Testing of Diesel Fuel Injection System

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الأهداء

إلى يا من أجمل اسمك بكل فخر...
إلى من يرتعش قلبي لذكرك...
يا من ادععتني الله اهديك هذا البحث أبي الغالي
إلى أبي الغالي...
إلى طريقي المستقيم
إلى طريق الهداية
إلى ينبوع الصبر والتفاؤل والأمل
إلى كل من في الوجود بعد الله ورسوله أمي الغالية
إلى سندي وقوتي وملاذي بعد الله
إلى من اثروني على أنفسهم
إلى من علموني علم الحياة
إلى من أظهروا لي ما هو أجمل من الحياة أخوتي
إلى الذين حملوا أقدس رسالة في الحياة...
إلى الذين مهدوا لنا طريق العلم والمعرفة...
إلى من علمنا التفاؤل والمضي إلى الأمام...
إلى وقفنا جانباً عندما ضلنا الطريق أم.د. محمد فاضل
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NOMENCLATURE

- \( A \) = area (m\(^2\))
- \( D \) = diameter of nozzle (m)
- \( P \) = Pressure (\( \frac{N}{m^2} \))
- \( Q \cdot \) = heat transferred (\( \frac{m^3}{s} \))
- \( V \) = velocity (\( \frac{m}{s} \))
- \( m \cdot \) = mass (\( \frac{kg}{s} \))
- \( C_d \) = coefficient of discharge
- \( N \) = speed (rpm)
- \( \rho \) = density (kgm\(^{-3}\))
Abstract

The purpose from any successful diesel injection system is to inject fuel accurately and the correct time to each cylinder.

This work investigates the performance of solid injection system experimentally under different load and speed conditions. The experimental results reported dramatic increase in the fuel volume flow rate of because of load increasing.

The measured results were collected at eight different speeds started from 293 rpm and ended with 1300 rpm. It is observed that each nozzle has its own history in the sense of flow rate and velocity. Nozzle no. 4 was chosen as the best nozzle depending on its higher flow rate and velocity as compared to other nozzles. The experimental results are compared with the theoretical one and a reasonable agreement was found.
Chapter One

Introduction

1-1 General

The essential features of the compression-ignition or diesel engine combustion process can be summarized as follows. Fuel is injected by the fuel-injection system into the engine cylinder toward the end of the compression stroke, just before the desired start of combustion. The liquid fuel, usually injected at high velocity as one or more jets through small orifices or nozzles in the injector tip, atomizes into small drops and penetrates into the combustion chamber. The fuel vaporizes and mixes with the high-temperature high-pressure cylinder air. Since the air temperature and pressure are above the fuel's ignition point, spontaneous ignition of portions of the already-mixed fuel and air occurs after a delay period of a few crank angle degrees. The cylinder pressure increases as combustion of the fuel-air mixture occurs [1].

The consequent compression of the unburned portion of the charge shortens the delay before ignition for the fuel and air which has mixed to within combustible limits, which then burns rapidly. It also reduces the evaporation time of the remaining liquid fuel [2]. Injection continues until the desired amount of fuel has entered the cylinder. Atomization, vaporization, fuel-air mixing, and combustion continue until essentially all the fuel has passed through each process. In addition, mixing of the air remaining in the cylinder with burning and already burned gases continues throughout the combustion and expansion processes. One of the major
problems for fuel injection systems is not getting a dribbles at the end of the injection, even a small extra drip would throw off the combustion cycle. Another problem is the cavitation it is produced due to pressure waves initiated by the sudden closure of the needle valve in the injector at the end of effective stroke of the pump plunger, and prevent it return.

In this project an effort has been made to investigate the performance of solid fuel injection system under variable speed and load.

Fig (1.1) Diesel engine

1-2 Requirements of a Diesel Injection System

The purpose of the fuel injection system is to deliver fuel into the cylinder when the fuel reaches inside the cylinder, it is ignites by extremely hot air that has formed there due to the heat of cylinder, while precisely controlling the injection timing, fuel atomization, and other parameters [3]. Some important points must be achieved in any injection which is listed below:
1. The fuel should be introduced into the combustion chamber within a precisely defined period of the cycle.

