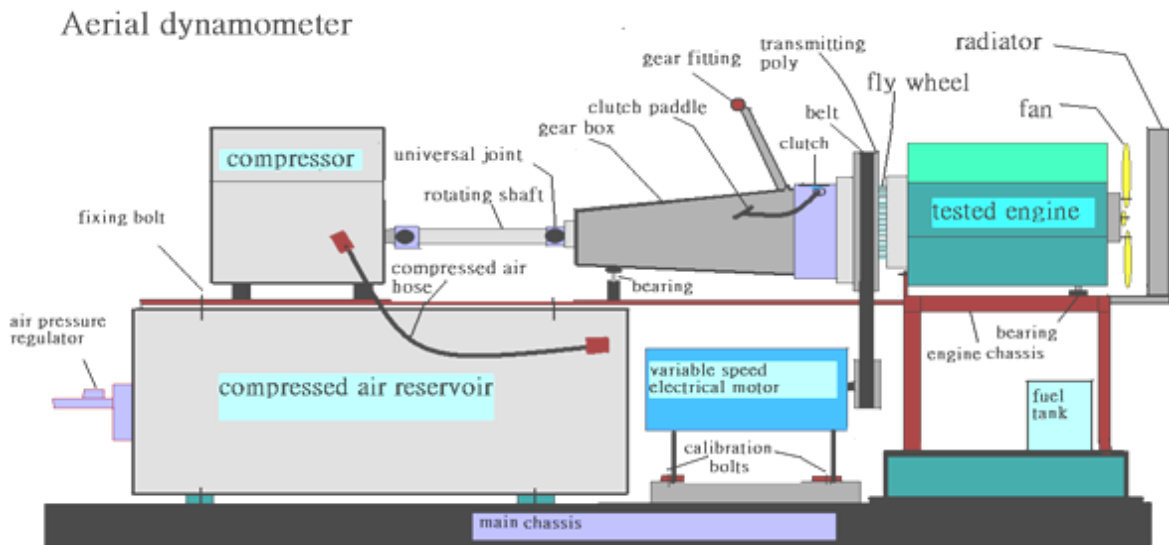


Fig 8 Scheme of Friction and indicated power measuring instrument bed

Usually, the test operator will fasten his engine under test to the dynamometer test bed and use a shaft coupling to tie the engine under test to a pulley then to a gear box and this gearbox in turns to the load compressor which supplies a compressed air reservoir of 500 liter volume by a hose. .The engine shafts must be exactly aligned (on the same axis) .

The dynamometer has a tachometer read-out points on a visual display - pointer instrument - to represent the rotational speed of the engine and gearbox as shown in fig 9. .



Fig 9 A photo of the aerial dynamometer



Fig 10 The pressure regulator

Test and procedure:

When the engine is held at a specified RPM (or series of usually sequential RPMs) for a desired amount of time by the variable pressure loads as provided by the (power pressurized unit),

At this mentioned method the speed and pressure control are accomplished by using a new and easy method of loading and reloading of the engine, also mechanical losses could be decreased. The operator can set the pressure to which the engine (under test) could be loaded to drive the engine at a desired speed, to determine the engine capability.

The operator can control the pressure level of loading by a manual pressure regulator Fig 10 to determine and suit the pressure to get a partial load on the engine to get desired and specified RPM.

The test equipment and procedures really are able to test directly for friction power, and test indirectly for brake and indicated powers.

The basic plan was to test a conventional friction power by variable speed electrical driving motor with low and moderate speeds.

Data list of engine parameters that allowed to be tabulated are: pressure of compressor which is regarded to be the load on the diesel engine (P), time elapsed to achieve the preceding pressure in a 500 liter reservoir (t), rotational speed of the engine or compressor (N), the current that has been consumed by motor (I) to drive the engine, the effective voltage on the motor (V).

Results and discussion:

Results gained from this test should be analyzed to demonstrate the precision of data and the instrument used in this test to estimate importance where it could be relied on to carry out experiments.

Graphs plotted in this paper represent many properties of this instrument.

In Fig11 the consumed current (I) by the driving motor versus the engine rotational speed. It represents that consumed current starts with a high specific value at low engine speed as the - starting friction in the engine is high, and this value begins to decrease for higher speed for small range of speed at 400 RPM, which means that oil pump works at the best efficiency at this speed. But the consumed current takes an opposite direction and increases for more speeds as physically known friction varies proportionally with speed.

In Fig12 the friction power (KW) versus the rotational speed (RPM).

It explains the previous paragraph as the friction power proportion to the consumed current.

In Fig13 the brake power (KW) versus the effective pressure (bar) of compressed air which is used as a load on the diesel engine.

