International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 08 | Aug - 2021 ISSN: 2582-3930

Study and Experimental Analysis on Dust Holding Capacity of Engine Air Cleaner Filter Media at Steady and Dynamic Condition

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Abstract – Air Cleaner Assembly is a most important part of automobile sector for any type of vehicle, it affects the performance of the engine, A typical filter testing condition do not strictly control the introductory parameters; Hence there is always a variation between the laboratory filter testing and the actual operating condition. Air cleaner dust feeding results are useful to predict the total life of the air cleaner element, testing condition are effect on the results. Air cleaner assembly is also used for increasing the life of engine, increasing the performance of the fuel consumption, decreasing the noise, vibration & harshness (NVH) and enhancement of the engine NVH characteristics provides passenger's comfort. The Noise is reduced. This Paper focused on dust loading capacity in air cleaner assembly at different two conditions, one is steady condition and another is dynamic condition. Both tests are conducted in laboratory. In dynamic condition model is based on generation of random vibration distribution. The test predicts the more dust collection, which was found to be strongly and increased depending on the test condition.

Key Words: Air Cleaner Assembly, Air Cleaner Media, Performance, Vibration, Pressure Restriction, Dust Holding Capacity.

1. INTRODUCTION

Air cleaner assembly is required to all Si and Ci engine type of automotive vehicles. Working of the air cleaner assembly is to separate the dust particle from the air. In the air cleaner assembly air filter is placed which separate the dust particle. In the market there is many type of air cleaner filter media is available with different material. Due to separation of dust particle form air, clean air received but engine, so the life of the engine and efficiency of the engine is increased. The design of the air cleaner assembly is different for each vehicle. It depends on the purpose of the vehicle, size of engine and structure required to fit the assembly. The area of air cleaner filter media is also depend on vehicle and purpose of the vehicle.

Air Cleaner performance test is done in the laboratory. For air cleaner performance test some standard are specified (ASH-RAE 52.2:2017, ISO 16890:2016, EN 779:2012, ISO 5011:2020, etc.) only specify a testing temperature range close to the room temperature or the testing temperature is not mentioned.

Now a days due to the increasing pollution air get more dusty, engine gives more efficiency on highway because there is less dust and constant flow is coming to the engine but as we are going in small town or rural area there no road construction developed so vehicle move in dirty area where more dust particle is present the efficiency of engine get reduce, life of the engine is also reduced. The air cleaner assembly provides a clean air to the engine from the atmosphere. Work of the air cleaner assembly is to separate the dust particle from the air and provide clean air Noise, Vibration and harshness are most effective parameters to develop with different conditions while study and check practical prospective at steady condition and dynamic condition some difference was occurs. [1-2].

The performance and pressure restriction or differential pressure of the air cleaner assembly of two wheelers are also affecting on the shape of the air cleaner assembly, diffuser is also connected to the assembly but the diffuser is attached for larger engines or high performance engine. Also performance effect on air cleaner filter element, which type of filter we are using. Because there is lot of aftermarket air cleaner element is also available but that cannot give a performance like OEM air cleaner element, some aftermarket element gives greater performance than the OEM result but the economically price of that aftermarket is more than the OEM's air cleaner element. Some of the industries are only making aftermarket elements. They changed the shape of the air cleaner filter elements for passing the air easily and reduce the pressure restriction of an air cleaner assembly the result is that performance of the engine get increased and life of the engine also more, no need to change air filer element frequently [3-4].

Air cleaner performance is also affecting on dust loading capacity and efficiency, for efficiency of the filtration area is also important, more filtration area gives less Pressure Restriction and gives higher performance due to less power required to intake the clean air. The different type of structure also used to increase the filtration area for improving the performance [5]. Natural frequency, vibration comes from the engine and alsovibration comes due to rigid of rough road condition. Vibration comes from engine is different at different speed or at RPM. As RPM or speed of vehicle increased the vibration comes from engine also changed and it will also affecting on performance [6].

Air cleaners operate in versatile environments, such as different relative humilities (RH), temperatures. Air cleaner filter media are mostly made of cellulose, because it is cheap and easy to manufacture and process. Working of air cleaner assembly is always in moving condition of vehicle. From the engine some vibration is generating continuously which is effect on the air cleaner element. In entire research only vibration characterization is done on the air cleaner assembly, in this paper I have to study and compare the practical analysis of air cleaner assembly at steady and dynamic condition, to determine the difference in result. The dust loading capacity of air cleaner element important measure for service life of engine. The dust loading capacity can be measured in the laboratory by performing test. It is an important tomaintaining the low pressure drop across the air cleaner element while holding more dust mass, which could reduce costs of the air cleaner itself and maintenance costs of the all air cleaning equipment. The dust particle size of the dust is in micron level.

In the laboratory study, for dust loading test, sodium chloride (NaCl) and potassium chloride (KCl) are used, because they are cheap, widely available, and non-toxic.

2. Methodology and Experimental setup

Methodology:

In the air cleaner performance testing two different type of testing condition are compared, one is steady condition and another is dynamic condition. Required is full setup of Air cleaner assembly testing, in this testing we are compare the Pressure Restriction (ΔPr) of the air cleaner assemblywith various flow rates (m^3/min), another test is air cleaner performance test this test for dust holding capacity of element and air cleaner assembly.