2. The amount of the fuel injected per cycle should be metered very accurately.

3. The quantities of the fuel metered should vary to meet changing speed and load requirements.

4. The injected fuel must be broken into very fine droplets i.e. good atomization should be obtained.

5. The beginning and the end of injection should be sharp i.e. there should not be any dribbling or after-injection.

6. The weight and size of fuel injection system must be minimum.

1.3 The Aim of the Project Work

The purpose of the present work is to investigate the performance of solid injection system by measuring the quantity of fuel that injected from each nozzle under different speed and injection pressure conditions.

1.4 Layout of the present work

This introduction makes up the first chapter, and is immediately followed by the next chapter which reviews the past results published in the open literature on injection system. Chapter three describes the experimental setup and procedure. Chapter four is devoted to the presentation of results and the discussion of these results. Chapter five presents the conclusions drawn from this work in addition to some future suggestions to develop this work further.
Chapter Two

Types of Fuel Injection in Diesel Engine

2.1 Introduction

In diesel engine air is drawn into the cylinder during suction stroke and compressed to a very high pressure, thus raising air temperature to a value required to ignite the injected fuel into the cylinder [1]. Fuel is injected into the cylinder at the end of the compression stroke, thus requiring a high injection pressure. During the process of injection the fuel is broken into a fine spray of very small droplets. These droplets take heat from the hot compressed air. The surfaces of these droplets form vapor, which in turn mixes with air to form a fuel-air mixture.

2-2 Types of Injection systems

Diesel injection systems can be divided into two basic types. They are:

2.2.1 Air Injection: the fuel is metered and pumped to the fuel valve by a camshaft driven the fuel pump. The fuel valve is opened by means of mechanical linkage operated by the camshaft which controls the timing of injection [4]. The fuel valve is also connected to a high pressure line fed by a multistage compressor which supplies air at a pressure about 60 to 70 kgf/cm². When the fuel valve is opened, the blast sweeps along with it the fuel and a well-atomized fuel spray is sent to the combustion chamber. This method is generally use in the large stationary and marine engines. The advantages of air injection system are discussed below:

1. Good atomization obtained. A high indicated mean effective pressure can be attained as rapid combustion results due to good mixing of fuel and air.
2. Heavy and viscous fuels, which are cheaper can also be injected.

3. The fuel pump is required to develop only a small pressure.

**The main Disadvantages are reported below:**

1. It’s complicated and expensive since it’s required a high pressure multistage compressor.

2. Separate mechanical linkage is required to time the operation of the fuel valve.

3. due to the compressor and the linkage the bulk of engine increase. This also results in reduced (bhp) due to power losses.

4. The fuel in the combustion chamber burns very near to the injection nozzle which many times lead to overheating and burning the valve and its seat

5. The fuel valve seating requires a considerable skill.

6. In the case of sticking of the fuel valve, the system becomes quite dangerous due to the presence of high pressure air.

![Air Injection System Image](image)

Fig (2.1) Air injection system [5]
2.2.2 **Solid injection**: injection of fuel directly into the combustion chamber without primary atomization is termed as solid injection. This is also called airless mechanical injection [4]. Every solid injection must have:

1. A pressurizing unit (the pump) and
2. An atomizing unit (injector).

The different types of solid injection systems vary in the manner of operation and control of these two basic elements. The main types of modern fuel injection systems are:

1. The individual pump and injector (jerk pump system). In this system there is a separate metering and compression pump is used for each cylinder. The pump which meters the fuel also times the injection. A jerk pump is a reciprocating fuel pump which meters the fuel and also furnishes the injection pressure. Jerk pump is universally used for medium and high speed diesel engines.

