



Correlation between Hot and Cold Test Procedures on IC Engines

¹Aayush Bhatnagar

Student at

South Indian Education Society Graduate School of Technology
Nerul, Navi Mumbai, Maharashtra, India

Abstract: Engine testing is a fundamental aspect of the automotive industry, crucial for ensuring performance, reliability, and compliance with regulatory standards. It involves subjecting engines to various operating conditions and environmental factors to evaluate their functionality, efficiency, and emissions characteristics. This article explores the association between hot and cold engine testing, using Minitab software to assess crucial data such as Exhaust Gas Recirculation (EGR) and Throttle Position Sensor (TPS) and various others. A thorough analysis was carried out in order to better understand the performance differences between hot and cold engine situations. The link between EGR, TPS, and engine performance parameters was investigated using Minitab statistical analysis software. Key findings indicate substantial relationships between EGR, TPS, and ultimate output characteristics, providing insight into the dynamic behavior of engines under various temperature circumstances.

IndexTerms – Cold Testing, Hot Testing, Minitab.

1.INTRODUCTION

To test performance before mass production and installation in a vehicle. Historically, the test was to determine the power and fuel consumption, as well as the effectiveness of cooling, vibration and noise, lubrication, controllability, and other factors in order to improve the design and configuration and integrate new materials and technology. Modern regulations force engines to reduce harmful emissions and comply with stringent regulations, so testing is becoming more sophisticated. The sensors and actuators send data to the Engine ECU (Engine Controlling Unit), which communicates with the test bed software to record the tested parameters, compare them to performance acceptance norms, and provide a test result in the form OK / Not OK. It also provides information on each test cycle step and engine behavior in those operating conditions to aid in diagnosis and research. After the engine is assembled properly, the harness is attached and every sensor is fitted properly, the engines are sent for testing. The diesel engines testing is done by two types (1) Hot Testing & (2) Cold testing.

1.1 COLD TESTING

After the engine is assembled, the engine is sent to the cold testing. The harness cable is attached to the ECU, and the radiator coolant and fuel lines are attached. Also, the turbocharger is given the intake. Then the connected engine goes into the cold test bed. The cycle time for cold testing is 2 minutes. As a contrast to Hot testing, in cold testing the fuel is not actually ignited. An electric motor is used to test the engine. The average rpm is around 800 where all the parameters are checked.

Firstly, all the sensors are checked by the ECU if they are running properly or not. After the sensor test, the electric motor starts up which makes the engine run. Parameters like Cam and Crank, vibration, injectors are checked. After the test is completed the oil and coolant lines are disconnected and the harness is removed. After this the clutch plate is installed and the engine moves towards the hot test. The advantages include that the fuel is not ignited and in turn no noise or air pollution. The disadvantages include Blow by and Specific Fuel Consumption are not measured

1.2 HOT TESTING

The engines are started and tested as if they were in their respective vehicles during the Hot Test process, also known as bench tests. The fuel is burned. The operation of this process is essentially a dynamometer brake that absorbs the energy produced by the engine. There is an automated system which is being used which helps in running the engine at specified rpms and gets the parameters being checked. The engine is connected to the ECU which is present in the test bed.

The hot test is done so that the benchmark which one car provides is same throughout all the engines that are being assembled. Generally, an eddy dynamometer is used which is attached to the clutch plate which makes the engine run. An eddy current dynamometer is an electro-mechanical energy conversion machine that changes mechanical energy to electrical energy. Before starting of the test the ECU checks all the sensors.

Parameters like oil temperature, blow by, fly up speed are measured in this type of testing. After the test UV light is used to check for any leakages. After this the engine gets an OK Tag and is moved on to the trim line for further attachments. There are several types of engine tests in the industry, the most common of which are: (1) Durability test. (2) Performance testing; (3) lubricant and fuel testing; and (4) special investigations (5) Exhaustion system test; (6) catalysis agent test. At full load, performance tests are commonly used in diesel automotive engines. This will determine the maximum engine power in each rotation of its operation, based on quality requirements. The advantages include checking blow by but the disadvantages include air pollution and time taken is more as compared to cold testing.