It refers to the most characterized property of this aerial dynamometer; where the brake power produced by the diesel engine is a function of the effective pressure of the compressor.

So that the brake power increases as the pressure increases but the relation is not linear.

In Fig14 the time elapsed (sec) versus the effective pressure (bar), this is the time waited to achieve the specified pressure which is used as a load and after this time the regulator valve open when the specified pressure overlap the determined pressure.

It clarifies the relation between pressure and time, the time here is a function of pressure, where the time increases with pressure increasing, and the time elapsed at higher pressure (between 8-10 bar) is less than the time needed at lower pressures.

Note that the rotational speed of diesel engine decreases with increasing load pressure in Fig15 the time elapsed (sec) versus the effective pressure (bar) but with constant rotational speed.

This paragraph differs with step 4 that the speed here is compensated with increasing pressure so the rotational speed is constant and the time elapsed to achieve the same pressures of graph 4 is less, as the speed is higher.

In Fig16 the engine speed (RPM) versus the effective pressure (bar).

As remarked in graph 5 , here the engine speed decreases whenever the pressure increases as the pressure regarded as a load

In Fig17 indicated power (KW) versus the effective pressure (bar). represents the indicated power as a function of the effective load pressure, it differs with the brake power in graph 3 within the magnitude of the friction power so that the indicated power is slightly higher than brake power as seemed here.

In Fig18 three kinds powers indicated, brake, friction powers versus the engine speed (RPM).

It shows a comparison with whole kinds of powers, so that it represent the small difference between indicated and brake power.

