

RESEARCH REVIEW ON FIELD OF EXHAUST MANIFOLD DESIGN

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Abstract - In the current century, spark ignition engines have become an isolated part of society, and are used in many fields of energy. They act as the backbone for transport systems, but, as a bitter truth they behave like a major source of air pollution. There are basically three types of emissions, one emerged from an SI engine; Exhaust emissions, evaporative emissions and crankcase emissions, and the major pollutants emitted from these engines are CO, CO₂, SOX, NOx. The current work aims to reduce emissions. It is a well-established fact that smooth combustion reduces emissions, and the exhaust process greatly contributes to completing the smooth combustion process. In the present work, multiple designs of exhaust for a multi-cylinder spark ignition engine are optimized to reduce emissions, by evaluating back pressure. For this purpose, four different designs, such as, short bend center exit, short bend side exit, long bend center exit with reducer, and long bend side exit with reducer are considered, and their performance is evaluated separately. Loading conditions are performed. The resulting performance scores of various models are evaluated based on back pressure, and based on these scores; the overall performance score is examined. In the next step, different models are ranked based on the overall performance score.

Key Words: Exhaust manifold, back pressure, exhaust velocity, CATIA v5, ANSYS workbench

1. INTRODUCTION

Air pollution can be defined as an addition of any material which will deleterious effect on the life on the earth. The main pollutants contributed by IC engines are carbon monoxide, nitrogen oxides, unburned hydrocarbons, and other particulate emissions. In addition to this, different fuels used in engines also emit carbon dioxide in large quantities, which is more concerned to greenhouse effect. A renounced meteorologist recently predicted that polluted air can put an end to life on the earth within a century. This, in turn, will reduce the emissions of carbon dioxide. A viable alternative to IC engines or alternative fuels is not likely to be available within the next few decades. Therefore, all efforts should be made to develop better engines, and methods to reduce the pollution from IC engines.

1.1 THEORETICAL CONSIDERATIONS

In an internal combustion (IC) engine, combustion of fuel takes place inside the engine cylinder in the presence of

oxygen (present in air), and a large amount of mechanical energy is obtained. For the purpose of combustion, either petrol is used along with air in case of spark ignition engines, or compressed air is used and diesel is sprayed in diesel engines. This process generates tremendous mechanical energy. Inside the engine cylinder, the piston power is transmitted to a shaft known as crank shaft, which converts reciprocating motion of the piston into rotary motion. Today's IC engines can be classified in many ways. Internal combustion (IC) engine rankings in some of the following methods:

1. Based on request

- a) Automobile engine;
- b) Aircraft engines;
- c) Locomotive Engine;
- d) Marine engines; and
- e) Stationary engines.

2. Based on the basic engine design

- a) Single cylinder engine,
- b) Multi-cylinder line engine,
- c) V-engine,
- d) Radial engine,
- e) Opposed piston opposed cylinder engine, and
- f) Rotatory engine.

3. Based on Operating Cycle

- a) Atkinson (full extension SI engine);
- b) Diesel (e.g. diesel engine);
- c) Dual (original diesel engine);
- d) Miller (early / late inlet valve closing type SI engine); and
- e) Otto (Convectional for SI engine).

4. On the basis of the working cycle

- a) Four stroke cycle;
 - b) Two-stroke cycle;
 - c) Clean, straight / crankcase / cross-flow, back flow / loop, uniform flow; and
 - d) Naturally Aspirated or Turbocharged.
5. Based on the valve / port design
- a) Poppet valve; and
 - b) Rotatory Valve.
6. Based on location Valve / port
- c) Head T- type;
 - d) Head L- type;
 - e) France head
7. Based on fuels used
- a) Convectional
 - b) Oil derivatives, petrol, diesel
 - c) Other sources, coal, standing biomass, tar, rock
 - d) Substitute
 - e) Petroleum derivatives CNG, LPG
 - f) Biomass derived: alcohol, vegetable oil, producer gas, biogas and hydrogen
 - g) Blending
 - h) Two fuel and dual-fuel
8. Based on Composition Preparation
- a) Carburetion; and
 - b) Fuel Injection.
9. Based on ignition type
- a) Spark ignition (SI); and
 - b) Compression ignition (CI).

2. LITERATURE REVIEW

Present chapter tells about the opinions of different researchers on pollutants form SI engines, and exhaust manifold designs, and finds the gaps found during the survey of literature, which constitute the objectives of the research, and concludes with the summary.

2.1 REVIEWS OF RELATED LITERATURE

A summary of literature based on different approaches adopted by researchers in the field of exhaust manifold design is present as follows:

1. Arcoumanis C (1994)

The researcher adopted a modelling approach for investigating flow distribution in exhaust manifold by modifying inlet and exhaust manifolds. Research also conducted experimentations for investigating the emission conditions for the engine.