| Sr No | Engine Performance Parameter | Hot Testing | Cold Testing |
|-------|---------------------------------------|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | Torque at different RPMs | Checked at different RPM with Dynamometer | 1. Friction: Breakaway Torque & Continuous Torque 2. Engine Timing: Cam Crank Timing Test 3. Air Flow: Intake Vacuum Test 4. Fuel: Common Rail Test & Diesel Injector Test 5. Exhaust Back Pressure: Exhaust Pressure Test |
| 2 | SFC | Checked with SFC meter | 1. Diesel Injector Test 2. Common Rail Test with IMV Control |
| 3 | Oil Pressure | Checked with pressure transducer | 1. Oil relief Test at reduced RPM 2. Oil Gallery Pressure test |
| 4 | Engine Blow-by at 4000 RPM and idling | Checked with Blow by meter | 1. Continuous Torque as a function of piston ring tightness 2. Exhaust pressure test to check proper opening of exhaust valves |
| 5 | Engine Wiring Harness Check | Static & Dynamic check with ECU initialization | Checked @ cold Test as function of various tests including the sensor static test & various actuator test. |
| 6 | Smoke | Checked with smoke meter | 1. Diesel Injector Test 2. Common Rail Test with IMV Control |
| 7 | Turbocharger Boost Pressure | Checked with pressure transducer | N/A |

Table 1.2.1 – Parameter comparison of Hot Testing and Cold Testing.

| Resources Measured | Hot Test | Cold Test |
|------------------------------------|----------------|-------------------|
| Productivity | 15 mins/engine | 90 seconds/engine |
| Work force requirement | 5 | 1 |
| Average Fuel Consumption | 1.5 L/Engine | 0.1/Engine |
| Average Electricity Consumption | Yes | Yes |
| Average Compressed Air Consumption | Yes | Yes |
| Noise Level | 100 to 150 dB | 80 dB |
| Water requirement | Yes | No |
| Exhaust gas treatment | Yes | No |