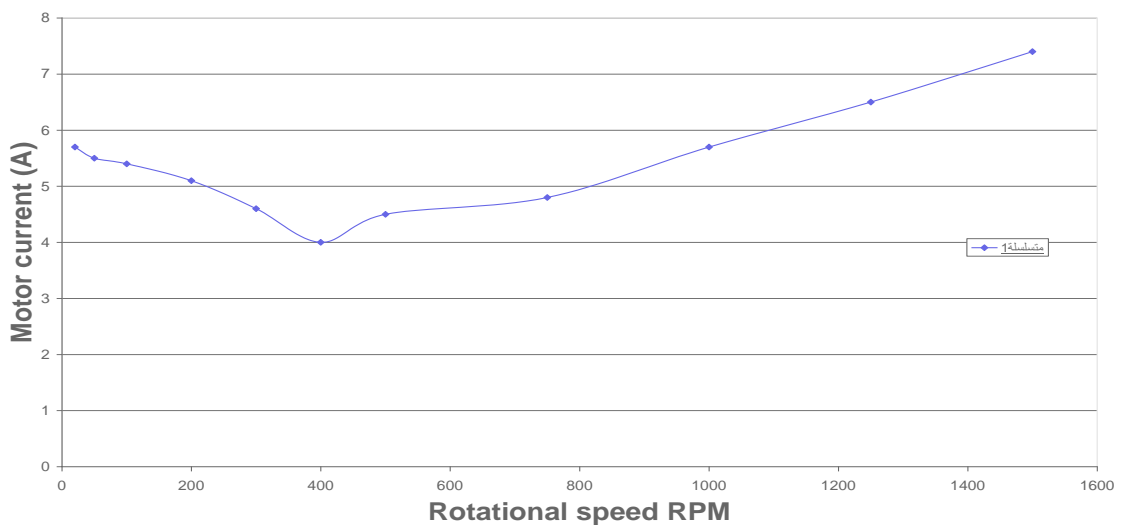


Fig 11 The relation between current and speed

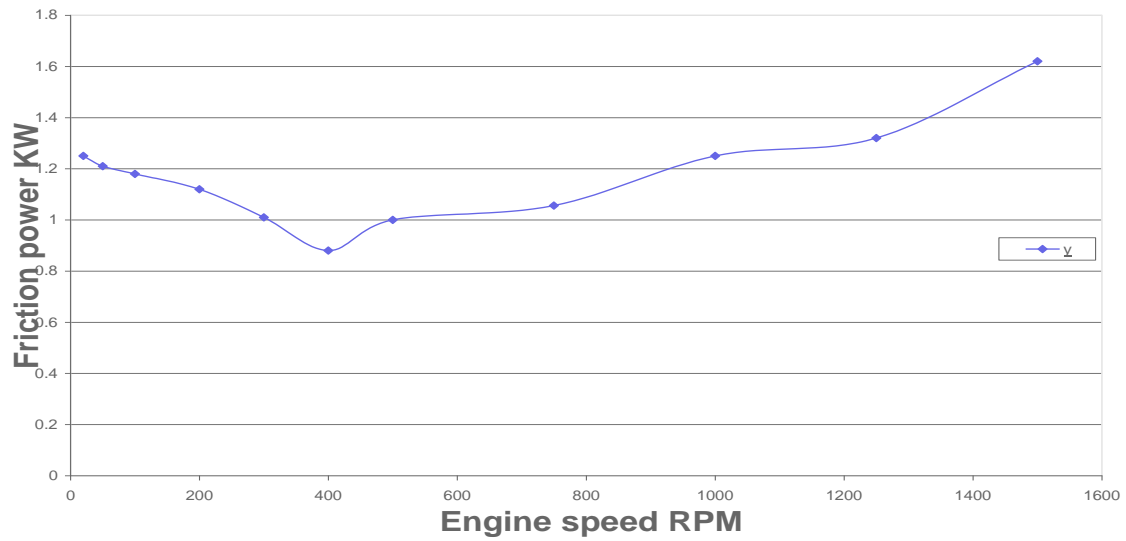


Fig 12 The relation between friction and speed

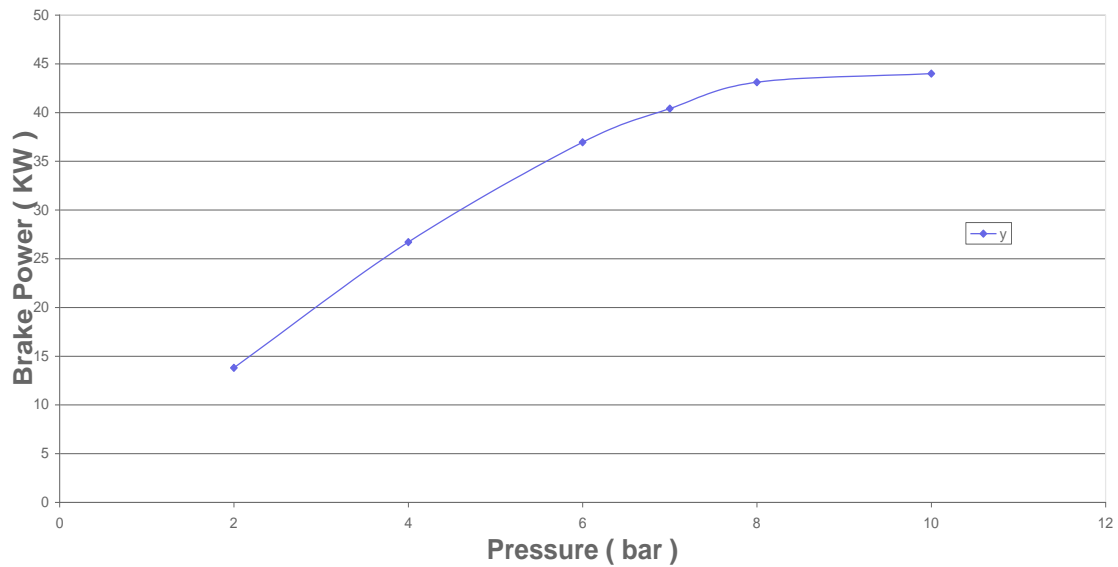


Fig 13 The relation between brake power and speed

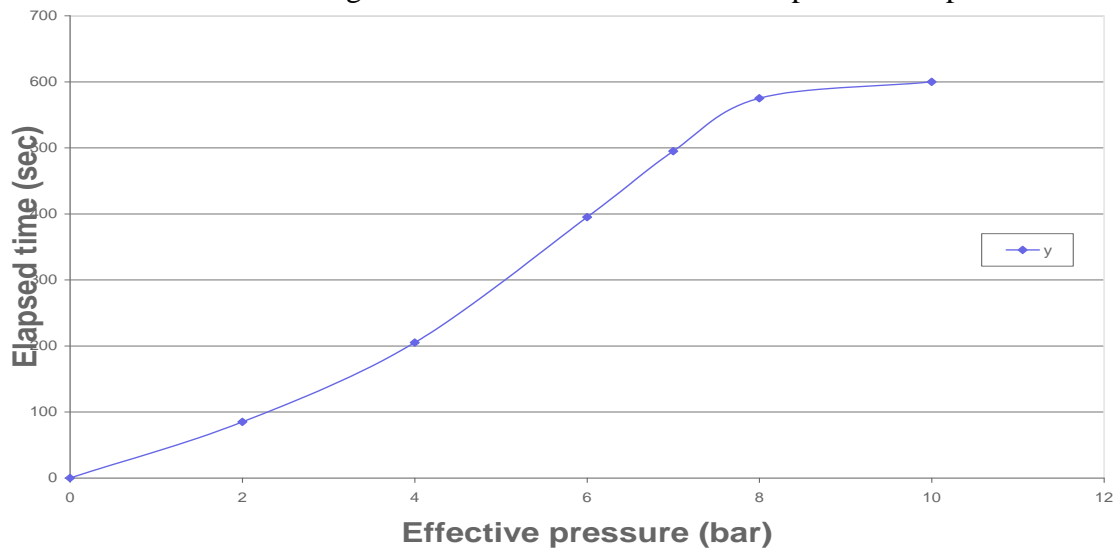


Fig 14 The relation between time and pressure

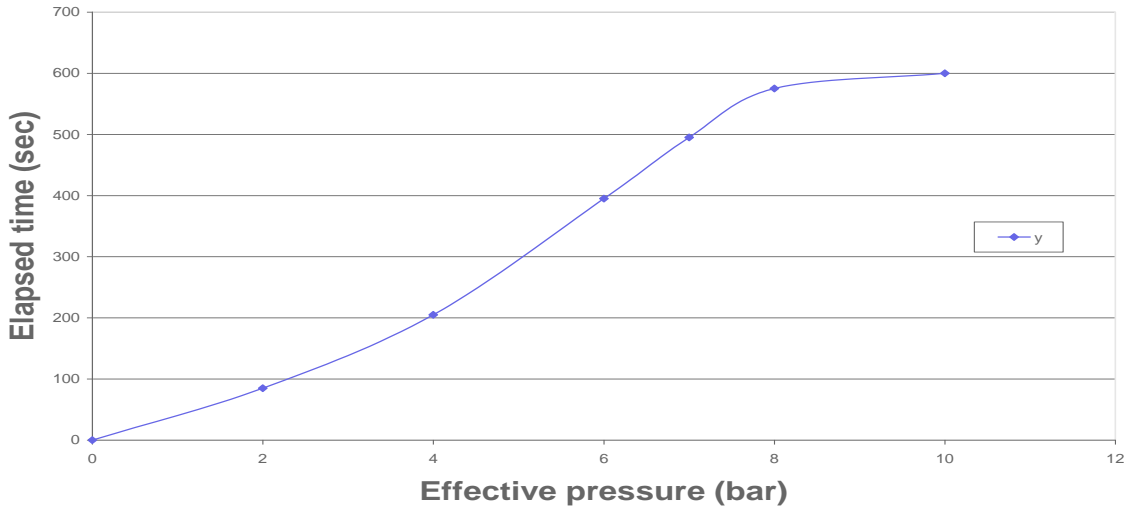


Fig 15 The relation between time and effective pressure at constant speed