![Jerk system](image)

**Fig (2.2) Jerk system [5]**

2. Common rail system. The atlas imperial diesel company of Oakland, California, Developed its first common-rail diesel fuel system in 1919. It is consist of an
injection pump, injection line, and fuel injectors. In this system for each cylinder there is a separate metering and timing element which is connect to an automatic injector injecting fuel into the cylinder [4]. Also it’s requires that the nozzle for different cylinder must be accurately matched to insure good fuel distribution between various cylinder.

![Common rail injection system](image)

**Fig.(2.3) Common rail injection system [5]**

3. Distributor system. Fig.(2.4) shows a schematic diagram of a distributor system. In this system the pump which pressurizes the fuel also meters and times it. The fuel pump after metering the required amount of fuel supplies it to a rotating distributor at the correct time. To supply each cylinder, the number of injection stroke per cycle for the pump is equal to the number of cylinders. The advantages of this system are shown;

1. Small cost.

2. Uniform distribution

3. One metering element
4. Electrical Injection

Unlike traditional hydraulic injection, which use energy even while idle, all-electric injection consume energy only when required for a given action, and motor output is matched to load requirements.

Instead of being driven by a hydraulic system, all-electric machines use digitally controlled, high speed and highly efficient servo motors to drive the whole process. Each axis is controlled by an independent motor for injection, extruder, clamping and ejection.
2.3 Fuel Pump

A large number of fuel pump designs have been developed by various manufactures. It’s not possible to discuss all of them. Therefore only one type of fuel pump will be discussed. Fig.(2.6) shows a complete injection system.

Operation: when the plunger is at bottom of its stroke the fuel flows through the inlet port into the barrel and fills the space above the plunger and also the vertical groove and the space below the helix. When the plunger starts moving up, a certain amount of fuel goes out of the fuel chamber through the ports until the plunger reaches its position and closes the ports. On further upwards movement of the plunger the trapped fuel is compressed and is forced out through the delivery valve to the pipe leading to the injector which immediately injects the fuel into the combustion chamber. The injection process continues till the end of the upward stroke of the plunger when the lower end of the helix uncovers the spill port.

![Injection Pump Diagram](image)

Fig.(2.6) Injection pump [5]
2.4 Injection Nozzles

The main requirements of an injector nozzle are as follows [4]:

(1) To inject fuel at sufficiently high pressure so that the fuel enters the cylinder with a high velocity (less penetration).

(2) The penetration should not be high so as to impinge on cylinder walls. This may result in poor starting.

(3) The fuel supply and cut off should be rapid. There should not be any dribbling.

The type of nozzle used is greatly dependent on the type of combustion chamber in use. The mixing of fuel and air depends on the relative velocity between them, which in turn is greatly affected by the nature of the air movement in the combustion chamber. The injection nozzles may be classified as open or close type

**Open type:** has the fuel orifice, or orifices and the part of the fuel passageway open to the burner or cylinder pressure at all times. Open burners are cheap but less efficient and are rarely used, one example being opposite piston two stroke Junkers diesel engines.

**Closed type:** the advantages of a closed nozzle as compared to those of an open nozzle lie in its avoidance of pressure drop and in its control of injection pressure also the needle cannot be blocked by deposits this nozzle is proffered in practice.

2.4.1 Component of Fuel Injector Nozzle

Fuel injector nozzle is composed of the following components. They are,

1. Nozzle holder
2. Pressure spring
3. Cap nut
4. Retaining nut
5. Pressure spindle and
6. Needle valve assemblies

Fig. (2.7) Nozzle assembly [5]

2.5 Closing Remarks

The previous sections deal with the analysis of different types of injection systems. An attempt has been done to study the performance of solid injection system experimentally. The pump supplies diesel to four injectors which inject fuel through four scaled tubes instead of engine cylinders. The pump is rotating with the aid of an electric motor instead of crankshaft in real engine.
Chapter Three
Experimental Work

3-1 Introduction

In general, the main function of the diesel fuel system is to inject the amount of fuel into the engine cylinder and at the same time to all cylinders in which the combustion stage will occur in a timely manner, The combustion occurs in the diesel engine when the fuel mixture mixes with the compressed hot air and does not use an electric spark as in the gasoline engine.