Table 1.2.2 Operational Parameters of Hot and Cold tests

2. DATA COLLECTION:

| Sr No. | Engine No. | Engine OK/NO OK | | Remarks |
|--------|------------|-----------------|-----------|----------------------------|
| | | Hot Test | Cold Test | |
| 1 | 2XXXX | Pass | Pass | |
| 2 | 2XXXX | Pass | Fail | Cam and Crank sensor issue |
| 3 | 2XXXX | Pass | Pass | |
| 4 | 2XXXX | Pass | Fail | Dynamic and Static |
| 5 | 2XXXX | Pass | Fail | Dynamic and Static |
| 6 | 2XXXX | Pass | Fail | Static |
| 7 | 2XXXX | Pass | Fail | Dynamic, Static, EGR TPS |
| 8 | 2XXXX | Pass | Pass | |
| 9 | 2XXXX | Pass | Fail | Static |
| 10 | 2XXXX | Pass | Fail | Static |
| 11 | 2XXXX | Pass | Fail | Exhaust Pressure |
| 12 | 2XXXX | Pass | Pass | |
| 13 | 2XXXX | Pass | Fail | Common Rail Issue |
| 14 | 2XXXX | Pass | Pass | |
| 15 | 2XXXX | Pass | Pass | |
| 16 | 2XXXX | Pass | Fail | Static |
| 17 | 2XXXX | Pass | Fail | Injector |
| 18 | 2XXXX | Pass | Fail | Common Rail |
| 19 | 2XXXX | Pass | Fail | Exhaust Pressure |
| 20 | 2XXXX | Pass | Pass | |
| 21 | 2XXXX | Pass | Pass | |
| 22 | 2XXXX | Pass | Pass | |
| 23 | 2XXXX | Pass | Pass | |
| 24 | 2XXXX | Pass | Fail | EGR TPS |
| 25 | 2XXXX | Pass | Fail | Common Rail |
| 26 | 2XXXX | Pass | Pass | |
| 27 | 2XXXX | Pass | Fail | Exhaust Pressure |
| 28 | 2XXXX | Pass | Pass | |
| 29 | 2XXXX | Fail | Fail | Injector |
| 30 | 2XXXX | Pass | Pass | |
| 31 | 2XXXX | Pass | Pass | |
| 32 | 3XXXX | Pass | Fail | EGR TPS |
| 33 | 3XXXX | Pass | Fail | Common Rail |
| 34 | 3XXXX | Pass | Pass | |
| 35 | 3XXXX | Pass | Pass | |
| 36 | 3XXXX | Pass | Fail | Dynamic, Static, EGR TPS |
| 37 | 3XXXX | Pass | Fail | EGR TPS |
| 38 | 3XXXX | Pass | Fail | Injector |
| 39 | 3XXXX | Pass | Fail | Oil Relief |
| 40 | 3XXXX | Pass | Fail | Exhaust Pressure |
| 41 | 3XXXX | Pass | Pass | |
| 42 | 3XXXX | Pass | Fail | Dynamic, Static, EGR TPS |
| 43 | 3XXXX | Pass | Pass | |
| 44 | 3XXXX | Pass | Fail | Static Dynamic |
| 45 | 3XXXX | Pass | Pass | |
| 46 | 3XXXX | Pass | Fail | Exhaust Pressure |
| 47 | 3XXXX | Pass | Fail | Dynamic Static EGR TPS |
| 48 | 3XXXX | Pass | Fail | Static Dynamic |
| 49 | 3XXXX | Pass | Pass | |
| 50 | 3XXXX | Pass | Pass | |
| 51 | 3XXXX | Pass | Pass | |
| 52 | 3XXXX | Pass | Pass | |
| 53 | 3XXXX | Pass | Pass | |
| 54 | 3XXXX | Pass | Fail | Injector |
| 55 | 3XXXX | Pass | Fail | Common Rail |
| 56 | 3XXXX | Pass | Pass | |
| 57 | 3XXXX | Pass | Pass | |
| 58 | 3XXXX | Pass | Pass | |
| 59 | 3XXXX | Pass | Fail | Exhaust Pressure |
| 60 | 3XXXX | Pass | Pass | |
| 61 | 3XXXX | Pass | Pass | |
| 62 | 3XXXX | Pass | Fail | Static |
| 63 | 3XXXX | Pass | Fail | EGR TPS |
| 64 | 3XXXX | Pass | Fail | Static |
| 65 | 3XXXX | Pass | Fail | Static Dynamic |
| 66 | 3XXXX | Pass | Pass | |
| 67 | 3XXXX | Pass | Fail | Injector |
| 68 | 3XXXX | Pass | Pass | |
| 69 | 3XXXX | Pass | Pass | |
| 70 | 3XXXX | Pass | Pass | |
| 71 | 3XXXX | Pass | Fail | Common Rail, Injector |
| 72 | 3XXXX | Pass | Pass | |
| 73 | 3XXXX | Pass | Fail | Static |
| 74 | 3XXXX | Pass | Fail | Exhaust Pressure |
| 75 | 3XXXX | Pass | Pass | |
| 76 | 3XXXX | Pass | Fail | |
| 77 | 3XXXX | Pass | Fail | Static |
| 78 | 3XXXX | Pass | Pass | |
| 79 | 3XXXX | Pass | Pass | |
| 80 | 3XXXX | Pass | Fail | EGR TPS |
| 81 | 3XXXX | Pass | Fail | Static |
| 82 | 3XXXX | Pass | Fail | Injector |
| 83 | 3XXXX | Pass | Fail | Injector |
| 84 | 3XXXX | Pass | Fail | Static |
| 85 | 3XXXX | Pass | Fail | Static |
| 86 | 3XXXX | Pass | Pass | |
| 87 | 3XXXX | Pass | Fail | Common Rail |
| 88 | 3XXXX | Pass | Fail | Injector |
| 89 | 3XXXX | Pass | Pass | |
| 90 | 3XXXX | Pass | Pass | |
| 91 | 3XXXX | Pass | Pass | |
| 92 | 3XXXX | Pass | Fail | Static |
| 93 | 3XXXX | Pass | Fail | Injector |
| 94 | 3XXXX | Pass | Fail | Static |
| 95 | 3XXXX | Pass | Pass | |
| 96 | 3XXXX | Pass | Pass | |
| 97 | 3XXXX | Pass | Fail | Exhaust Pressure |
| 98 | 3XXXX | Pass | Fail | Static |
| 99 | 3XXXX | Fail | Fail | Common Rail |
| 100 | 3XXXX | Fail | Pass | |

