بسم الله الرحمن الرحيم

Department of Mechanical & Chemical Engineering (MCE)
ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

Organisation of Islamic Cooperation

PREDICTION OF ENGINE CONDITION BY ANALYZING SOUND WAVE

BY

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A thesis submitted to the Department of Mechanical & Chemical Engineering (MCE) in partial fulfillment of the requirement for the degree of Bachelor of Science in Technical &Vocational Education in Mechanical Engineering

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DECLARATION

It is hereby declare that the undergraduate project work reported in this thesis has been performed by me and this work has not been submitted elsewhere for any purpose (except for publication).

Signature of the candidate

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Dedicated

To

Our Beloved Parents

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We seek excuse for any errors that might be in this report despite our best efforts.

ABSTRACT

Engine performance very much depends on the proper alignment & working condition of different components (such as piston, piston rings, connecting rod, different valves, crank shaft, cam shaft etc), Lubrication system, and fuel injection system. If the components are not properly aligned or working condition is not good then engine produce excessive noise other than its ideal condition. This paper shows a systematic way to determine engine condition by analyzing sound wave produced by engine. Hence engine is tested for three working condition. That is when it is working at ideal speed, without one spark plug and without an air filter. Engine sound is recorded by a sound recorder for different conditions and then analyzed on MATLAB. It has been observed that for a particular problem engine produce vibration of certain frequency. If the frequency range of particular problem is known then it will be easier to predict the problem of the engine**.**

Keywords: Engine condition, air filter, spark plug, sound wave, MATLAB, Spectrogram

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Chapter-1

INTRODUCTION

1.1 Thesis Organization

The petrol engine is a very complicated system due to the existence of the turbocharger and all the other subsystems. These engines offer various advantages, among which are high efficiency, high power concentration and long operational lifetime On the other hand, their large size can cause great difficulties in the diagnosis of improper operation. The entire system is so complicated that in many cases it is almost impossible to predict by simple analysis the impact of a malfunction on a measurable engine parameter.

Engineers make use of measurable engine parameters to examine the behavior of petrol engine. The parameters usually measured, are exhaust gas temperatures and cylinder pressure diagrams. But even after this data is in hand it is extremely difficult in many cases to identify the cause of the faults since all these parameters may have a similar effect.

This paper deals with the analysis of engine condition by simply analyze sound produced by the engine. If the components of engine are not properly aligned or working condition is not good then engine produce excessive noise other than its ideal condition. Hence engine is tested for three working condition due to lack of time. That is when it is working at ideal speed, without one spark plug and without an air filter. Engine sound is recorded by a sound recorder for different conditions and then analyzed on MATLAB

1.2 APPLICATION AREA / OBJECTIVES

- It provides knowledge about the fault and its recovery techniques even for the novice.
- It provides necessary procedures for adjusting engine parameters.
- It gives visual explanations of important engine systems and exploded views.
- It avoids any dependence on printed repair manuals and troubleshooting charts.
- It maintains a consistent and high level of expertise in engine diagnosis.
- It avoids any dependence on relatively inexperienced diagnosticians (mechanics)
- by giving expert diagnosis procedures.

It gives consistent and systematic diagnosis procedures

1.3 DEFINITION OF USED TERMS

Definition of 'Engine:

An engine is a device, which transforms one form of energy into another form. Normally, most of the engines convert thermal energy into mechanical work and therefore they are called 'heat engines'.

Heat engines can be broadly classified into two categories:

i. Internal Combustion Engines (IC Engines)

ii. External Combustion Engines (EC Engines)

1.4 IC and EC Engines

IC Engines

1.GASOLINE ENGINE –AUTOMOTIVE, MARINE AIRCRAFT

2.DIESEL ENGINE -AUTOMOTIVE,MARINE,POWER,LOCOMATIVE

3.GAS ENGINES –INDUSTRIAL POWER

EC Engines

1.STEAM ENGINES – LOCOMOTIVES,MARINE
2.STEAM TURBINE – POWER,LARGE MARINE

1.5 Classification of Internal Combustion Engines

Internal Combustion engines are of two types,

i. Rotary engines

ii. Reciprocating engines

a)Two stroke & four stroke engines
b)Petrol & diesel engines

1.6 TERMS CONNECTED WITH I.C. ENGINES

Bore: The inside diameter of the cylinder is called bore

Stroke: The linear distance along the cylinder axis between two limiting position s is called stroke.

Top Dead Center (T.D.C.) : the top most position of the piston towards cover end side of the cylinder is called T.D.C.

Bottom dead Center (B.D.C.) : The lowest position of the piston towards the crank end side of the cylinder is called B.D.C.

Clearance Volume : The volume contained in the cylinder above the top of the piston , when the piston is at top dead center , is called the clearance volume.

Swept Volume: The volume swept through by the piston in moving between T.D.C. and B.D.C, is called swept volume or piston displacement.

Compression Ratio: It is the ratio of Total cylinder volume to clearance volume

1.7 PETROL ENGINE:

1.7.1 CONSTRUCTION DETAILS

Basic Engine Components and Nomenclature

Even though reciprocating internal combustion engines look quite simple, they are highly complex machines. There are hundreds of components that have to perform their functions satisfactorily to produce output power. There are two types of engines, viz., spark ignition (S1) and

compression-ignition (CI) engine. Let us now go through the important engine components and the nomenclature associated with an engine.

Cylinder

As the name implies it is a cylindrical vessel or space in which the piston makes a reciprocating motion. The varying volume created in the cylinder during the operation of the engine is filled with the working fluid and subjected to different thermodynamic processes. The cylinder is supported in the cylinder block.

Piston

It is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system. It fits perfectly (snugly) into the cylinder providing a gas-tight space with the piston rings and the lubricant. It forms the first link in transmitting the gas forces to the output shaft.

Combustion Chamber

The space enclosed in the upper part of the cylinder, by the cylinder head and the piston top during the combustion process, is called the combustion chamber. The combustion of fuel and the consequent release of thermal energy results in the building up of pressure in this part of the cylinder.

Inlet Manifold

The pipe which connects the intake system to the inlet valve of the engine and through which air or air-fuel mixture is drawn into the cylinder is called the inlet manifold.

Exhaust Manifold

The pipe that connects the exhaust system to the exhaust valve of the engine and through which the products of combustion escape into the atmosphere is called the exhaust manifold.

Inlet and Exhaust Valves

Valves are commonly mushroom shaped poppet type. They are provided either on the cylinder head or on the side of the cylinder for regulating the charge coming into the cylinder (inlet valve) and for discharging the products of combustion (exhaust valve) from the cylinder.

Connecting Rod

It interconnects the piston and the crankshaft and transmits the gas forces from the piston to the crankshaft. The two ends of the connecting rod are called as small end and the big end. Small end is connected to the piston by gudgeon pin and the big end is connected to the crankshaft by crankpin.

Crankshaft

It converts the reciprocating motion of the piston into useful rotary motion of the output shaft. In the crankshaft of a single cylinder engine there is pair of crank arms and balance weights. The balance weights are provided for static and dynamic balancing of the rotating system. The crankshaft is enclosed in a crankcase.

Piston Rings

Piston rings, fitted into the slots around the piston, provide a tight seal between the piston and the cylinder wall thus preventing leakage of combustion gases

Gudgeon Pin

It forms the link between the small end of the connecting rod and the piston.

Camshaft

The camshaft and its associated parts control the opening and closing of the two valves. The associated parts are push rods, rocker arms, valve springs and tappets. This shaft also provides the drive to the ignition system. The camshaft is driven by the crankshaft through timing gears.

Cams

These are made *as* integral parts of the camshaft and are designed in such a way to open the valves at the correct timing and to keep them open for the necessary duration.

Fly Wheel

The net torque imparted to the crankshaft during one complete cycle of operation of the engine fluctuates causing a change in the angular velocity of the shaft. In order to achieve a uniform torque an inertia *mass* in the form of a wheel is attached to the output shaft and this wheel is called the flywheel.

Four-stroke Spark-ignition Engine

In a four-stroke engine, the cycle of operations is completed in four strokes of the piston or two revolutions of the crankshaft. During the four strokes, there are five events to be completed, viz, suction, compression, combustion, expansion and exhaust. Each stroke consists of 180° of crankshaft rotation and hence a four-stroke cycle is completed through 720° of crank rotation. The cycle of operation for an ideal four-stroke SI engine consists of the following four strokes:

1.8 Introduction of EFI Engine

EFI

An engine’s fuel injection system must manage three things: how much air an engine has, how much fuel is needed to mix with the air (dependent on conditions) and what the proper timing for the ignition of the mixture will be. All the basics of power that dictate how well an engine performs are controlled by a modern car’s EFI system. For example, let’s say your car has a turbocharged engine and at 4,000 rpm with full boost it will require 18-20 degrees of timing.

Air filter

An air filter is an important part of a car's intake system, because it is what allows the car to "breathe." An engine needs an exact mixture of fuel and air in order to run, and all of the air enters the system first through the air filter. This catches the dirt and other foreign particles in the air, preventing them from entering the system and possibly damaging the engine.

Car air filters are generally pretty cheap, due to the filter's simple construction. Most are paper-

Chapter 2
Literature Review

2.1 ENGINE NOISE SOURCES

It is well accepted that the major noise sources in internal combustion engines include the following categories:

Combustion-related process,

Mechanical movements,

Intake and exhaust systems

The rest two categories can be studied with the same linear system. The deterrence is in the nature of the excitation forces. The intake and exhaust systems can be modeled similarly with deterrence in their source characteristics

The Combustion and Mechanical Induced Noise- The structure of a diesel engine can be sampled to a one-degree-of-freedom system as shown in Fig. 1(a) [1]. The equivalent electrical circuit of the model is given in Fig. 1(b). In the case of the combustion-induced noise, the acting force is composed of the gas excitation, inertia and friction forces. The mechanical-induced noise model considers the reversible force due to the engine crank mechanism and inertia force in practice, a diesel engine has numerous resonance frequencies because most mechanical parts inside the engine can be simulated by the above model [11]. For example, the theoretical analysis indicates that the crankcase walls may have more than

20 resonance frequencies in a narrow-frequency band.