3-2 Parts of the injection system

3.2.1 Pump

Is the device that pumps fuel in the cylinder of a diesel engine traditionally, the injection pump is driven indirectly from the crankshaft by gears, chains or a toothed belt [often the timing belt] that also drives the camshaft. But in this experiment the pump is rotated by the electrical motor they are connected together by rod shaft.

Fig. (3-1) Injection Pump
3.2.2 Injection nozzles

A sample of the injector assembly is shown in Fig.(3.2). For experimental purpose the pipes that connect the pump with injectors are welded efficiently with copper pipes to increase their length.

![Fig (3.2) Injector assembly](image)

3.2.3 Motor

The electric motor has a speed about 1400rpm rotates the injection pump through a coupling flange as shown in Fig.(3.3).

![Fig (3.3) Motor device](image)
3.2.4 Pressure gauges

Pressure gauges are the most instruments that can used in any project. It indicates an attention to maintenance and reliability that can be compromised. In this work two pressure gauges have been used. The first one for low pressure cycle reads up to 60 bars and the second gauge records the pressure in the high pressure cycle. The latter can be read up to 600 bars.

Fig (3.4) Gauge Pressure

3.2.5 Tank with filter

A 60 liters capacity fuel tank has been used in this project. All the necessary pipes that connects the tank with the injection pump are fixed probably. The considerable fuel tank is shown in Fig. (3.5).

The fuel filters help to protect the most expensive parts of the engine by filtering out any foreign particles that can damage a fuel injector. Protecting the fuel system and the engine from harmful particles, helps to prolong the life of your vehicle. On the other hand the damaged fuel filter can result in erratic performance, poor gas mileage and in some cases, complete engine shutdown. Even the smallest particles can cause considerable wear and tear to the engine.
3.2.6 Scaled tubes

Instead of four cylinders in ordinary diesel engine, four scaled tubes of 25ml size is used in this project. The injector nozzles inject diesel fuel directly through each scaled tube. It is supplied with a safety valve at the end of it to keep the fuel inside the tube.
3.2.7 IC Drive

An electrical electronic component is used to control another circuit or component, such as a high-power transistor, liquid crystal display (LCD), and numerous others. It is utilized to regulate the current flowing through a circuit. An amplifier can also be considered a driver for a voltage regulator that keeps an attached component operating within a broad range of input voltages.

In this project the IC drive is used to change the speed of motor which in turns the injection system under study is investigated with different speed and load conditions.

![IC drive device](image)

**Fig (3.7) IC drive device**

All the test rig parts are settled to gather with a frame that is used for this purpose. The final setup of the experimental test rig is shown in Fig. (3.8).
Fig.(3.8) Testing diesel fuel injection system.
3.3 Experimental Procedures

The experimental steps start with pumping the diesel fuel to the injectors at high pressure. The fuel is passing through filter which is used to protect the fuel pump. Each injectors sprays the fuel though nozzle to the scaled tube. Then we set the time to 20 sec using stop watch and measure the volume flow rate for each nozzle at different speed. The motor speed is controlled by IC drive. The fuel is collected inside the tubes and accumulates in it. The discharge valve in each tube is then opened and repeat the same process at different speeds. The operating range of motor speed is taken as (293, 350, 445, 510, 700, 900, 1100, 1300) rpm

The flow velocity in each nozzle is calculated from equation below:

\[ V = \frac{Q}{(\pi/4)d_n^2} \]  

(3.1)

The diameter of nozzle is measure and found to be 0.6 mm

The mass flow rate is given by:

\[ m^* = \rho_f VA \]  

(3.2)

The density of fuel \( \rho_f \) is taken to be 830 kg/m\(^3\)

The pressure of injection is measured with the aid of pressure gauge at each speed.