Table 2.1 Data Collection of Hot and Cold Test Methods and the remarks

As you can see even if the engine fails in the cold test, it is sent to the hot test, where it passes. This shows that the cold test is unreliable, and its limits need to be changed.

| Issues for Cold Test | |
|----------------------|----------------|
| Error | No. of Engines |
| Cam and Crank | 1 |
| Dynamic | 8 |
| Static | 23 |
| EGR TPS | 8 |
| Injector | 9 |
| Common Rail | 8 |
| Exhaust Pressure | 8 |
| Oil Relief | 1 |

Table 2.2 Issues being faced in Cold Testing

3. LITERATURE REVIEW

For this study we have used Minitab software to find out the limits of diesel injectors, static sensors and dynamic sensors. Minitab is a statistical analysis software which helps in analyzing the data collected accurately, with reliability and with faster and more efficient analyzing techniques. Since it was created in 1972, Minitab has become the leading statistical software for quality improvement. It is used in every manufacturing industry that uses data analysis and statistics to make their products and processes better.

The software performs various statistical tests, including t-tests, ANOVA, and regression analysis. Minitab can also be used to create graphs and charts to represent data visually. Businesses use Minitab to understand their customers better, improve their products and services, and make more informed decisions.

Advantages of Minitab over Excel:

- Excel is primarily used for number entering, while Minitab can be used to perform statistical analysis. It means that excel is good one for the tasks like the financial modelling, whereas Minitab is good one for the jobs like analyzing data sets.
- Minitab is designed for the statisticians and other data specialists whereas excel is designed for the general users.
- As compared to Excel, Minitab offers more options and features for statistical analysis.

4. DATA ANALYSIS:

This requires deeper study how testing parameters are correlated with each other in both processes. We have seen the dependency of all parameters in data collected above for 100 sample engines.

4.1 Static Sensors

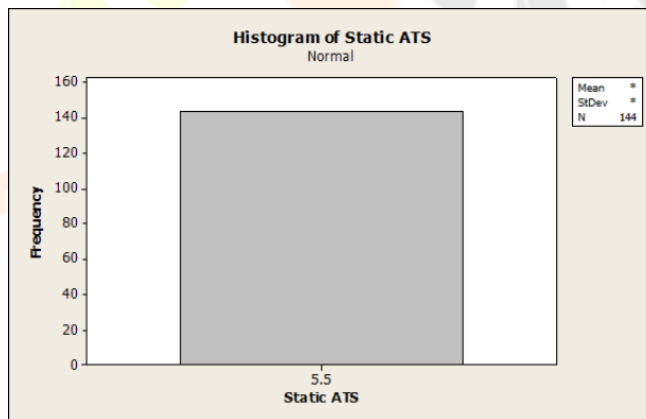


Figure 4.1 Analysis curve for ATS Static

Interpretation:

1. There is no curve present as there is no deviation of the values.
2. Thus we can take the LSL as 4.5 and USL as 6.5

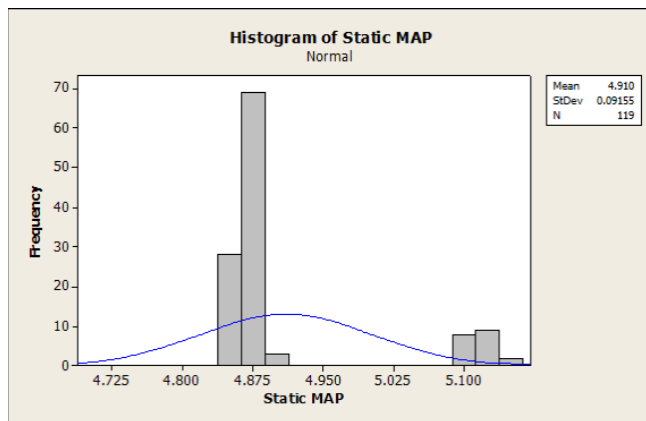


Figure 4.2 Normal Distribution for Static MAP

Interpretation:

1. The LSL will be 4.5 and the USL will be 5
2. The normal distribution curve has shifted to the right due to out of the range values.