The system responses are rather complex. One of the reasons is due to the numerous numbers of the excitation forces. Another reason is that most of the excitation forces are the non-stationary impacts in nature. Hence, the overall system response is a combination of all the individual responses expressed as [12].

Engine Noise - An engine is a mechanical device that produces some form of output from a given input. An engine whose purpose is to produce kinetic energy output from a fuel source is called a prime mover, alternatively, a motor is a device which produces kinetic energy from a preprocessed "fuel" (such as electricity, a flow of hydraulic fluid or compressed air). The various factors that contribute to the noise in engine.

Combustion Noise - Combustion noise is produced because of unsteady combustion of fluid and is of two types turbulent combustion noise and periodic combustion oscillation. The turbulent combustion noise or combustion roar has no specific frequency but is composed of broad-band frequency spectrum. This noise is amplified if the flame is enclosed with the system resonance frequencies dominating. The requirements for reduction of this noise tend to be opposition to those for efficient combustion. Combustion oscillations involve a feedback cycle that converts chemical energy into oscillatory energy in the gas flow to the combustion region. The mechanism is such that the pressure waves generated are so phased to the velocity fluctuations. The noise spectrum involves one specific frequency and its harmonics and that frequency is related to the resonant modes of the combustion chamber. Some of the possible cures are:

1. Modification of combustion chamber geometry

2. Change of air-fuel ratio, burner type etc.

3. Change of burning rate

It should be noted that combustion roar in reciprocating engines which has frequency of the firing rate is not related to the combustion noise, but is due to the gross fluctuation in the flow rate produced by periodic action.

Mechanical Noise - Mechanical noise is the noise which is generated by various impacts between the engine parts. This noise source is more important in the higher frequency range rather than in lower frequency range where combustion noise is important. There are lots of moving parts, for example, gear, valves, and rocker arms, piston and cylinder liner some are as follows:

Engine clicking noise - A clicking or tapping noise that gets louder when you reserve the engine is probably tappet or upper valve-train noise caused by one of several things low oil pressure, excessive valve lash, or worn or damaged parts.

Collapsed lifter noise - Worn, leaky or dirty lifters can also cause valve-train noise. If oil delivery is restricted to the lifters (plugged oil galley or low oil pressure) his lifters won't "pump up" to take up the normal slack in the valve-train. A "collapsed" lifter will then allow excessive valve lash and noise.

Valve lashes noise -Too much space between the tips of the rocker arms and valve stems can make the valve-train noisy, and possibly cause accelerated wear of both parts.

Damaged engine parts noise- Excessive wear on the ends of the rocker arms, cam followers (overhead cam engines) and/or valve stems can open up the valve lash and cause noise.

Rapping or deep knocking engine noise - A deep rapping noise from the engine is usually "rods knock" a condition brought on by extreme bearing wear or damage. If the rod bearings are worn or loose enough to make a dull, hammering noise.

Piston Slap Noise -Piston slap noise is generated by the sudden impact of the piston to the

Cylinder wall is considered to be predominant due to the higher amount of energy released. In the compression stroke, the connecting rod pushes the piston upwards overcoming the gas force. The force acting on the piston has a lateral component and the piston slides upwards on the minor thrust side of the cylinder wall. Thus, as the crank pin passes through the cylinder center line, the lateral component of force on the piston pin changes direction, causing the piston to accelerate through the clearance and slap against the major thrust side of the cylinder wall. There are at least two piston slaps per revolution, but the major impact occurs at T.D.C. before the power stroke. These simple models do not take into account others factors which may affect the piston motion such as:

1. Piston pin offset.
2. Rocking motion of piston.
3. Frictions at piston pin as well as piston's outer surface.
4. Piston configuration, especially under operation.
5. Pressure distribution around piston due to the squeezing motion of oil film.
6. Compliance of cylinder liner wall.

2.2 Relation between noise, engine design and parameters

Despite the numerous exciting forces which almost simultaneously excite the engine structure. Since the gas force resulting from combustion tends to be the predominant force in most of the engines, the relationship between the gas force characteristics and emitted noise can be used to establish a basic model to identify the effects of fundamental engine design and operating parameters.

The three basic parameters of an engine are

1. Speed
2. Size
3. Load

Engine speed -The engine structure characteristics can be defined by use of electro-dynamic vibration generators, and the broad response readily established as shown by the solid envelop line. It will be seen that when the structure is subjected to a constant sinusoidal force it exhibits maximum response in the high - frequency range from 800-2000 Hz.

If the engine speed is doubled, the engine structure is now excited with lower order harmonics which have higher amplitudes. Since the general slope of the force spectrum is about 30 dB/decade an increase of excitation by 9 dB will be obtained with further speed the same pattern is followed. It can be concluded that the characteristics of force determine the rate of increase with engine speed.

Engine size -Measurement carried out on a large number of engines with engine size is considerably less. An increase of size to ten times gives an increase of noise of 17.5 dB(A). The detailed investigations now indicate that vibration levels of the engine surfaces are about the same irrespective of their size, thus the increase of noise with size is simply due to larger radiating surface area.

Engine load -Engine load has no effect on noise, which is in agreement with the findings that noise is simply due to the initial ignition of the fuel. This occurs at the same intensity whether the engine is running at no load at all or full load. It can be

concluded that:

1. The gas force determines the rate of increase of noise with engine speed.

2. At high engine speeds the gas force has a less significant effect on noise.

3. Engine noise is independent of the horsepower produced.

Bearing Noise - Crankshaft bearings are always replaced when rebuilding an engine because they are a wear component. Heat, pressure, chemical attack, abrasion and loss of lubrication can all contribute to deterioration of the bearings. The above features give rise to the noise. Some of the factors that cause bearing noise are as follows:

Dirt: Dirt contamination often causes premature bearing failure. When dirt or

Other abrasives find their way between the crankshaft journals and bearing, it can become embedded in the soft bearing material. The softer the bearing material, the greater the embed ability, which may or may not be a good thing depending on the size of the abrasive particles and the thickness of the bearing material.

Heat: Heat is another factor that accelerates bearing wear and may lead to Failure if the bearings get hot enough. Bearings are primarily cooled by oil flow between the bearing and journal. Anything that disrupts or reduces the flow of oil not only raises bearing temperatures but also increases the risk of scoring or wiping the bearing.

Misalignment: Misalignment is another condition that can accelerate bearing wear. If the center main bearings are worn more than the ones towards either end of the crankshaft, the crankshaft may be bent or the main bores may be out of alignment.

Disassembly: Disassembly can be another cause of premature bearing failure. Common mistakes include installing the wrong sized bearings, installing the wrong half of a split bearing as an upper, getting too much or not enough crush because main and/or rod caps are too tight or loose, forgetting to tighten a main cap or rod bolt to specs, failing to clean parts thoroughly and getting dirt behind the bearing shell when the bearing is installed.

Corrosion: Corrosion can also play a role in bearing failure. Corrosion results when acids accumulate in the crankcase and attack the bearings causing pitting in the bearing surface. This is more of a problem with heavy-duty diesel engines that use high sulfur fuel rather than gasoline engines, but it can also happen in gasoline engines if the oil is not changed often enough and acids are allowed to accumulate in the crankcas

Spark Knock (Detonation) -Spark knock is a knocking, rattling or pinging noise that may be heard when the engine is accelerating or is working hard under load (driving up a hill, towing a trailer, passing on the highway, etc.). Spark knock means the fuel is detonating. Some of the factors that cause spark knock are as follows:

EGR valve not working- The EGR valve is supposed to open when the engine is accelerating or lugging under a load. This allows intake vacuum to suck some exhaust in through the EGR valve to dilute the air/fuel mixture slightly. This lowers combustion temperatures and prevents knock. Inspect the operation of the EGR valve, and check for a buildup of carbon deposits on the valve port that may be blocking the flow of exhaust back into the engine.

Compression ratio too high- If an engine has been rebuilt and the cylinders have been bored to oversize, it will increase the engine's static compression ratio. Engines that are supercharged or turbocharged are also at much higher risk of detonation because the forced air induction system increases compression.

Engine overheating- If the engine is running too hot because of low coolant, a cooling fan that isn't working a plugged radiator, bad water pump, sticking thermostat, etc., it may cause the fuel to detonate.

Performance of fuel used-Regular grade gasoline is supposed to have an Octane rating of 87. If the gas station or their refiner is cutting corners and the fuel is not 87, it may knock.

Exhaust Noise -The engine exhaust noise originates at the exhaust tailpipe openings and is transmitted through the cabin walls, firewall, and nose gear bay. This is the loudest and most objectionable noise heard. Mufflers are described in 2.4.

The engine exhaust noise originates at the exhaust tailpipe openings and is transmitted through the cabin walls, firewall, and nose gear bay. This is the loudest and most objectionable noise heard. Mufflers are described in 2.4.

2.3 Testing fuel injectors

There are times when testing fuel injectors makes a lot of sense. This page discusses how to do it and offers the tools to get it done. It is often a necessary test when dealing with a stubborn rough running condition, engine run on after the key is turned off or even poor fuel
economy.

Fuel injection services are a popular up sell at many auto repair facilities. Often these cleaners and services are purchased for good measure without knowing if they are needed. These delivery components can be pressure drop tested and diagnosed.

In my opinion you shouldn't clean an injector unless it needed. Why do I feel this way? On the early GM port fuel type injectors I have seen them malfunction after cleaning. Some cleaners are so harsh that they can damage the windings or harm the spray pattern.

An injector is nothing more than an electrically operated solenoid that is actuated to allow fuel to flow at a set rate. Although many think that this is a complicated component the operation is actually quite basic. The solenoid is energized and held open until it delivers the correct amount of gas and then turned off.