3.4 Theoretical Background

Theoretically the quantity of fuel injected per cycle depends upon the amount of air available (displacement volume) and the load of the engine. The fuel is supplied into the combustion chamber through the nozzle holes. Roughly the velocity of the fuel through nozzle orifice can be given by:
\[ V_t = C_d \sqrt{\frac{2 \Delta P_N}{\rho_f}} \]  \hspace{1cm} (3.3)

\( V_t \): theoretical velocity of fuel.

\( C \): orifice flow coefficient \( (0.66) \)

\( \Delta P_N \): pressure difference between injection and cylinder pressure

The total volume of the fuel injected per second \( Q \) is given by:

\[ Q = \left( \frac{\pi}{4} d_n^2 \times n \right) \times V \times \left( \frac{\theta}{360} \times \frac{1}{N} \right) \times \left( \frac{N}{60} \right) \]  \hspace{1cm} (3.4)

\( d_n \): diameter of orifice, \( n \): number of hole \((=1)\), \( \theta \): injection duration

\( N \): Engine revolution per minute.

\[ m_f^* = C_d A_f \sqrt{2 \rho_f \Delta P_N} \]  \hspace{1cm} (3.5)
Chapter Four

Results and Discussions

4.1 Introduction

In this chapter the experimental results are presented. The experimental findings are measured at each motor speed. As mentioned before 8 speeds are chosen with the help of tachometer.

![Flow rate vs speed graph](image)

**Fig.(4.1) Volume flow rate with speed**

Fig.(4.1) shows the effect of variable load condition in terms of motor speed on the volume flow rate in each nozzle. An increasing the flow rate is observed as a result of increasing speed due to increase in the pressure of injection which in turns
increases the quantity of fuel discharged from pump. It can be seen that nozzle no. 4 sprays more fuel as compared to other nozzles. Therefore, the performance of each nozzle can be investigated clearly from this study.

![Fig.(4.2) Injection pressure with speed](image)

The relation between engine speed and injection pressure is shown in Fig.(4.2). Since the fuel pump is connected directly with the motor via flange coupling, so it's logical to expect an increase in the pressure of injection because of increase in the load condition. The maximum pressure of injection up 1300 rpm was 106 bar.
Fig.(4.3) Injection pressure with speed

Fig.(4.3) displays the effect of variable speed on the flow velocity. The fuel velocity is determined from equation (3.2). The velocity of fuel increases with increasing the motor speed. While the velocity of nozzle 1 is 1.131 m/s at 293 rpm, it was 3.399 m/s at 1300 rpm. At 1300 rpm the flow velocity of nozzle 4 is 7% higher flow velocity of nozzle one.

The massage from this figure says: since the flow velocity of each nozzle is differing from other nozzles, hence the performance of each nozzle is different.
Fig.(4.4) Total mass flow rate with speed

Fig.(4.4) shows the comparison between experimental and theoretical results. As the motor speed is increased, the total accumulated mass flow rate increased. The difference between experimental and theoretical results is due to the variation of pressure difference between nozzle and the pressure inside the combustion chamber; therefore the pressure difference is kept to 50 bars.
Chapter Five

Conclusions and Future Work

5.1 Conclusions

The main conclusions are drawn from the present study:

1. Noticeable increase in the flow rate of injection as a result of increasing speed.
2. As the load increases, the pressure of injection increases.
3. Each nozzle has its own flow rate and velocity.
4. The experimental results confirmed that the best nozzle was nozzle no.4 followed by nozzle no.3 then nozzle no.2 and finally nozzle no.1 comes.
5. The experimental device can be considered as a promising tool to investigate and calibrate the performance of solid injection system.

5.2 Future Work

The main recommendations to develop this work in the future can be summarized below:

1. Study the performance of air injection system by inserting an air compressor to the test rig.
2. An accurate flow meter has to added after the pump and before the injectors.
3. Simulation study using Solid works should be studied to compare the simulated results with the experimental findings.
List of References


اسم التجربة : اختبار مضخة حقن الوقود اللاهوائي (Testing of Solid Fuel Injection Pump)

الغرض من التجربة:

التعرف على المبدأ الرئيسي لنظام حقن الوقود الصلب في محركات الديزل ومعايرة عمل هذه المضخة من خلال حساب معدل التدفق الحجمي للفوائد وسرعة جريان الوقود بالإضافة إلى معایرة عمل النواعير عند تعرضها لسرعات دوران وتحملات مختلفة.