Two wheeler vehicles have small air cleaner and required less pressure drop and minimum flow rate as compare with other automotive or heavy duty vehicles, This test is conducted with the reference of ISO5011 standard of two wheeler air cleaner assembly which is single stage air cleaner, It not necessary to attached pre- cleaner or more filter element. Measure the pressure restriction at 50%, 75%, 100%, 125% & 150% of the required flow rate. The dust feed rate is less than 5g/min for two wheelers. Dust concentration Based on the test flow, calculate the test dust feed rate using a dust concentration.

Test Setup:

Two different setup is required for steady and dynamic condition for 1st setup for air cleaner performance testing at steady condition without giving any vibrations to the air cleaner assembly from outside or from the machine, that steady condition results given from the testing.

For 2nd setup, addition of vibration fixture bed in the 1stsetup, below the air cleaner assembly as shown in fig2. and continue the same test as done for steady condition setup. While testing the vibration are given to the assembly.

The filter loading tests in the laboratory is simulating with filter operation in real conditions. But in real condition and lab condition some difference because in real condition the vehicle is in motion and in the lab the condition of air cleaner is steady condition. There is two type of test first is pressure restriction or differential pressure test in this test pressure restrict by air cleaner filter media is measure. And second is the air cleaner performance test, in this testing the dust holding or dust feeding of the filter media is calculated.

As discussed, In this study two different type of setup prepared for air cleaner performance test. In the both setup the full air cleaner performance test is perform. The test is conducted in the laboratory for both conditions.

Vibrations are generated in the engine and it passed to the air cleaner assembly as well as due to worst road conditions some extra vibration or sudden movement effect on air cleaner assembly. For creating this type of condition one extra fixture is attached to the air cleaner assembly. This is placed under the air cleaner assembly as shown in fig.2. The working of the fixture is to create the vibration and gives vibration to the air cleaner assembly. Pressure restriction test is non distractive type of test and air cleaner performance test is distractive test.

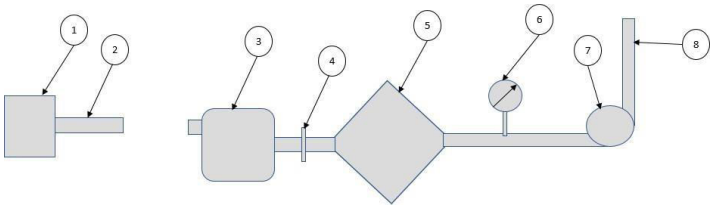

Fig.1- 2D Drawing of Test Setup for Steady Type of Condition Test.

In this work, performance test of air cleaner assembles with steady and dynamic condition. The air cleaner assembly used in this experiment is basically preparedand designed for two wheeler vehicle. Material used for air cleaner assembly is plastic. Paper media is used as filter element. Setup images are shown below.

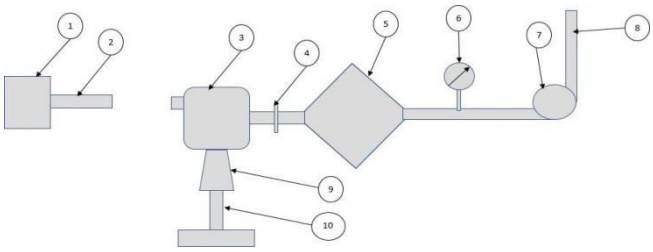

Fig.2- 2D Drawing of Test Setup for Dynamic test Condition.

Where,

1. Dust Holder,
2. Nozzle,
3. Air Cleaner Assembly,
4. Pressure Sensor,
5. Absolute Filter,
6. Flow meter/ Flow Adjuster.
7. Blower,
8. Air send to Atmosphere,
9. Mechanical Vibration Fixture Bed,
10. Stand for the Fixture.

2.1 Experiment

For this experiment the inputrequired as flow rate dust feed rate and terminal pressure. For steady type of test condition, The Nominal flow rate for the pressure restriction is 0.368m3/min. according to the standard at pressure restriction to be check at 50%, 75%, 100%, 125%, 150% of the nominal flow rate. And for air cleaner performance test terminal pressure is also same for both steady and dynamic test condition, all parameters are same. In the dynamic condition

vibration fixture bed is added the vibration are generate by fixture bed is 70Hz as shown in Fig.3 and Fig.4.