Fuel injector problems

Injectors that are dirty or have failed completely will either be stuck in the open or closed position. An injector that does not open can cause hard starts, lack of power and the rough running condition.

An injector that is stuck partially open can cause loss of fuel pressure and can allow raw gas to leak into the cylinder and down into the oil sump.
After this goes on for a while you might be able to pull the dipstick and possibly notice an over filled oil level condition. Another sign that raw fuel is leaking into the oil is the smell of raw gas mixed with the engine oil. This can often be strong enough that you can smell it on the dip stick when checking the oil level.

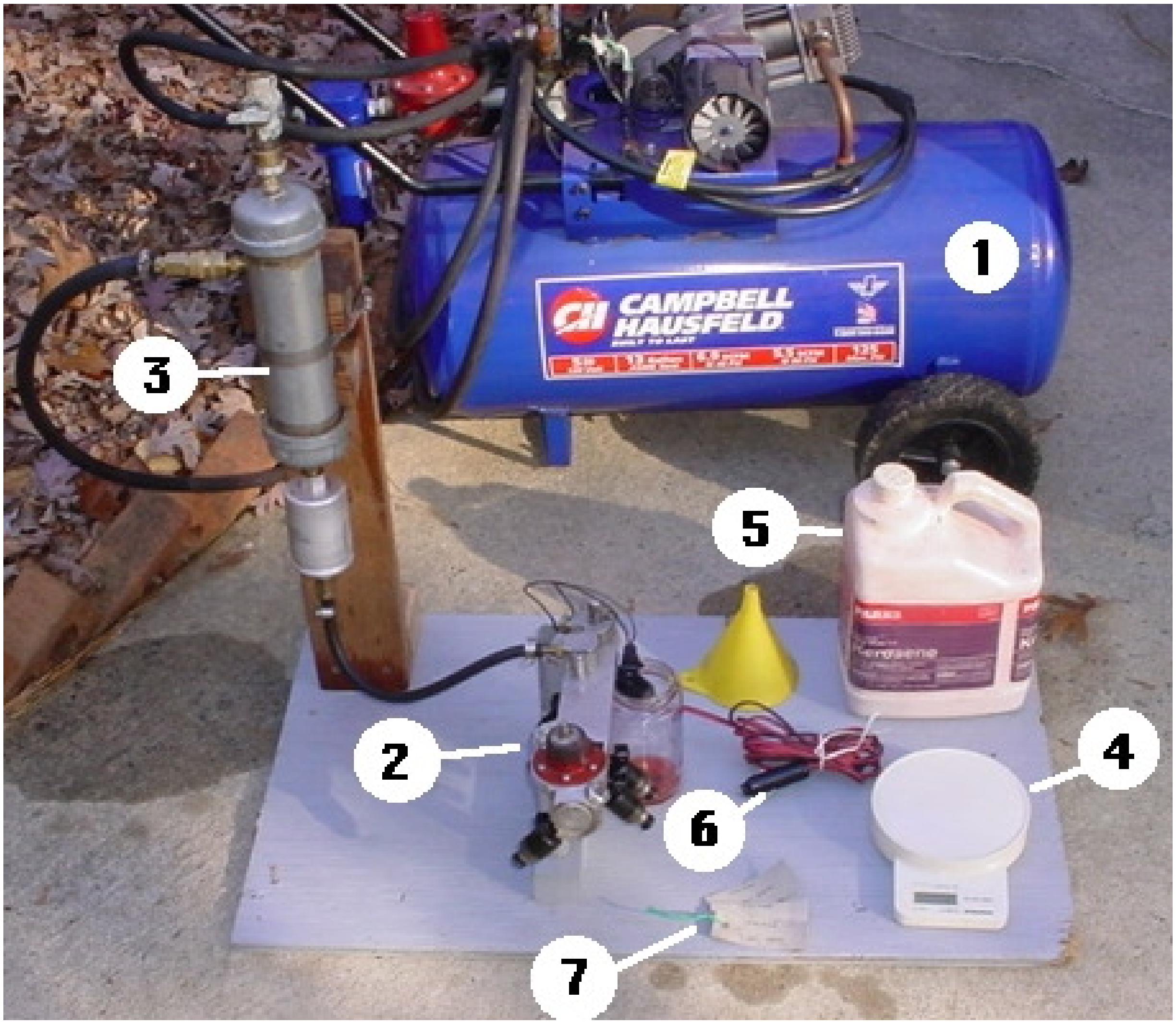

FIGURE 2-A: view of the entire setup

To be a little clearer when you turn off the key to shut down the engine the injection is closed and the engine should immediately die. If it continues to run on or clatter and sputter instead of turning off completely and immediately you have fuel dripping.

A *dirty injector* is a possible cause of the above condition. Build up of gum or carbon deposits on the tip can prevent it from sealing completely when the solenoid is not energized. This allows raw fuel to continue to enter the cylinder. This is then ignited by heat and compression like a diesel engine.

The closer the injector is to the engine the more heat it is exposed to and the more likely a gummy deposit can develop.

Details of test

The first thing to do when testing an injector is to make sure that the electrical side of the circuit is working correctly. If you do not get a fire signal no gas will flow to the combustion chamber on that cylinder.

The signal itself originates from the power train control module on most types of automobiles. On some models this is called the injection driver module but in both cases it's a low voltage pulse which makes testing the circuit with a standard test light difficult. Hence time to buy another special tool.

They make a test device that plugs into the injector connector known as noid light. This will flash when the injector is being signaled to open and stay lit until the unit is closed.

This can test the entire engine management side on some models. It's true that a meter can be used for the same test but the ease of use by just looking for the flash is nice. You can also test the resistance of the injector itself with an ohm meter.
Resistance should be within a given range again dependent on the specific model being tested. The two common things that are found with damaged windings is high resistance or an open injector meaning the delicate internal wings are severed.

When I find that the injectors are being fired correctly and electrically sound the next thing I do is to perform an injector balance test. This test can help isolate clogged, dirty, or inoperative injectors.

Different engines will have different procedures for performing this test and a vehicle specific auto repair manual is recommended for testing. Using a GM car as an example, what you do is connect a fuel pressure gauge to the test port on the fuel rail. You turn the key on (engine off) to build pressure in the fuel rail.

This is why the fuel pump runs for at least 2 seconds when the ignition is turned on. You can stop here and watch the gauge to make sure the rail holds this pressure for a few minutes as continued leak down could indicate a problem. With the key on and the engine off you then mechanically trigger each one with the electronic fuel injector pulse tester pictured at the top of this page (or similar device) and record how much the fuel pressure drops in the rail.

They make *injector test equipment* in kits to help accomplish these tasks for specific models. This is the way to go if you are a dealership technician sticking to a single brand of car. Here is the important point, When each **individual injector** is mechanically activated it should drop the fuel pressure in the rail the same amount as on the others.

Manufacturers will usually include a plus or minus tolerance of 2-3 PSI as an allowable variance. If you have one injector that drops 10 PSI and the other injectors drop 25 PSI then the injector with the low flow rate needs to be inspected.

When you are testing, units with low pressure drops are the ones to look out for. When the tip or orifice is dirty or severely restricted you will find there will not be much pressure decrease when it's energized. These may need to be cleaned with professional injector cleaning tools (below) or it may need to be replaced.

Give this testing fuel injectors page a bookmark or share with a friend.

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Test a Bad Fuel Injector Ohm Meter

If all fuel injectors "click," then the operator may perform an Ohm meter test. Ohm meters refer to devices used to measure the resistance across an injector's terminals. Once the vehicle is turned off, the Ohm meter can be attached to the fuel injector wiring. If resistance does not meet the fuel injector's specifications as stated in the manual for that vehicle, the injector should be replaced.

Fig: 2.B -A digital multimeter will help diagnose problems with the fuel injectors in the vehicle.

A bad fuel injector in your vehicle can cause your engine to idle roughly, can increase fuel consumption, and can lead to other performance problems. In most cases, you can trace problems with a bad fuel injector to a clogged nozzle, stuck valve or failed coil. With the correct tools, you can diagnose a suspected bad injector before you decide to replace it unnecessarily. This procedure applies to fuel injectors found on electronic fuel injection, or EFI, systems only.

Engine test stand

An engine test stand is a facility used to develop, characterize and test engines. The facility, often offered as a product to automotive OEMs, allows engine operation in different operating regimes and offers measurement of several physical variables associated with the engine operation.

A sophisticated engine test stand houses several sensors (or transducers), data acquisition features and actuators to control the engine state. The sensors would measure several physical variables of interest which typically include:

- crankshaft torque and angular velocity
- intake air and fuel consumption rates, often detected using volumetric and/or gravimetric measurement methods
- air-fuel ratio for the intake mixture, often detected using an exhaust gas oxygen sensor
- environment pollutant concentrations in the exhaust gas such as carbon monoxide, different configurations of hydrocarbons and nitrogen oxides, sulfur dioxide, and particulate matter
- temperatures and gas pressures at several locations on the engine body such as engine oil temperature, spark plug temperature, exhaust gas temperature, intake manifold pressure
- atmospheric conditions such as temperature, pressure, and humidity

Information gathered through the sensors is often processed and logged through data acquisition systems. Actuators allow for attaining a desired engine state (often characterized as a unique combination of engine torque and speed). For gasoline engines, the actuators may include an intake throttle actuator, a loading device for the engine such as an induction motor. The engine test stands are often custom-packaged considering requirements of the OEM customer. They often include microcontroller-based feedback control systems with following features:

- closed-loop desired speed operation (useful towards characterization of steady-state or transient engine performance)
- closed-loop desired torque operation (useful towards emulation of in-vehicle, on-road scenarios, thereby enabling an alternate way of characterization of steady-state or transient engine performance)

Engine test stand applications

- Research and Development of engines, typically at an OEM laboratory
- Tuning of in-use engines, typically at service centers or for racing applications
- End of production line at an OEM factory. The changing of the engines to be tested takes place automatically, and fluid, electrical and exhaust gas lines are connected to the test stand and engine and disconnected from them by means of docking systems. When the engine docks in the test stand the mechanical drive shaft is automatically connected to it.