المقدمة:

استعملت محركات الديزل في البداية للأغراض الإنتاجية في الصناعة وكذلك في البواخر والإغراض البحرية ونظرا لضخامة حجمها وثقل وزنها ولم تكن في حينها ملاءمة للكثير من السيارات ولكن لمزاياها المتعددة من حيث رخص الوقود وعدم وجود منظومة الاحتراق المبخرة وعمر مشتغلين في هذا الحقل إلى اجراء تحسينات وإجراء التحسينات لجعلها ملائمة. في بداية الأزمة كانت طريقة حقن الوقود تتم بواسطة عصف الهواء ذو الضغط العالي جدا (Air injection) ولكن هذه الطريقة في الوقت الحاضر استبدلت بطريقة الحقن الجاف أو اللاهوائي (Solid injection) والذي يكون من جزء الضخ من مكبس واستطوانات في جميع المحطات ووجود وحدة أخرى تسمى وحدة الحقن بين المضخة والحائق أي في محركات الديزل. وبصورة عامة الوظيفة الرئيسية لمنظومة حقن وقود الديزل هي حقن كمية من الوقود في الوقت المناسب لتحول إلى رذاذ داخل أسطوانة المحرك. يحدث الاحتراق في محرك الديزل عندما تختلط شحنة الوقود مع الهواء الحار المضغوط ولا تستخدم هنا شرارة كهربائية كما في محرك البنزين.

مجالات استخدام محركات الديزل

1. في محطات توليد الطاقة الكهربائية. (وذلك لقلة التكاليف الكلية وقلة احتياجه إلى موارد المياه ورخصة التكاليف الكلية وقلة احتياجها إلى موارد المياه ومتين)

2. القاطرات

3. في البواخر والإغراض البحرية المختلفة.

4. في المناجم والانفاق ومكائن الحفر في الآبار بالإضافة إلى سيارات النقل الخاصة والعامة.

واحطط في محركات الديزل أن تكون:

1. خفيفة الوزن وسريعة الدوران وصغيرة الأسطوانات.
2. سهولة الإدارة في السرع المختلفة وبهد ادارتها في الأجواء الباردة.

3. إن لم تحدث الكثير من الدخان أو غازات العادم ذات الرائحة.

مزایا محركات الديزل ((Advantage of Diesel Engine))

1. قلة استهلاك الوقود
2. رخص كلفة الوقود
3. توفير الأمان في الاستعمال

4. العزم (Torque) يتناسق وخاصية في السرع النهائية العالية.
5. اداء المحرك (Performance) بالنظر لعدم وجود منظومة الاشتعال والمبخرة وملحقاتها الشائعة.

في محركات البنزين والتي تسبب 25% تقريبا من عطلات المحرك لذلك فإن محرك الديزل أكثر

6. ملائم في اداء العمل وتوقفاته قليلة نسبيا.

(الادامة (Maintenance))

بما أن مضخة الضغط العالي والحاقات دقيقة الصنع وبقياسات مضبوطة لذا فإنها تحتاج إلى ادامة
قليلة. على سبيل المثال فإنها تشتعل لمدة تصل إلى (5000)خمسة آلاف ساعة بدون ادامة وكذلك

بالنسبة للحاقات تحتاج ادامة أقل من شمعات الجر.

(Mixture Distribution)

7. توزيع المزيج

بالنظر لمعايرة كميات الوقود بصورة متساوية لكل حاقنة وثم حقن هذه الكميات بتوقيت صحيح الى
كل اسطوانات لذا تعطي الافضلية لهذا النظام في التوزيع.