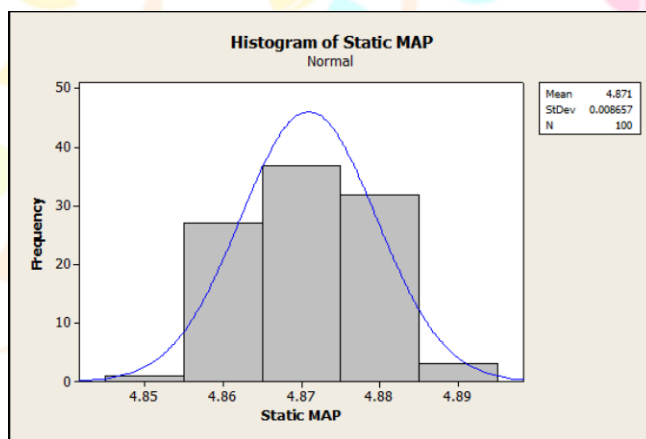


Figure 4.3 Normal Centralized Distribution for Static MAP

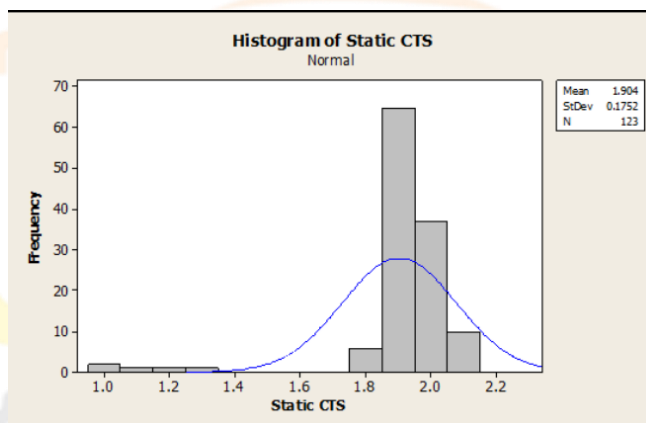


Figure 4.4 Normal Distribution for Static CTS

Interpretation:

2. The LSL will be 1.8 and the USL will be 2.2.
3. The normal distribution curve has shifted to the left due to out of the range values.

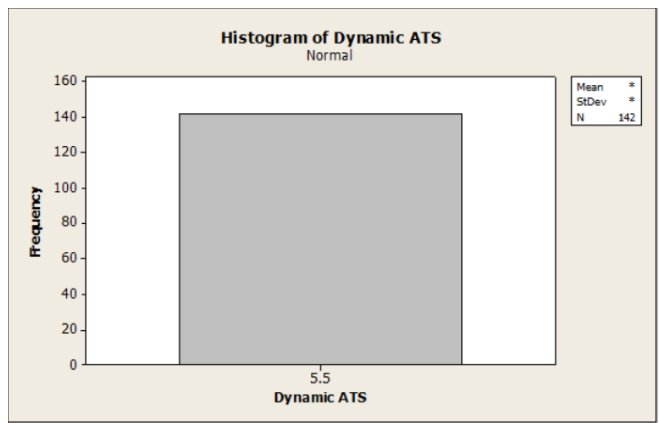


Figure 4.2.1 Normal Distribution for Dynamic ATS

Interpretation:

2. There is no curve present as there is no deviation of the values.
3. Thus, we can take the LSL as 4.5 and USL as 6.5.

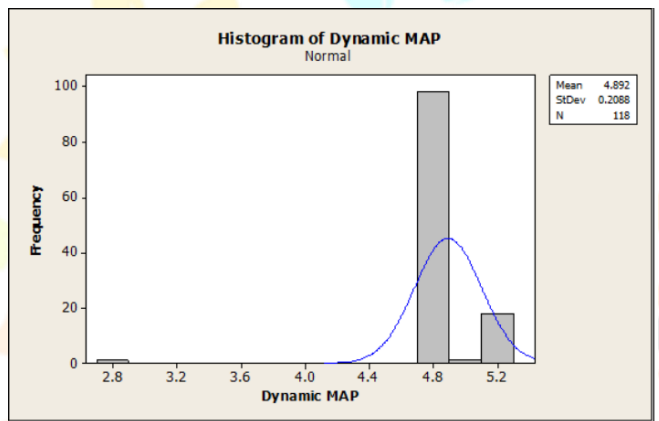


Figure 4.2.2 Normal Distribution for Dynamic MAP

Interpretation:

1. The LSL will be 4.4 and the USL will be 5.5.

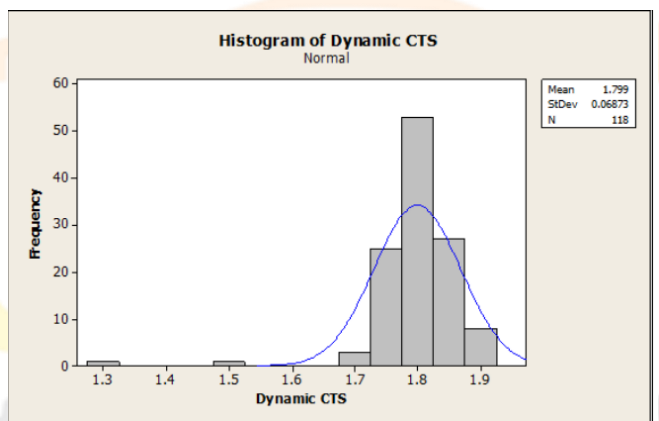


Figure 4.2.3 Normal Distribution for Dynamic CTS

Interpretation:

1. The LSL will be 1.6 and the USL will be 2.

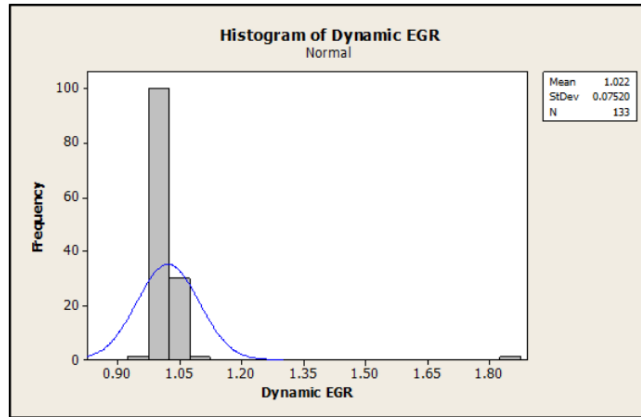


Figure 4.2.4 Normal Distribution for Dynamic EGR

Interpretation:

1. The LSL will be 0.5 and the USL will be 1.25

4.3. EGR and TPS

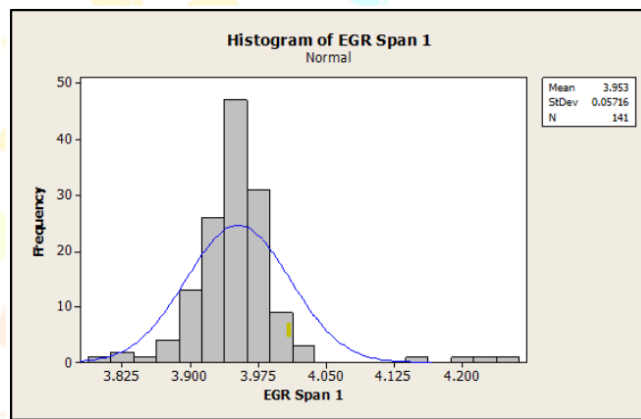


Figure 4.3.1 Normal Distribution for EGR Span 1

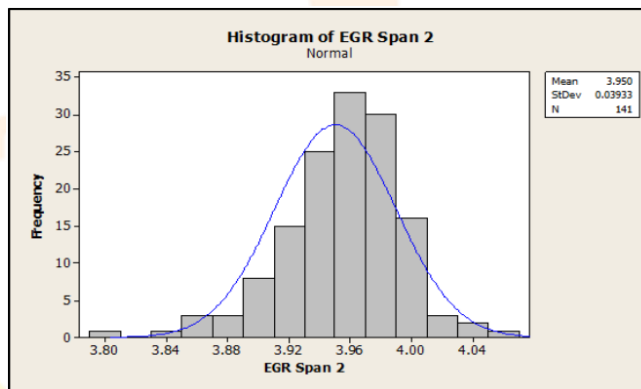


Figure 4.3.2 Normal Distribution for EGR Span 2

Interpretation:

1. The LSL will be 3.8 and the USL will be 4.2

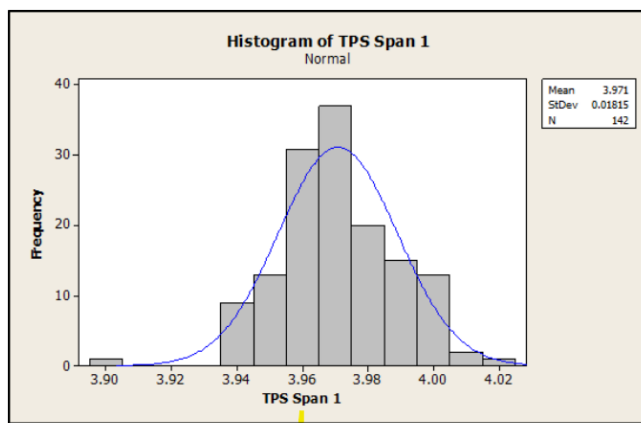


Figure 4.3.3 Normal Distribution for TPS Span 1

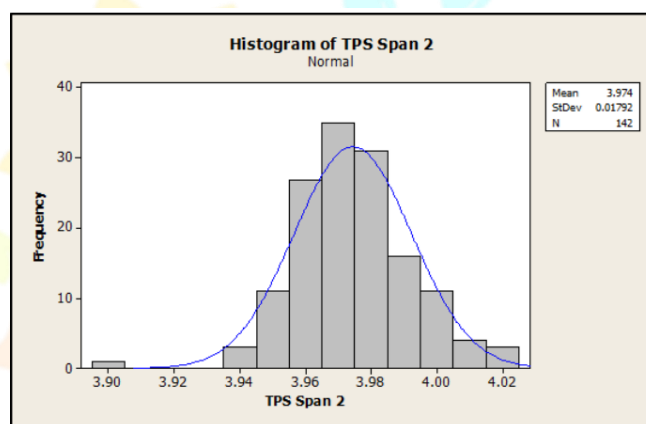


Figure 4.3.4 Normal Distribution for TPS Span 2

Interpretation:

1. The LSL will be 3.92 and the USL will be 4.1.

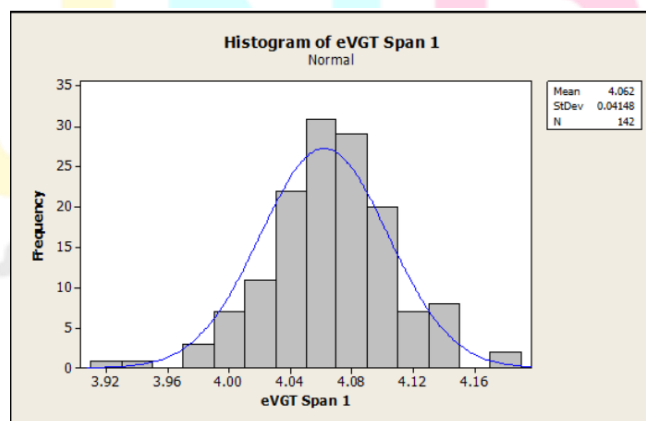


Figure 4.3.5 Normal Distribution of eVGT Span 1

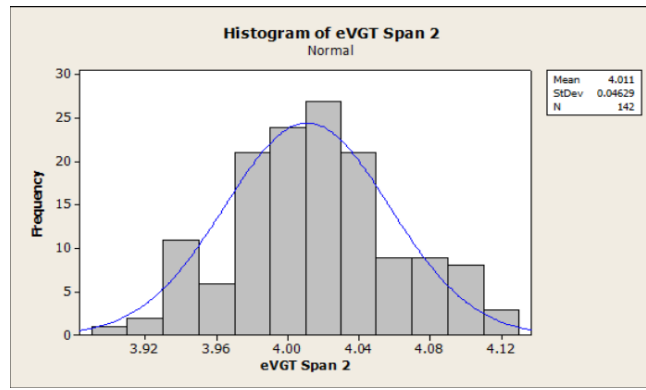


Figure 4.3.6 Normal Distribution for eVGT Span 2

Interpretation:

1. The LSL will be 3.90 and the USL will be 4.2.

5. SUMMARY AND CONCLUSION

We are summarizing the observations and analysis in this chapter to conclude the project findings and identify the recommendations for sustenance and improvements.

Conclusion based on analysis:

| Serial No. | Parameters | OLD LSL | OLD USL | NEW LSL | NEW USL |
|------------|-------------|---------|---------|---------|---------|
| 1 | Static ATS | 4 | 6 | 4.5 | 6.5 |
| 2 | Static MAP | 3 | 6 | 4.5 | 5 |
| 3 | Static CTS | 0.05 | 2 | 1.8 | 2.2 |
| 4 | Dynamic ATS | 4.8 | 5.8 | 4.5 | 6.5 |
| 5 | Dynamic MAP | 4.8 | 5.6 | 4.4 | 5.5 |
| 6 | Dynamic CTS | 0 | 2 | 1.6 | 2 |
| 7 | Dynamic EGR | 0 | 5.5 | 0.5 | 1.25 |
| 8 | EGR Span 1 | 3.5 | 4.15 | 3.8 | 4.2 |
| 9 | EGR Span 2 | 3.5 | 4.15 | 3.8 | 4.2 |
| 10 | TPS Span 1 | 3.5 | 4.1 | 3.92 | 4.1 |
| 11 | TPS Span 2 | 3.5 | 4.1 | 3.92 | 4.1 |
| 12 | eVGT Span 1 | 2.5 | 4.15 | 3.9 | 4.15 |
| 13 | eVGT Span 2 | 2.5 | 4.15 | 3.9 | 4.15 |

Table 5.1: The new and old limits of the parameters

Conclusions based on cost and operational parameters:

| Sr No. | Resources Measured | Hot Test | Cold Test | Comparison | Advantage |
|--------|------------------------------|----------------|---------------|----------------------------------------------------------------------------------|-----------|
| 1 | Productivity | 15 mins/engine | 2 mins/engine | One cold test bed does 40% more testing than 4 hot test bed tests simultaneously | Cold Test |
| 2 | Work Force | 5 | 1 | 70% less manpower required in Cold Testing | Cold Test |
| 3 | Complexity | Yes | Yes | Cold Test is more complex | Hot Test |
| 4 | Real drive condition testing | Yes | No | Hot Test is performed at various load and RPM | Hot Test |
| 5 | Water Requirement | Yes | No | No cooling in cold test as engine does not run | Cold Test |
| 6 | Noise Level | 100 - 105 dB | 50 dB | Hot Test needs chamber due to high noise | Cold Test |
| 7 | Engine Leakage Detection | Visual | Value Based | The leakage is calculated upon inlet and outlet for cold test | Cold Test |
| 8 | Exhaust Gas treatment | Yes | No | No pollution in cold testing as fuel is not ignited | Cold Test |
| 9 | Electricity Consumption | Yes | Yes | Both need electricity to run | Same |
| 10 | Compressed air consumption | Yes | Yes | Both need compressed Air | Same |

Table 5.2 Conclusion based on cost and operational parameters

Based on productivity, operational cost and assembly process improvements strengthening, Cold test is having a bigger advantage as compared hot testing as shown above.

The only benefits of the hot testing process are the engines' ability to be tested in real drive conditions and the organization's familiarity with the procedure. However, if we take into account productivity, operational costs, the quality of the testing data, and safety, the cold test process is preferable and can replace audit or frequency-based hot testing of engines as the primary testing process, according to industry standards.