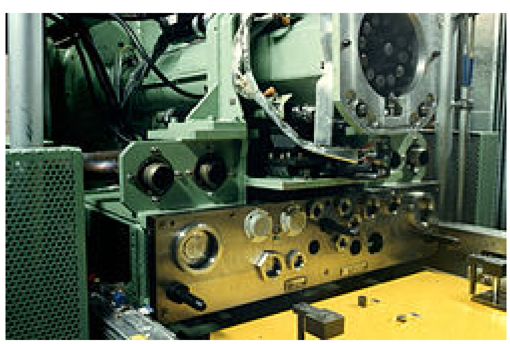

Fig: 2.C-Engine Test Stand with WALTHER-PRAEZISION Multi coupling System

Engine testing for research and development

Research and Development (R&D) activities on engines at automobile OEMs have necessitated sophisticated engine test stands. Automobile OEMs are usually interested in developing engines that meet the following threefold objectives:

- to provide high fuel efficiency
- to improve drivability and durability
- to be in compliance to relevant emission legislation

Consequently, an R&D engine test stands allow for a full-fledged engine development exercise through measurement, control and record of several relevant engine variables.

Fig: 2.d-HORIBA engine test stand type TITAN

Typical tests include ones that:

- determine fuel efficiency and drivability: torque-speed performance test under steady-state and transient conditions
- determine durability: ageing tests, oil and lubrication tests
- determine compliance to relevant emission legislations: volumetric and mass emission tests over stated emission test cycles

- gain further knowledge about the engine itself: engine mapping exercise or development of multidimensional input-output maps among different engine variables. e.g. a map from intake manifold pressure and engine speed to intake air flow rate.

Magnifying LDV sensors in engine testing

Laser technology adds useful tools to improve engine design during engine testing. Lasers sensors using laser Doppler velocimetry with magnifying LDV sensors can record the movements of gas particles during the entire 2-stroke, 4-stroke or rotary combustion cycle. These spark plug velocimeter (SPV) sensors can be inserted into the spark plug hole of the combustion chamber of the engine.

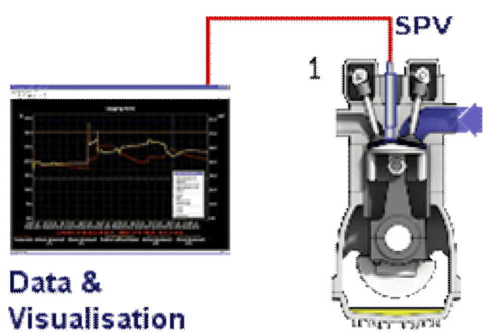

Fig: 2. e: Spark plug velocimeter - SPV

The sensors can be adjusted to all depth levels of the pistons movement - typically ranging from 0 - 50mm. The magnifying LDV sensors will record the velocity and direction of the movement of gas particles. Engine design can then be optimised with the recorded data and the visualisation of the combustion cycle. The flow and direction of the gas particles can be improved by changing shape and sizes of the chamber, valves, spark plug, injectors and pistons resulting in improved combustion and performance and in reduced emissions. Engine heads with two spark plug holes per cylinder can be used to record the velocity and direction of the movement of gas particles in an engine running under live, firing conditions. SPVs can also be added to the intake and the exhaust to record flow of particles in these areas to further improve engine design.

An engine test stand is a facility used to develop, characterize and test engines. The facility, often offered as a product to automotive OEMs, allows engine operation in different operating regimes and offers measurement of several physical variables associated with the engine operation.

A sophisticated engine test stand houses several sensors (or transducers), data acquisition features and actuators to control the engine state. The sensors would measure several physical variables of interest which typically include:

- crankshaft torque and angular velocity
- intake air and fuel consumption rates, often detected using volumetric and/or gravimetric measurement methods
- air-fuel ratio for the intake mixture, often detected using an exhaust gas oxygen sensor
- environment pollutant concentrations in the exhaust gas such as carbon monoxide, different configurations of hydrocarbons and nitrogen oxides, sulfur dioxide, and particulate matter
- temperatures and gas pressures at several locations on the engine body such as engine oil temperature, spark plug temperature, exhaust gas temperature, intake manifold pressure

- atmospheric conditions such as temperature, pressure, and humidity

But the process is very costly as the test bench is costly. For this reason in the present work a method is proposed to simulate the effect of various engine faults on engine behavior. The method is based on a simulation model that has been developed in the past and used as basis for a diagnostic technique. The simulation model describes the operation of the engine and its subsystems, i.e. the fuel system, the air intake system, fuel injection system and the exhaust system. In the present work, the simulation model is further improved to account in a more fundamental way for the mechanisms of fuel air mixing inside the engine cylinder and Fuel injection system in EFI engine. It is possible to simulate various engine faults. Failure, variation of injection timing, injector failure and failure in the components of the gas exchange mechanism (air cooler, turbine, compressor and exhaust duct).

MATLAB is leading software by which analysis of sound wave propagation is nearly accurate. Given a high enough sample rate, the double precision vector has sufficient resolution for almost any type of processing that may need to be performed - meaning that one can usually safely ignore quantization issues when in the MATLAB environment. However there are

potential resolution and quantization concerns when dealing with input to and output from MATLAB, since these will normally be in a fixed-point format. We shall thus discuss input and output: first, audio recording and playback, and then audio file handling in MATLAB, Recording sound directly in MATLAB requires the user to specify the number of samples to record, the sample rate, number of channels and sample format.

It has been observed that for a particular problem engine produce vibration of certain frequency. If the frequency range of particular problem is known then it will be easier to predict the problem of the engine.

2.4 PURPOSE OF A CAR AIR FILTER

All cars have air filters, which are a necessary adjunct to proper engine operation. What follows is a brief description of the most basic purposes of a car air filter

Filter Outside Air

- The main purpose of an automotive air filter is to filter and clean outside air before it gets sucked into a car engine and burned along with fuel to produce combustion.

Protect Vehicle Engine

- Air that gets sucked into a car engine needs to be as clean as possible to prevent engine contamination and, in some cases, engine damage. An air filter is the main line of defense against preventing damaging particulate matter from entering a vehicle's engine. Dirty air can reduce engine efficiency and cause damage; an air filter prevents this.

Protect Carburetor/Fuel Injection System

- A carburetor or fuel injection system is responsible for injecting both gas and air into an engine's cylinders, a combination more commonly referred to as an engine's air/fuel mixture. Both carburetors and fuel injection systems use tiny portals and valves to function. Any debris or obstruction that enters these portals and valves can cause serious malfunction and/or damage. An engine air filter protects these delicate parts by filtering incoming air before it enters a carburetor or fuel injection system.

Increase Fuel Economy

- A clean, properly installed and functioning air filter increases both engine performance and gas mileage. By filtering incoming air into an engine, an air filter ensures that air burned inside of an engine is as clean as possible. Clean, purified air ignites quicker and better inside of an engine cylinder, an occurrence that increases engine combustion efficiency, which increases fuel economy.

Augment Carburetor/Fuel Injection Function

- As air gets sucked into a car's engine, it must first pass through the air filter before it reaches either the carburetor or fuel injection system, which is in charge of combining incoming air with gasoline, a combination that creates an engine's air/fuel mixture. A dirty air filter obstructs air flow and limits the amount of air that reaches the carburetor or fuel injection system, either of which responds by reducing the amount of gas injected into the air. A clean air filter augments carburetor/fuel injection function by maintaining an adequate amount of air flow.

Lasting of car's air filter

Any engine that runs by internal combustion of fuel requires air to operate. That's because without air, specifically, oxygen, fuels like gasoline and diesel can't burn and provide the explosive force to power the engine.

The trick is, not just any old air will do. In modern automobiles, the air must be cleaned before it gets sucked into the engine's air intake plenum and combustion chambers. If not, you run the risk of dust, dirt and debris quickly fouling up the engine, causing poor performance and potentially shortening the life of the car. Foreign particles act as abrasives on the metal parts of an engine, wearing away at engine bearings, piston rings and cylinders.

In addition, modern engines rely on a precise ratio of air to fuel. When the engine is starved of air, the fuel mix is said to run too "rich," which in effect puts added strain on the engine.

2.5 **Critical assessment of reviewed literature:**

The study of engine noise has been carried out since the early stages of engine development. In 1931, Ricardo "First found a descriptive relationship between the combustion pressure rise and the noise produced [1]. Later, a number of parameters in determining the noise developments were investigated which include the "rst and second derivatives of cylinder pressure. These methods were elective in revealing the relationship between engine combustion and noise. Some of them still play an important role in identifying the sources of engine noise [2].

Although there are a number of engine noise sources, one of the most fundamentals is the combustion-induced noise [3]. It occurs towards the end of the compression stroke and subsequent expansion stroke. The rapid pressure change due to the combustion transmits through engine structures and forms a part of the airborne noise. This pressure change also causes the vibration of the engine components such as the cylinder head, pistons, connecting rods and engine body. The vibration of these components then provides another part of the overall engine noise. Together these noise sources account for over 80% of total engine noise. The combustion-induced noise is however the dominant source. It occurs around the top dead centre (TDC).

Other noise sources are due to engine functions such as the injection of fuel and the operation of inlet and exhaust valves. These sources usually produce low level noise and make up a fraction of the overall noise. Yet all have designated times of occurrence in terms of crank angles. For instance, fuel injection is usually performed around [8}103] before the TDC in the compression stroke. The exact instances of these events depend on the individual design of the diesel engines.