2. Ahmed and Gowreesh (2015)

This research work consists of application of different CFD techniques to identify the optimum exhaust manifold for a 4-cylinder, 4-stroke petrol engine. In the research work, five variants of header based on manifold pipe geometry, namely, convergent inlet pipe, reduced convergent length, divergent-straight-convergent, reduced, divergent length, and enhanced convergent length, ideal divergent and convergent, and reduced straight length, are considered. The simulations were carried out with the help of simulation and analysis software ANSYS FLUENT using unstructured meshes. In the research work, boundary condition used was mass flow inlet. On the basis of results obtained, researchers reported that the minimum back-pressure at the exhaust manifold outlet can be achieved with the help of reducers.

3. Amruthraj, et al. (2012)

In the present work, researchers have studied the exhaust when a additive (brown gas) is mixed with air and petrol in 4 stroke SI engine. Results of the analysis show that with this combination, percentage of hydrocarbon emissions has reduced by 99.92%, and CO emissions are reduced by 98.668%.

4. Bafghi (2013)

In his research work, researcher analyzed the effect of exhaust gas to air manifold on NOx on different loads, the smoke temperature at exhaust, bsfc, vol. efficiency, and changes in thermal efficiency. Results of this research show that on increasing the exhaust temperature to the manifold, volumetric and thermal efficiency of the engine decreases.

5. Chi et al.(2012)

In this research work, performance of a single cylinder SI engine was estimated using 1-dimensional, GT-Power software. The virtually obtained power output, was then, compared against the experimental data. During the research work the considered parameters were the intake runner diameter, the position of restrictor, the exhaust runner lengths, and the sphere plenum diameter. For

designing the plenum for both the manifolds Helmholtz theory was applied, and the optimization experimental study was conducted with the help of Orthogonal Array Testing Strategy (OATS). The results obtained from the experimental analysis show satisfactory level of similarity with results of GT-Power software predictions.

6. Chiavola et al. (2001)

The researchers carried out the study of flow behaviour on intake and exhaust systems of an IC engine, and found that the phenomena of flow in ducts closely affects the volumetric efficiency of the engine.

7. Cho et al. (2013)

The researcher designs the exhaust manifold for a 4s- SI engine, to run at 700 – 1500 RPM, and with power output up to 600 kilowatts. In the research work, thermal expansion analysis, and vibration analysis of the exhaust manifold was carried out.

8. Choongsik and Junemo (2001)

The researchers performed the research to analyze the effect of exhaust gas re-circulation on combustion characteristics of a petrol engine.

9. Dattatray et al. (2013)

The researchers focused on thermal analysis of exhaust system for a motor bike silencer for the purpose of reducing hot spot through design improvement, and suggest for improving life of the device. During the research, they used a customized power coating for making mufflers used in automotive applications. As a result they analyzed that modified design offers reduced hot spots.

10. Dattuet al. (2014)

In this research work, researchers carried out thermal analysis for the exhaust manifold of tubular type, for various operating conditions. In the research work, researchers considered four different types, namely, radius 48 mm exhaust valve at extremely left, radius 48 mm exhaust valve at center, radius 100 mm exhaust valve at the extremely left, and radius 100 mm exhaust valve at the center. The materials used for this purpose were cast iron, and aluminium. On the basis of results obtained, researchers suggested that as a material aluminium shows better thermal performance as compared to cast iron, and the exhaust manifold with 48 mm radius with exhaust valve at the center, shows superior thermal properties as compared to the other options.

11. Durat et al. (2014)

The researchers carried out both computational fluid dynamics and experimental analysis for investigating

thermal performance of exhaust system for a SI engine. For this purpose, an experimental study was conducted to analyze the behaviour of gas flowing in exhaust pipe. The result shows satisfactory values.

12. Ghazikhani et al. (2014)

The researchers focused on exergy recovery for a diesel engine of direct injection type. In the research work investigations were performed for turbocharged diesel engines for different RPM and torque values. For this purpose, a double pipe heat exchanger with reversed flow conditions was used. The research shows that by increasing load and engine speed the recovered exergy of the system increases, while the bsfc reduces by approximately 10%.

2.2 GAPS IN THE LITERATURE

On the basis of above mentioned literature survey, following gaps are being identified:

There is a limited research available considering different geometries of exhaust manifold; there is a limited research conducted for analyzing pressure and velocity changes happening in the header and their effect on exhaust emission; and Comparative study of different geometries of exhaust manifold for reducing exhaust emission problem.

Based on the gaps noticed in literature, objectives for the present research work are targeted.

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