8. قلة فقدان الحرارة في منظومة التبريد لذا يمكن استعمال مبردة صغيرة.
9. غازات العادم أقل ضررا وذلك لخلوها من غاز أول أوكسيد الكربون (CO).
10. عدم وجود تداخل في موجات الراديو بسبب خلوها من منظومة الاشتعال.
11. سرعة ثقيلة للحمل الكامل (Full load) بعد ابتداء التشغيل بقليل.

وظيفة منظومات حقن الوقود:

تقوم منظومات حقن الوقود على اختلاف انواعها بالواجبات ادناه:
1. معايرة كمية الوقود اللازم حقنها أي تثبيت كمية الوقود الموزعة على كل من اسطوانات المحرك عند حمل معين وذلك لضمان عمل المحرك بسرعة منتظمة.
2. توقيت الحقن وهو عبارة عن تحديد بدء الحقن في نظام دورة المحرك بحيث يستطيع أن يحرق أكبر كمية من الوقود مع الهواء المضغوط على أقصى كفاءة.
3. تنظيم معدل الحقن.
4. تذربة الوقود.

المجلة المستخدمة في التجربة:
1. خزان لجمع الوقود.
2. فلاتر لتصفية الوقود القادم من الخزان.
3. مضخة لنقل الوقود.
4. مضخة لحقن الوقود.
5. ماطور كهربائي.
6. أنابيب مطاطية لنقل الوقود من الخزان إلى المضخة.
7. ساعة توقيت لقياس الوقت اللازم.
8. أنابيب مطاطية لنقل الوقود من الخزان إلى المضخة.
9. مقياس لقياس عدد الدورات (التاكوميتر).
10. الزوجات التي تقوم بنشر الوقود وتجميعه في مكانه الخاص.
11. أنابيب أخرى وهي أنابيب من نحاس تقوم بقل الوقود من مضخة حقن الوقود إلى الزوجات.

طريقة إجراء التجربة:
قبل إجراء التجربة لا بد أن نعرف بأن هناك طريقتان لإجراء التجربة وهي ان نثبت الحجم ونغير الحجم أو نثبت الحجم ونقوم بتغيير الزمن. يكون الوقود في الخزان في بداية التجربة أعلى من مستوى الوقود في مضخة حقن الوقود.

عند التشغيل أي عند غلق الدائرة الكهربائية تدور المضخة وينقل الوقود من الخزان إلى الفلتر ويزداد ضغط الوقود هنا وتعمل الفلتر على تصفية الوقود وذلك لحماية أجزاء الوقود.
ان المضخة تعمل على ضخ الوقود بضغط عالي جدا الى ال
لإجراء عملية الاحتراق ولذا السبب تكون التابيب الموصلة بين المضخة و
نقطة التوصيل (nozzle) بحيث يكون هذا الضغط كافٍ
اما البالغات (النرولات) تعمل على ترذيب الوقود وتحول الوقود من سائل الى ذرات صغيرة وهذه
الذرات الصغرى تكون منتشرة ووزنها داخل غرفة الاحتراق وعند الحقن في الاسطوانة يكون الوقود
حار جدا والهواء يعتبر ساخنا نسبة الى الوقود في
الانتقاص ومن ثم نثبت الزمن ونقرأ الحجم ون تشغيل ساعة التوقيت. ونحسب عدد الدورات (N) ومن
الاطفو بواسطة جهاز قياس عدد الدورات وصولا الى الوقت (20sec) فتجمع الوقود داخل الاسطوانة
ونقرأ الحجم لكل اسطوانة ثم نفتح صمام التصرف من الاسطوانات (valve) وتكرر العملية.

المناقشة

1. حساب الحجم الزمني للوقود المحقون لكل نرول عند سرع واحتال مختلفة وايجاد العلاقة بينهما
2. حساب كتلة الوقود المحقون في جميع النرولات عند سرع واحتال مختلفة وايجاد العلاقة بينهما
3. ما هو الفرق بين نظام الحقن والهوائي والصلب ؟
4. ايجاد العلاقة بين ضغط الحقن مع سرعه دوران الماطور.
5. المقارنة بين كتلة الوقود المحقون في جميع النرولات نظريا وعمليا.