Although the above engine noise sources have distinctive time instances, it is still discount to resolve them accurately based on noise measurement. This is because the occurrences of each noise source are too close together. A variety of signal processing methods including statistical analysis, spectral analysis, time, frequency analysis and wavelet transform have been used to analyses engine noise [{4}6]. These methods are applied to investigate the noise-generation mechanisms and to reveal the individual features of the sources. Each method is based upon component energy contributions to retrieve information about engine noise.

Firstly, the noise signals are represented by using either the time domain, frequency domain or the joint time, frequency domain. The noise sources are then indented by the energy variations of the represented signals. As such methods are all based on energy conservation; they are useful for ending predominant information such as combustion peaks.

The other low-level noise sources cannot be indented successfully, using the methods mentioned above. This is because these methods retain the signal energy information from one domain to another. The low-energy noise sources are either buried by the combustion events or too small to be recognized.

Hence, these signal energy conservation based methods are unable to recognize such noises induced by fuel injections or valve movements, which contain relatively small energy.

The independent component analysis (ICA) brings a deferent strategy in dealing with the problems of blind source separation (BSS). In the ICA it is assumed that the measured data is a linear combination of the indirectly observed latent sources. As long as the latent signals are statistically independent the ICA should be able to decompose them into independent components (ICS) successfully. It has been reported recently that the ICA is an elective approach for analyzing brain electroencephalogram (EEG) data, image processing, feature extraction, telecommunications and electrical applications [{7}9].

However, the applications of the ICA to the analysis of mechanical signals such as vibration and sound have been little investigated. This paper focuses mainly on the study of the acoustic signals generated from a test diesel engine using the ICA in an error to identify its noise sources. The paper is organized as follows.

Section 2, Describes the theoretical models characterizing diesel engine noise, generation mechanisms, transmission paths and radiation. The principles, properties and implementation issues of the ICA are presented in Section 3.The numerical example using the ICA with simulated signals is given in Section 4 and Section 5. illustrates the separation results from the measured acoustic signals. The results are then varied from a number of ways. Section 6 summarizes the conclusions obtained through this initial work.

Nikhil Bhave [1] and Preeti Rao[2] had survey on the engine sound is used to derive suitable features. The performance of formant based features is compared with that of Mel-frequency cepstral coefficients (MFCC) via a k-NN classifier on a manually labeled database of traffic sounds.

W. LI, F. GU,[3] A. D. BALL, A. Y. T. LEUNG [4]AND C. E. PHIPPS[5] is applied to engine acoustic signals to identify the engine noise sources. The ICA decomposes the signals into a number of independent components (ICS) so the individual engine acoustic sources can be studied separately. The predictive models indicate that the engine noise generation mechanisms, applied to represent the ICS in the time, frequency domain. The source separation results from the recorded acoustic signals are in accordance with theoretical predictions and engine.

Paul Boersma [6] makes his method capable of measuring harmonics-to-noise ratios in the lag domain with an accuracy and reliability much greater than that of any of the usual frequency-domain methods.

<u>*Samat, S.A.*</u> *[8] Fac. of Electr. Eng[9].* Use of spectrum estimation with cross spectrum correlation to monitor the condition of automotive engines based on their sound signatures.

George Phillips[10] had survey Improper cooling system is the major cause of engine problems. Damaged and worn out engine components like distributor cap, rotor, spark plugs and ignition wires also contribute to improper functioning of the car engine. Worn out components result in engine surging, engine heating and creates faulty engine sounds. Damaged seals and valves results in excess of oil consumption and damaged exhaust pipe causes a hissing sound. In order to prevent faulty engine sounds, ensure that the engine components are in good condition and if not replace them.

Beluga[11] is a basic sound analysis program written in MATLAB for creating spectrograms and power spectra from sound files in .wav format and for extracting frequency contours.

ARTwarp[12,13] is a MATLAB-based program for the automated categorization of tonal animal sounds. It has been tested successfully for bottlenose dolphin whistles and killer whale calls (3) but will be applicable to any sound that can be described by frequency contours.

Hristo Zhivomirov[14] He done Time and frequency analysis, measurement of the crest factor, the dynamic range, etc

*Pankaj B. Gadge, Bipin D. Mokal, Uttam R. Bagal [15]*analyzed respiratory Sound using MATLAB And depending on position of maxima the respiratory sound is classified for indicating state of subject as normal or abnormal.

Chapter -3

EXPERIMENTAL PROCEDURE

3.1 BASIC AUDIO PROCESSING

Audio is normal and best handled by MATLAB, when stored as a vector of samples, with each individual value being a double-precision floating point number. A sampled sound can be completely specified by the sequence of these numbers plus one other item of information: the sample rate. In general, the majority of digital audio systems differ from this in only one major respect, and that is they tend to store the sequence of samples as fixed-point numbers instead. This can be a complicating factor for those other systems, but an advantage to MATLAB users who have two less considerations to be concerned with when processing audio: namely overflow and under flow.

Any operation that MATLAB can perform on a vector can, in theory, be performed on stored audio. The audio vector can be loaded and saved in the same way as any other MATLAB variable, processed, added, plotted, and so on. However there are of course some special considerations when dealing with audio that need to be discussed within this chapter, as a foundation for the processing and analysis discussed in the later chapters.

This chapter begins with an overview of audio input and output in MATLAB, including recording and playback, before considering scaling issues, basic processing methods, then aspects of continuous analysis and processing. A section on visualization covers the main time- and frequency-domain plotting techniques. Finally, methods of generating sounds and noise are given.

3.2 HANDLING AUDIO IN MATLAB

Given a high enough sample rate, the double precision vector has sufficient resolution for almost any type of processing that may need to be performed - meaning that one can usually safely ignore quantization issues when in the MATLAB environment. However there are potential resolution and quantization concerns when dealing with input to and output from MATLAB, since these will normally be in a fixed-point format. We shall thus discuss input and output: first, audio recording and playback, and then audio file handling in MATLAB, Recording sound directly in MATLAB requires the user to specify the number of samples to record, the sample rate, number of channels and sample format.

For example, to record a vector of double precision floating point samples on a computer with attached or integrated microphone, the following Matlab command may be issued speech = wave record (16000, 8000, 1, double)

His records 16 000 samples with a sample rate of 8 kHz, and places them into a 16 000 element vector named speech. The i argument specifies that the recording is mono rather than stereo. This command only works under Windows, so under Linux or MacOS it is best to use either the Matlab audio recorder function or use a separate audio application to record audio (such as the excellent open source audacity tool), saving the recorded sound as an audio file, to be loaded into Matlab as we shall see shortly.

3.2.1 Audio file formats

Wave: -The wave file format is usually identified by the file extension .wav, and actually can hold many different types of audio data identified by a header field at the beginning of the file. Most importantly, the sampling rate, number of channels and number of bits in each sample are also specified. This makes the format very easy to use compared to other formats that do not specify such information, and thankfully this format is recognized by MATLAB. Normally for audio work, the wave file would contain PCM data, with a single channel (mono), and 16 bits per sample. Sample rate could vary from 8000 Hz up to 48 000 Hz. Some older PC sound cards are limited in the sample rates they support, but 8000 Hz and 44 100 Hz are always supported. 16 000 Hz, 24 000 Hz, 32 000 Hz and 48 000 Hz are also reasonably common.

PCM and RAW hold streams of pulse coded modulation data with no headers or gaps. They are assumed to be single channel (mono) but the sample rate and number of bits per sample is not specified in the file - the audio researcher must remember what these are for each. pcm or .raw file that he or she keeps. These can be read from and written to by Matlab, but are not supported as a distinctive audio file. However these have historically been the formats of choice for audio researchers, probably because research software written in C, C++ and other languages can most easily handle this format.

A-law and μ-law are logarithmically compressed audio samples in byte format. Each byte represents something like 12 bits in equivalent linear PCM format. This is commonly used in telecommunications where the sample rate is 8 kHz. Again, however, the .au file extension (which is common on UNIX machines, and supported under Linux) does not contain any information on sample rate, so the audio researcher must remember this. Matlab does support this format natively. Other formats include those for compressed music such as MP3 (see Info box: Music file formats on page 11), MP4 specialized musical instrument formats such as MIDI (musical instrument digital interface) and several hundred different proprietary audio formats

If using the audio recorder() function, the procedure is first to create an audio recorder object, specifying sample rate, sample precision in bits, and number of channels,

Then to begin recording

aro = Audio Recorder (16000,16,1);

At this point, the microphone is actively recording. When finished, stop the recording and try to play back the audio:

Stop (aro) & Play (aro)- To convert the stored recording into the more usual vector of audio, it is necessary to use the getaudiodata() command:

speech=getaudiodata(aro, 'double');

Other commands, including pause() and resume(), may be issued during record- ing to control the process, with the entire recording and playback operating as back- ground commands, making these a good choice when building interactive speech experiments.

Storing and replaying sound-In the example given above, the 'speech' vector consists of double precision samples, but was recorded with 16-bit precision. The maximum represent able range of values in 16-bit format is between –32 768 and +32 767, but when converted to double precision is scaled to lie with a range of +/–1.0, and in fact this would be the most universal

Scaling within Matlab so we will use this wherever possible. In this format, a recorded

sample with integer value 32 767 would be stored with a floating point value of +1.0,

and a recorded sample with integer value –32 768 would be stored with a floating point value of –1.0. Replaying a vector of sound stored in floating point format is also easy:

Sound (speech, 8000*):*

It is necessary to specify only the sound vector by name and the sample rate (8 kHz in this case, or whatever was used during recording). If you have a microphone and speakers connected to your PC, you can play with these commands a little. Try recording a simple sentence and then increasing or reducing the sample rate by 50% to hear the changes that result on playback.