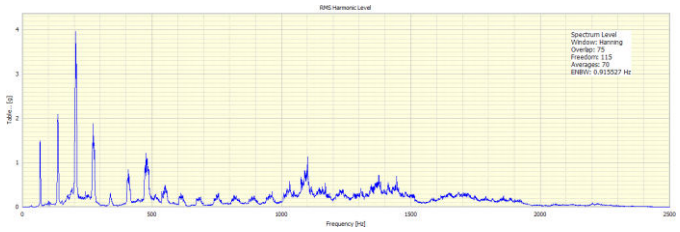

Fig.3: Vibrations from fixture

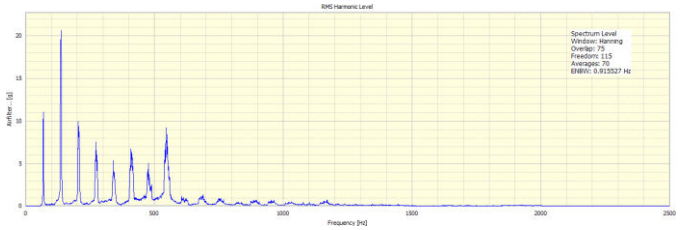

Fig.4: Vibration received from air cleaner assembly

The Test result of pressure restriction test for steady condition and dynamic condition is same. In the table and graph is also shown below.

Table1: Pressure Restriction Test Result at Steady and Dynamic Condition.

Flow Rate	Steady Condition	Dynamic Condition
% of Nominal	Pa	Pa
50%	35.6	35.7
75%	68.7	68.3
100%	109.2	110.4
125%	163.9	162.9
150%	227.8	227.9

As discuss above the pressure restriction test is nondestructive type of test so the pressure restriction test is done in both the assembly at steady and dynamic condition on that basis the result are shown. The Air cleaner performance testing is done in same assembliesone is used for steady condition test and another used for dynamic condition test with same inputs.

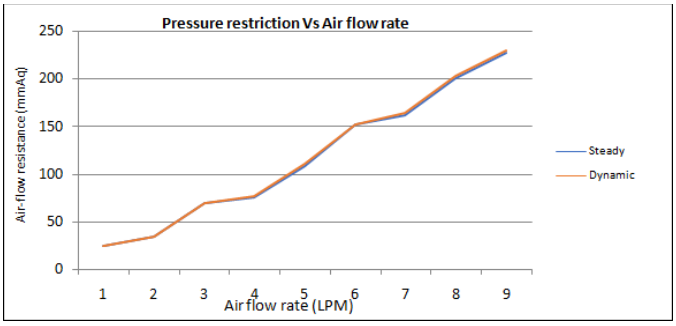

Fig5: Air Cleaner Pressure Restriction Result

For Air cleaner performance testing the nominal flow rate is 0.37 m3/min and dust feed rate is 1g/min. for the entire test the room temp and humidity is controlled as per given in standard. For both the testing, Flow Rate, Dust feed and terminal pressure are same. In the dynamic test the vibration given to the assembly is 70Hz entire the test.

Mounting of the air cleaner element is vertically the dust is collected on the air cleaner element is not get stuck on the element due to continuous vibration and the dust holding capacity is increased in the dynamic test condition.

Steady condition the dust holding capacity of the air cleaner element is 9grams and in dynamic test condition the dust holding increased to 10grams. Detail shown in below graph,

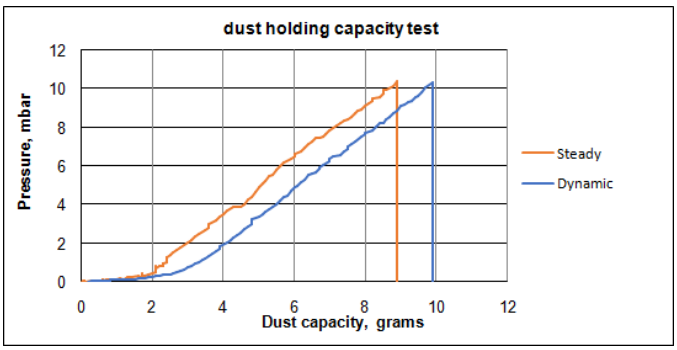

Fig.6: Dust Holding Capacity result

Fig.7: Before and After Testing Image of air cleaner assembly

For the air cleaner performance testing the ISO Fine dust is used refer to the standard and that is suitable to the environment.

3. OBSERVATIONS

In this experiment two different air cleaner assemblies are used. A pressure restriction test at steady and dynamic condition test are done on both the assemblies, no difference is occurring in the result. It is non distractive type of test, so these assemblies are used for air cleaner performance test.

After air cleaner performance test,it is observe that there is more dust collected in downside of the assembly. While testing at steady condition the dust is collected on the surface of air cleaner element or the dirty side of the media. But in dynamic testing in some amount of dust get separated from the air

cleaner assembly due to continuous vibration. Due to this the pressure increases in the air cleaner assembly slower than the steady condition of test. And extra dust is observed in the case of the air cleaner assembly.

4. CONCLUSIONS

From the pressure restriction testing it concludes that there is no change in pressure restriction test. But in air cleaner performance testing the dust holding capacity is change from 9gram to 10 grams. The dust holding capacity increased by 10-11% with the dynamic condition

The effect of engine vibration and vibration from road helps to increase the dust holding capacity of the air cleaner element only one condition is required; the mounting of the air cleaner element is vertical. If the mounting is horizontal then the dust holding capacity f the air cleaner element get reduced.

ACKNOWLEDGEMENT

This work is carried out by the equipment available at R&D analytical laboratory of Varroc Polymer Pvt. Ltd. Technical Center, Aurangabad, Maharashtra, India.

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