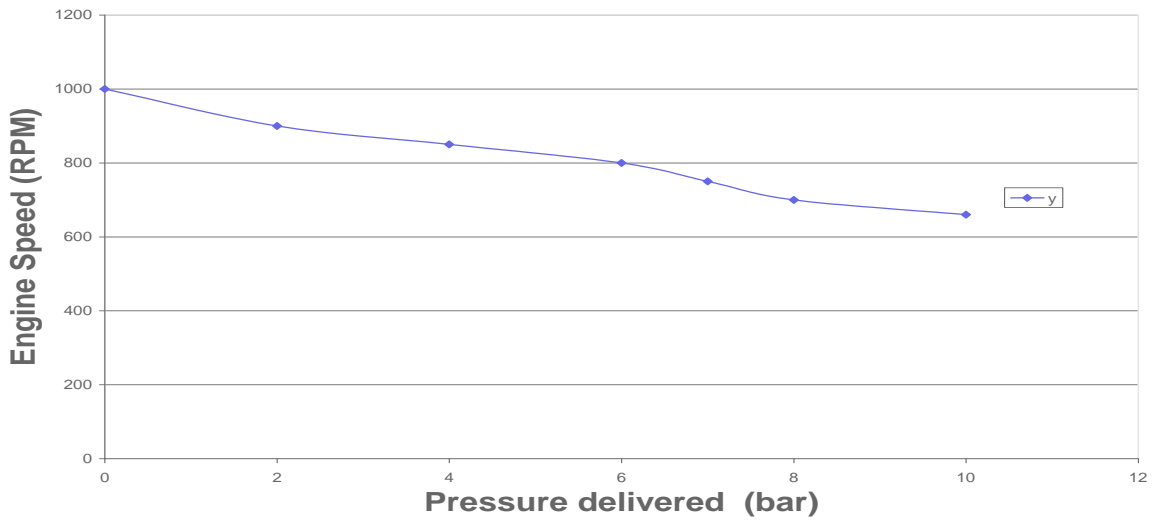


Fig 16 The relation between speed and pressure

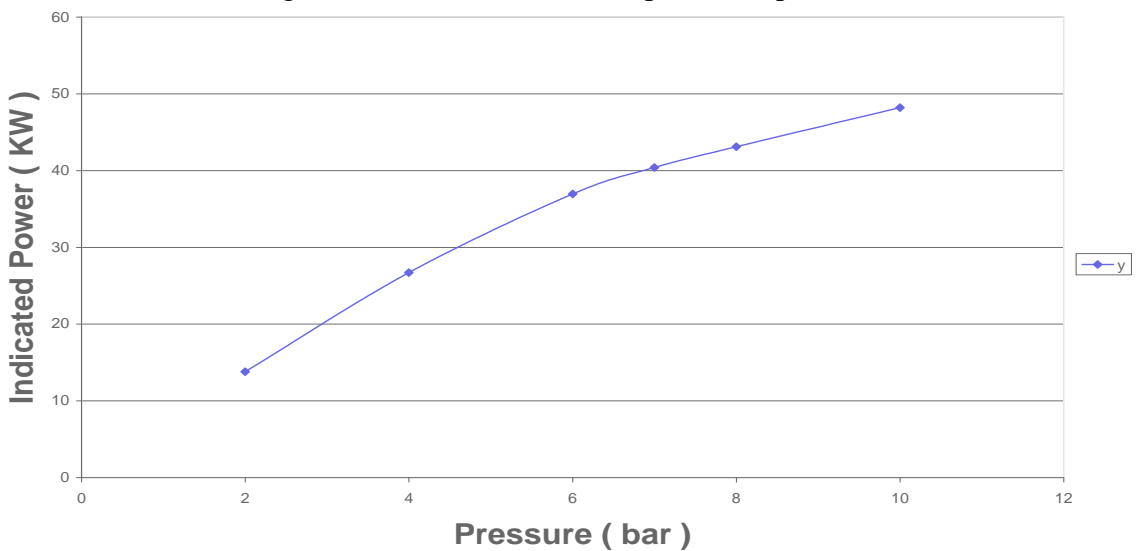


Fig 17 represents the relation between indicated power and pressure

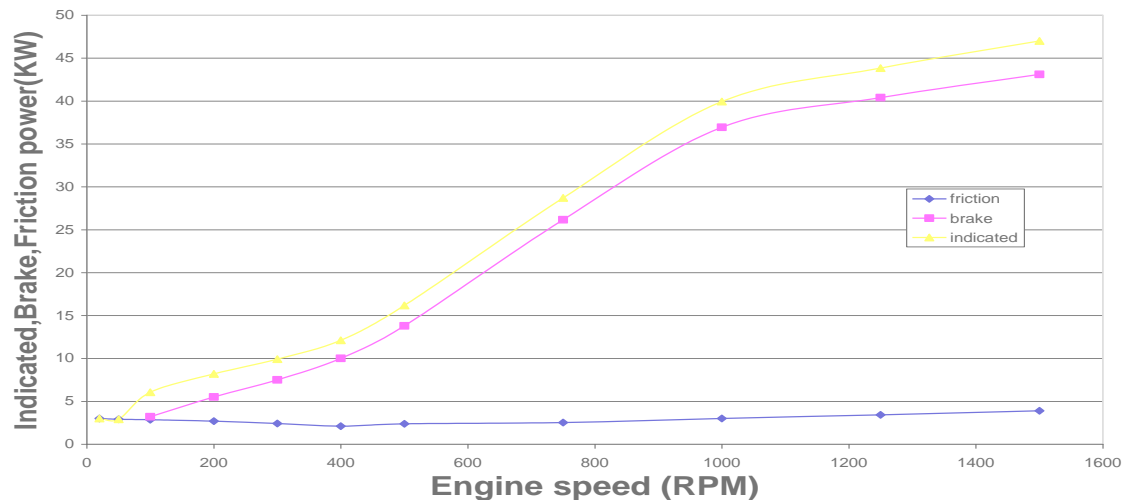


Fig 18 A triple relation between indicated, brake , friction power and speed

Recommendations:

In conclusion, it is recommended to perform more precise tests to study the relations between the practical field of the heating engines as (diesel) with the theoretical field that study the principles of these engines in what is called thermodynamic science which is based on the relations of gas laws by studying the properties of the compressed air in the reservoir at various pressures and make a compression between the engine power and these properties . It is recommended to use this instrument to study the efficiency of the gear box in this dynamometer where various torques could be gained.

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