Sometimes processing or other operations carried out on an audio vector will result in samples having a value greater than +/–1.0, or in very small values. When replayed

Using sound (), this would result in clipping, or inaudible playback respectively. In

Such cases, an alternative command will automatically scale the audio vector prior to Playback based upon the maximum amplitude element in the audio vector

Sounds (speech, 8000):

This command scales in both directions so that a vector that is too quiet will be amplified, and one that is too large will be attenuated. Of course we could accomplish something similar by scaling the audio vector ourselves:

Sound (speech/max (abs (speech)), 8000):

It should also be noted that Matlab is often used to develop audio algorithms that will be later ported to a fixed-point computational architecture, such as an integer DSP (digital signal processor), or a microcontroller. In these cases it can be important to ensure that the techniques developed are compatible with integer arithmetic instead of floating point arithmetic. It is therefore useful to know that changing the 'double' specified in the use of the wav record () and get audio () functions above to an 'int16'

Will produce an audio recording vector of integer values scaled between –32 768 and

+32 767.

The audio input and output commands we have looked at here will form the bedrock of much of the process of audio experimentation with Matlab: graphs and spectrograms (a plot of frequency against time) can show only so much, but even many experienced audio researchers cannot repeatedly recognize words by looking at plots! Perfectly audible sound, processed in some small way, might result in highly corrupt audio that plots alone will not reveal. The human ear is a marvel of engineering that has been designed for exactly the task of listening, so there is no reason to assume that the eye can perform equally as well at judging visualized sounds. Plots can occasionally be an excellent method of visualizing or interpreting sound, but often listening is better.

A Time-Domain Plot of A Sound Sample Is Easy In MATLAB:

Plot (speech) although sometimes it is preferred for the *x*-axis to display time in seconds

Plot ([1: size(speech)]/ 8000, speech);

Where again the sample rate (in this case 8 kHz) needs to be specified.

Audio file handling

In the audio research field, sound files are often stored in a raw PCM (pulse coded Modulation) format. That means the file consists of sample values only - with no reference to sample rate, precision, number of channels, and so on. Also, there is a potential ending problem for samples greater than 8 bits in size if they have been handled or recorded by a different computer type To read raw PCM sound into MATLAB, we can use the general purpose freed () function, which has arguments that specify the data precision of the values to read in from a binary file,

First open the file to be read by name

fid= fopen ('recording.pcm', 'r');

Next, Read in the entire file, in one go, into a vector:

Speech=fread (fid , inf , 'int16' , 0, 'ieee-le');

This would now have read in an entire file ('inf' or infinite values) of 16-bit integers. The format is IEEE little ending, which is what a PC tends to use. Alternatively (but rarely these days) we could have done.

Speech=fread(fid , inf , 'uint16' , 0, 'ieee-be');

Which would read in an entire file of unsigned 16-bit integers, in big ending format (such as a large UNIX mainframe might use). Finally it is good practice to close the file we had opened once we have finished reading from it.

If close (fid);

It is also useful to know how to save and load arrays within Matlab. Using a built- in Matlab binary format, an array of speech, can be saved to disc using the save command, and loaded using the load command. The normal filename extension for the stored file is '.mat'

3.3 Audio Conversion Problems

Given the issue of unknown resolution, number of channels, sample rate and end inanes, it is probably useful to listen to any sound after it is imported to check it was converted correctly (but please learn from an experienced audio researcher - always turn the volume control right down the first time that you replay any sound: pops, squeaks and whistles, at painfully high volume levels, are a constant threat when processing audio, and have surprised many of us). You could also plot the waveform, and may sometimes spot common problems from a visual examination. Figure 2.1 shows an audio recording plotted directly, and quantized to an unsigned 8-bit range on the top of the figure. On the bottom, the same sound is plotted with incorrect byte ordering (in this case where each 16-bit sample has been treated as a big-endian number rather than a little-endian number), and as an absolute unsigned number. Note that all of these examples, when heard by ear, result in understandable speech - even the incorrectly byte ordered replay (it is easy to verify this, try the Matlab swap bytes () function in conjunction with soundsc()).

Other problem areas to look for are recordings that are either twice as long or half as long as they should be. This may indicate an 8-bit array being treated as 16-bit numbers, or a 16-bit array being treated as doubles. As mentioned previously, the ear is often the best discriminator of sound problems. If you specify too high a sample rate when replaying sound, the audio will sound squeaky, and will sound s-l-o-w if the sample rate is too low. Incorrect endings will probably cause significant amounts of noise, and getting unsigned/signed mixed up will result in noise-corrupted speech (especially with loud sounds). Having specified an incorrect precision when loading a file (such as reading a logarithmic 8-bit file as a 16-bit linear) will often result in a sound playback that is noisy but recognizable.

Chapter-4

Analysis and Findings

4.1 Engine specifications

Model: E-EE101-AE HDK

Engine: 16v.EFI 1.31liter 5AFE

Type: 4cylinder Twin Cam16-valve

Piston Displacement: 1331cc

Max. Output: 4800rpm

Max. Torque: 4000 rpm

Fuel System (EFI): Electronic Fuel Injection

Fuel Type: octane, petrol

4.2 Specification of sound Recorder :

A 'CENIX Digital Voice Recorder Model no: VR W 240H' was used for recording the sound. Sound was recorded for four conditions:

- For Ideal speed when engine not warm up;
- For Ideal speed when engine warm up (after 10 min);
- For Ideal speed when without one spark plug;
- For Ideal speed without an air filter;

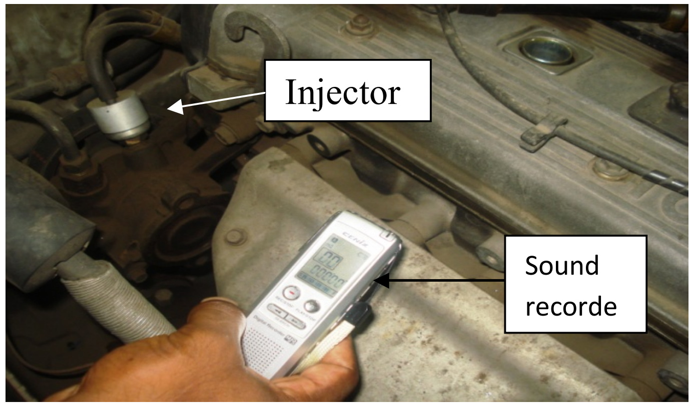

Figure:4.2.a- Sound recorded when engine not warm up.

Figure: 4.2.b -Sound recorded when one Injector not Work.

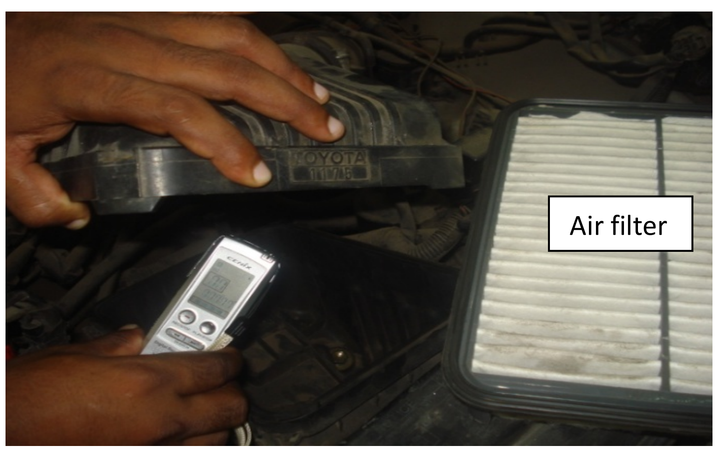

Figure:4.2.c- Sound recorded with air filter and without use air filter.

4.3 Analysis

4.3.1 ANALYSIS OF SOUND WAVE:

A MATLAB coding was generated for extracting spectrogram. A spectrogram, or sonogram, is a visual representation of the spectrum of frequencies in a sound. [16] Spectrograms are sometimes called spectral waterfalls, voiceprints, or voice grams.

Spectrograms can be used to identify spoken words phonetically, and to analyze the various calls of animals. They are used extensively in the development of the fields of music, sonar, radar, and speech processing,[17] seismology, etc.

The most common format is a graph with two geometric dimensions: the horizontal axis represents time, the vertical axis is frequency; a third dimension indicating the amplitude of a particular frequency at a particular time is represented by the intensity or color of each point in the image.

There are many variations of format: sometimes the vertical and horizontal axes are switched, so time runs up and down; sometimes the amplitude is represented as the height of a 3D surface instead of color or intensity. The frequency and amplitude axes can be either linear or logarithmic, depending on what the graph is being used for. Audio would usually be represented with a logarithmic amplitude axis (probably in decibels, or dB), and frequency would be linear to emphasize harmonic relationships, or logarithmic to emphasize musical, tonal relationships.

Spectrograms are usually created in one of two ways: approximated as a filter bank that results from a series of band pass filters (this was the only way before the advent of modern digital signal processing), or calculated from the time signal using the short-time Fourier transform (STFT). These two methods actually form two different Time-Frequency Distributions, but are equivalent under some conditions.

The band pass filters method usually uses analog processing to divide the input signal into frequency bands; the magnitude of each filter's output controls a transducer that records the spectrogram as an image on paper.

Creating a spectrogram using the STFT is usually a digital process. Digitally sampled data, in the time domain, is broken up into chunks, which usually overlap, and Fourier transformed to calculate the magnitude of the frequency spectrum for each chunk. Each chunk then corresponds to a vertical line in the image; a measurement of magnitude versus frequency for a specific moment in time. The spectrums or time plots are then "laid side by side" to form the image or a three-dimensional surface.

The spectrogram of a signal s (t) can be estimated by computing the squared magnitude of the STFT of the signal s (t), as follows:

$$\mathrm{spectrogram}(t,\omega) = |\mathrm{STFT}(t,\omega)|^2$$

4.4 Matlab Programme:

At first the sounds' file was setted or diffined its path on MATLAB irectory.Sound should be in WAV format.Then a new script has opened for writing the programme.The program written for generating the spectrogram (time vs frequency) and 'time vs amplitude graph' is given below:

```
% function Surface Prof (filename)
Filename = 'Voice 010(Ideal speed without injector)';
[Y, fs, nbits] = wav read (filename);

T = (1: length (y)) /fs;
Figure (1); subplot (2, 1, 1)
Plot (t, y)
Title ('Recorded signal')
Xlabel ('Time (t)')
Ylabel ('Signal Amplitude')

 L= size (y, 1);
NFFT = 2^next pow 2(L); % Next power of 2 from length of y
Y = fft (y, NFFT)/L;
f = fs /2* linspace (0, 1, NFFT/2+1);
Subplot (2, 1, and 2); plot (f, 2*abs (Y (1: NFFT/2+1)))
Title ('Single-Sided Amplitude Spectrum of y (t)')
Xlabel ('Frequency (Hz)')
Ylabel ('|Y (f)|')
 Figure; spectrogram (y (: 1))
```

The spectrogram (time vs frequency) and 'time vs amplitude graph' generated by the simulator for different conditions are given in the following figures:

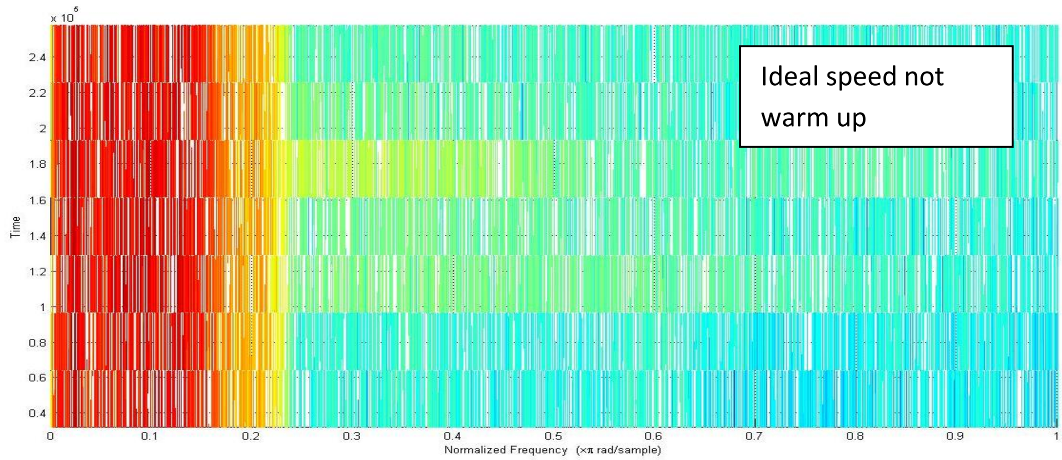

Figure:4.4.a- Time Vs Frequency for Ideal Speed (Not Warm Up)

Figure: 4.4.b-Time Vs Frequency for Ideal Speed (With Warm up After 10)

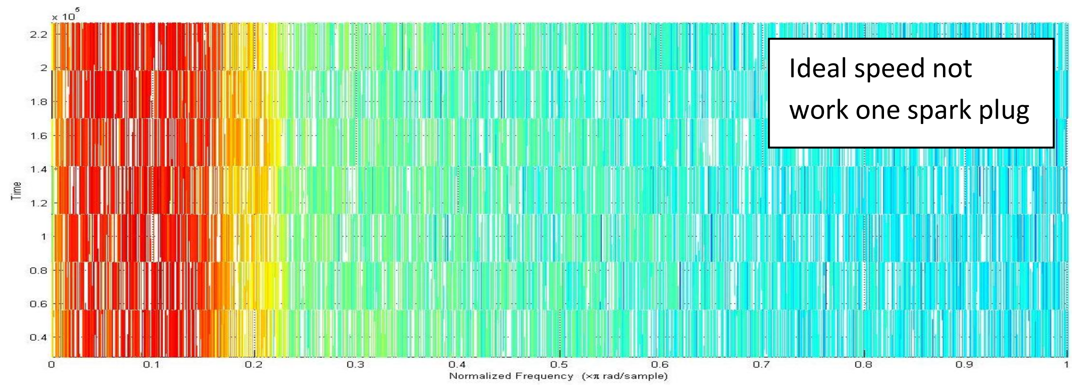

Figure: 4.4.c-Time Vs Frequency for Ideal Speed (Not Work One Spark Plug)

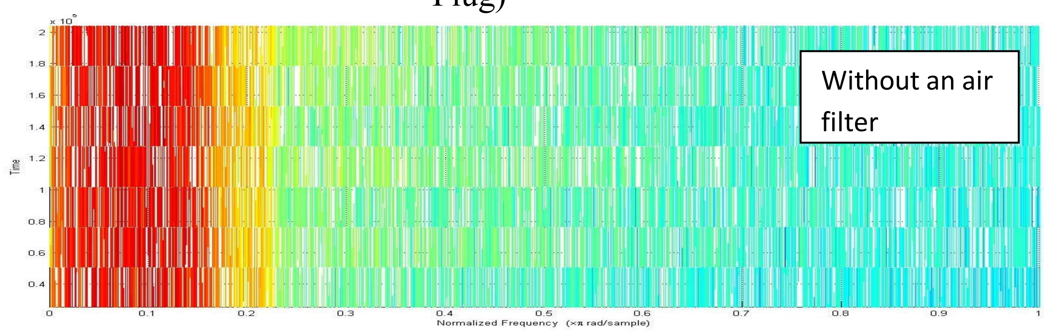

Figure:4.4.d- Time Vs Frequency for Ideal Speed (Without Air Filter)

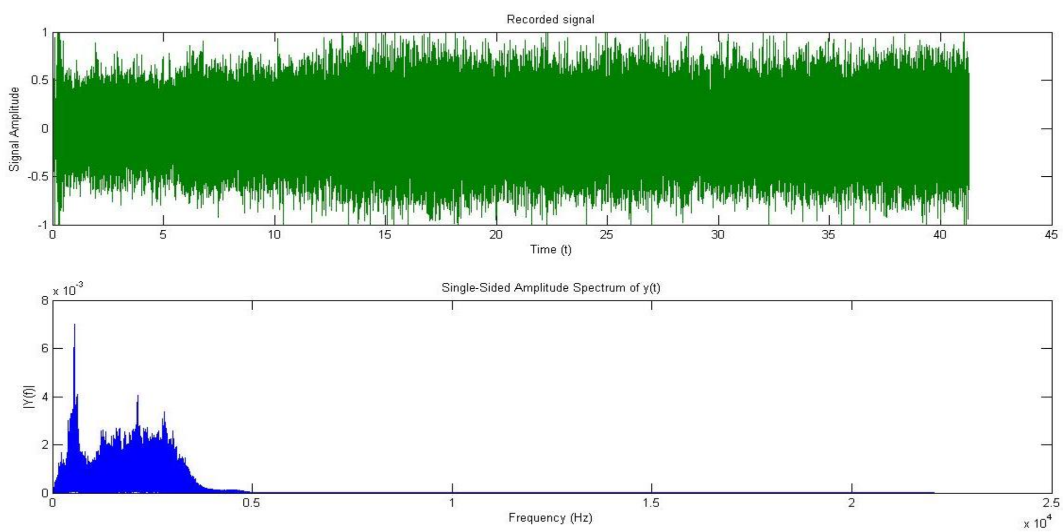

Figure: 4.4.e - For Ideal Speed (Not Warm Up)

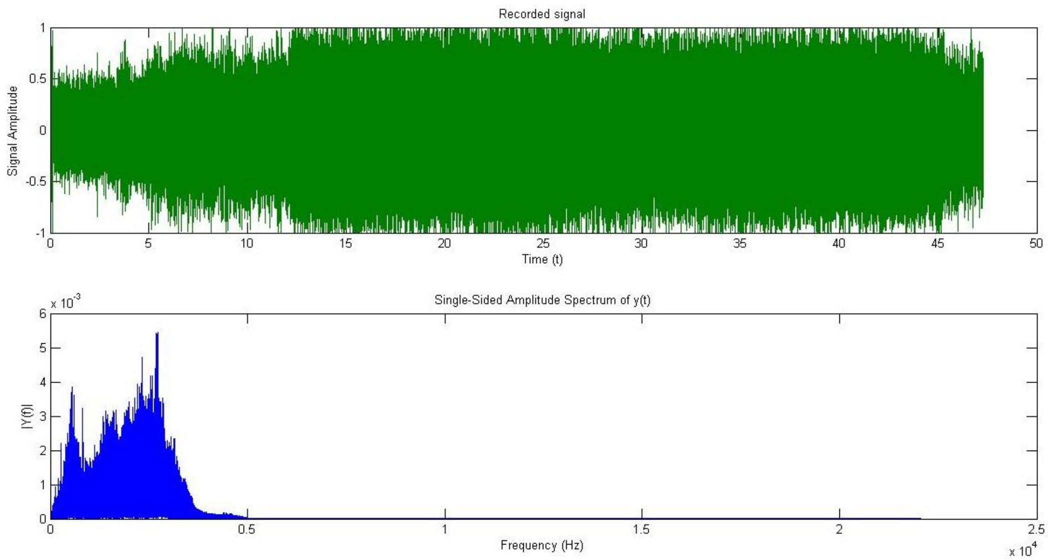

Figure: 4.4.f- For Ideal Speed (With Warm Up After 10)

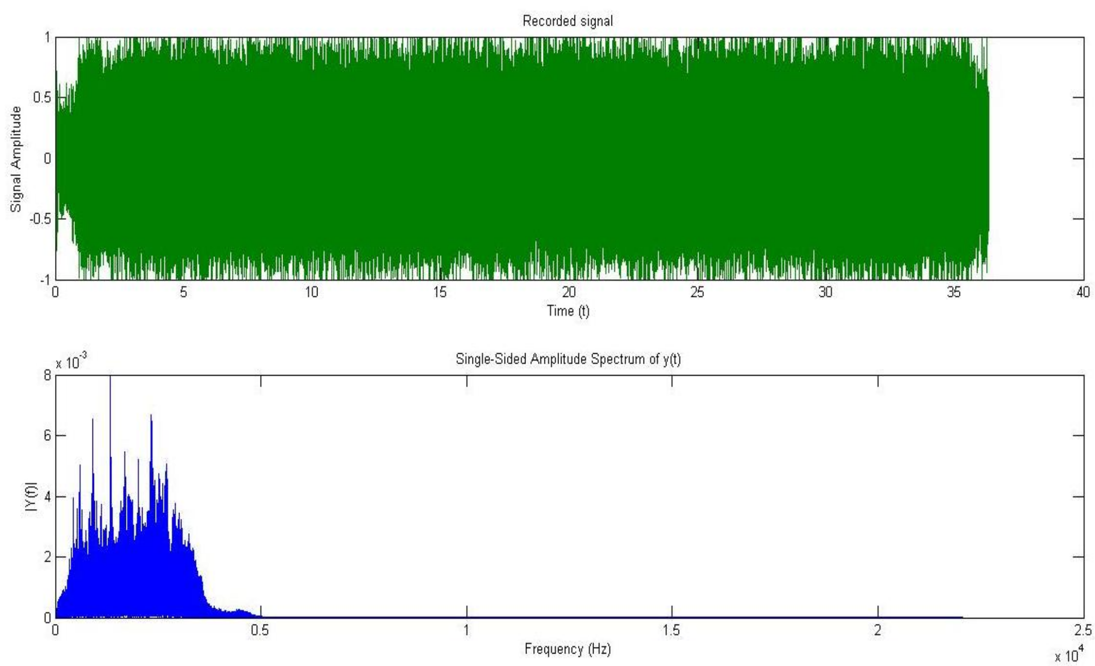

Figure: 4.4.g-for Ideal speed (not work one spark plug)

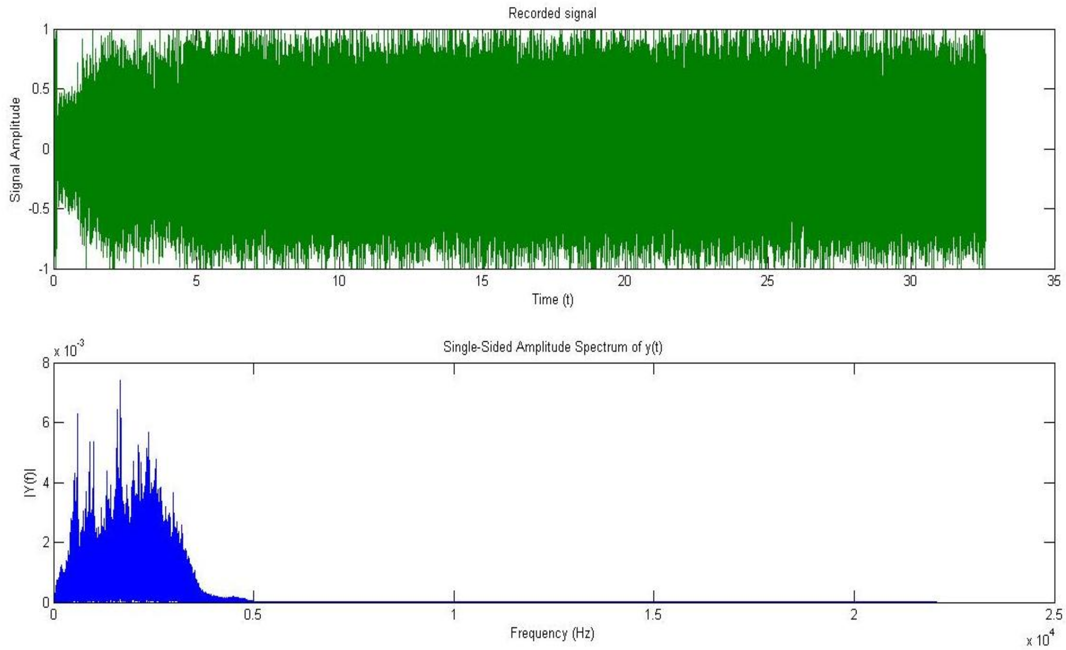

Figure: 4.4.h- for Ideal speed (without air filter)

4.5. Result:

Three experiments were conducted to determine the frequency and amplitude of the sound produced by the engine for different conditions. The results are shown in the table below.

sl. No	Condition	Experiment No.	Frequency(Hz)
1	Engine not warm up	a)	92
		b)	90
		c)	95
2	Engine warms up after 10 min	a)	97
		b)	102
		c)	103
3	without one spark plug	a)	85
		b)	82
		c)	86
4	Without an air filter	a)	116
		b)	111
		c)	109

4.6. Discussion:

From the spectrogram it is clear that Frequency range of an automobile vehicle with idle speed is 90 to 95 Hz. When engine warms up after 10 minutes the frequency range is increased to 97-103 Hz. But if one spark plug is disabled to work properly then frequency level decreased to 82-85 Hz. Again if there is no air filter or air filter is not working properly the frequency level increased to 109-116 Hz. Hence for the similar problem particular engine should produce particular frequency range. So, by above mentioned method it would be very easy to determine the engine problem.

Chapter-5

5.1. Conclusion

This paper mentioned a systematic method to determine the engine problem by analyzing sound wave generated by engine. The results obtained here are approximate value and only suitable for particular engine model. Here also the experiment was based on only two faulty conditions. But it may happen that by analyzing other conditions similar frequency range may appear. So there is a scope to eliminate these problems by further research.

Of course, a more detailed investigation is required before we can derive general conclusions but it seems that the proposed method provides valuable information to the engineer in his effort to understand the operation of the engine. Furthermore, it is revealed that the proposed method can be used as a tool for the development of a database for various faults. This is extremely important if we take into consideration the data provided in the user manual for various engines, describing the most common faults .Using the simulation model a wide range of engine faults can be examined, and the process is faster and economical when compared to various experimental methods.

5.2 RECOMMENDATION

This report shows the feasibility of using active vibration control to attenuate the vibrations of the intermediate mass on a two-stage passive isolation mount used on the Collins Class submarines. It is expected that if the vibrations of the intermediate mass are reduced, the vibratory energy transmitted from the engines to the hull and then radiated into the water would also decrease. To evaluate the feasibility of using an active system, a complete engine mount was built with the same physical properties as a mount on a real submarine. The intermediate mass was equipped with seven actuators and seven error sensors, thus enabling control in all six degrees of freedom. Inertial actuators were used to generate the control forces and accelerometers were used to provide controller error signals and a measure of the control system performance. A reduction in the acceleration level of the engine harmonics transmitted through the engine mounts will result in a similar reduction in the portion of the acoustic signature attributable to this path. The newly acquired actuators used for the tests described in this report allowed control of levels of vibration that were similar to those measured on an actual submarine. The controller used a standard feedforward LMS-algorithm to minimize the kinetic energy at the error sensors. shaker and the signal driving this shaker was also used as a reference signal for the feed-forward control system. Two diferent experimental set-ups of the complete engine mount were evaluated. The first set-up was the same as used in the previous experiments, where the engine mount was made softer than a real installation on the submarines and was used to verify earlier results obtained using low-cost actuators and also to demonstrate the advantage of the new more powerful actuators. The second set-up was representative of the mount stifness and the engine static load on an actual submarine. This configuration was almost identical to the submarine installation, which was reflected in the inertance measurements.

Experimental results showed that for the first setup, [1], it was difcult to achieve good attenuation for the second harmonic, as reported in the earlier work with the low-cost actuators. Therefore, it may be concluded that this difculty originates from the physical properties of the engine mount. In the second setup,

the frequencies corresponding to the 1.5^{th} and 2^{nd} engine orders were now the

dominant harmonics tones transmitted through the engine mount to the bottom
plate. This is also in agreement real submarine data. For the second setup, the
active vibration control system performed quite well for the 1.5^{th} and 2^{nd} as well as the 1.0 engine order with attenuations achieved as high as 30 dB.

Diferent combinations of actuators and error sensors were evaluated in order to
examine the possibility of decreasing the number of actuators used. Each engine is supported by eight engine mounts and each submarine is equipped with three en- gines which adds up to 162 actuators. This would be a significant cost in hardware and maintenance in a real submarine installation.

The real-time experiments demonstrated that an active system configured with seven actuators and seven error sensors, i.e. control in all six degrees of freedom,
yields overall attenuations of 18.2 dB, 25.9 dB and 29.9 dB for frequencies corre- sponding to the 1^{st}, 1.5^{th} and 2^{nd} orders, respectively. If the system was reduced

in significant levels of reduction in the vibrations transmitted to the hull. This will reduce the acoustic signature resulting from the transmission path by the same amount. The significance of this transmission path in terms of its contribution to the total signature will require experimental data from an actual submarine.

Chapter-6

Future Work

Defined as unwanted or excessive sound, noise can be caused by a variety of sources related to expanded infrastructure that supports modern society. As mobility increases, transportation, in particular, can be a key source of noise across modes, from airports to rail to new roads.

Studies have shown that some of the most pervasive sources of noise in our environment are those associated with transportation. Residences and businesses often are faced with increased highway traffic noise, both from newly constructed highways and from highways that are already in place.

The responsibility for evaluating and mitigating adverse environmental effects including highway traffic noise. Public concern about noise led to federal legislation in 1970 that authorized the use of federalâ€'aid highway funds for measures to abate and control highway traffic noise. Administration develop noise standards for mitigating highway traffic noise. The law required promulgation of traffic noise-level criteria for various land use activities. The law further provided approve the plans and specifications for a federally aided highway project unless the project included adequate noise abatement measures to comply with the standards.

The following sections provides an overview of transportation noise issues.

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