AUTOMATED EDDY CURRENT TESTING SYSTEM
FOR AUTOMOBILE PISTON BOWL INSPECTION

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Abstract

In recent years among different NDE Methods used for inspection in various industries Eddy Current Examination Method has become popular for detection of mainly surface flaws in large number of industrial items. To meet large production inspection requirements, automated ECT using on line or offline systems have been developed and are in very much use by various units manufacturing Black Bars / Bright Bars / Tubes / Automobile Components. The paper deals in particular with ECT system for inspection of Piston bowl area of Automobile Industry for detection of surface defects.

ECT System for Piston Bowl Inspection for surface defects:
Automatic Eddy Current Test/Scanning System for detection of surface flaws using Pencil Probe to follow the Piston bowl profile & with rotation of Piston. The paper mainly describes briefly Test System, Test Technique, ECT Probe used in the system, Reference Calibration Standard used, Marking & Sorting arrangements and Data Logging.

Keywords: Automobile Piston, Pencil Probes, Automation

1. Introduction

Automotive pistons form a very critical and integral component of the engine. It is extremely important that the pistons do not malfunction or disintegrate during the running lifecycle of the engine. Commonly, the piston can develop bonding defects (crown, skirt and back areas), crater cracks, porosity and deformations in the cooling galleries. All of these can be verified using ultrasonic non-destructive testing methods. However, especially in pistons of diesel engines, there is a danger of surface cracks developing in the piston combustion bowl rim area. If these cracks grow in size, the piston will disintegrate and damage the engine. The goal of this paper is to research and execute an automated method to detect such cracks at the production stage itself, thus, taking preventive steps to avoid disastrous breakdowns in the diesel engines.

2. Job (Piston) Specifications

<table>
<thead>
<tr>
<th>Diameter range</th>
<th>69 - 140 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>55 - 110 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>Up to 5 kgs</td>
</tr>
<tr>
<td>Material</td>
<td>Aluminum Silicon alloy</td>
</tr>
<tr>
<td>Bowl position</td>
<td>Center to 5mm offset</td>
</tr>
</tbody>
</table>

3. Evaluation Requirements

Defect type: Cracks caused due to oxide inclusions, shrinkages, pores, foreign material or irregular structures.
Sensitivity setting: 0.3mm depth x 0.3mm width x 0.3mm length artificial defects spread across the complete bowl area.
OK/NOT-OK criteria: 0.3mm defects are NOT-OK and 0.25mm defects are OK.
Inspection time: less than 23 seconds.
Ambient conditions: 50°C and 95% humidity.

4. Principle Of Evaluation

The eddy current electronics used in the system is Dr. Foerster GmbH & Co. KG’s Statograph ECM. A special pencil type probe with a ceramic tip is used for detection of the flaws. The probe is specially designed to concentrate on a very small area of the piston, which is directly under it. Hence, even an extremely small flaw will create a large disturbance percentage-wise with respect to the small scanned area. In our system, the probe will rotate and the probe will move over the concerned area of the piston bowl. The Statograph has all standard features such as gain, preamp, LP, HP, phase etc.
5. Testing Procedure

The goal of the evaluation is to find cracks in the combustion bowl rim area. For this purpose, the system will divide the complete test area into a number of preset rows. Each row will have readings from 0° to 359°. The test results will be presented as a Cscan result. During the test, the piston will rotate and the probe will move along the bowl rim contour, from the start to the end of the test limits. This is possible with the help of the movement of the various servo axes. Each position of the probe will be considered as a row. Each row will have readings corresponding to the circumference.

Initially, a master piston is used to set the sensitivity of the electronics. The master will consist of 0.3mm flaws, scattered across the bowl area in fixed degree orientations. During production testing, the max amplitude of the signal at each probe position is used to plot the Cscan diagram. If any of the amplitudes cross the set threshold (50%), then the piston is NOT OK. By clicking each point in the Cscan, the operator can view the corresponding signal form and amplitude. Thus, enabling the possibility of flaw sizing.

6. System Design

The system consists of a test bench, electrical panel and a housing for the electronics. The operator will interact with the system via an industrial grade computer and buttons on the test panel. A PLC module is used to control the mechanics of the system.
The test bench consists of 3 servo motors, which control the Z, Y and alpha movement of the probe arm. These are absolute servo motors with a brake system. The piston is placed on a rotary platform. The platform has a floating mechanism, which allows the system to center the piston before rotation. The outrun tolerance for the probe is just 10 microns. After centering, a pneumatic clamping system will hold the piston in position.

The speed of rotation will be controlled via the PC software.

Various positions of the probe

Above the mechanical setup, is a compartment to store the industrial PC and the Statograph electronics. The IPC interacts with both the PLC and the Statograph. The software allows the operator to set the evaluation parameters, such as gain, filters, frequency, preamp. The software presents the results in the form eddy current signals as well as a Cscan representation. After the results are generated, the operator can click anywhere on the cscan to closely analyze the amplitude and defect size in a particular area.

At the bottom of the main screen, there are counters to keep track of OK and NOT-OK jobs. The software can also be used to manually control the complete system. The operator can
control all the pneumatic movements as well as the servo axes movements of the system. If
the operator wishes to study the sensitivity of the probe at a certain orientation of the probe,
the probe can be moved to that area and the piston can be rotated to observe the signals.
Reports can be generated to observe the number of OK and NOT OK pistons.

During the production life cycle, the system will encounter pistons of various
dimensions and shapes. Hence, it is important to have a quick changeover from one type to
another. This can be easily done by selecting a job file in the software. On doing so, the
coordinates for the axes and pneumatics movements are changed based on the job. The
software will also interpret new scan areas.

Since there are so many individual movements involved, it is important to have a close look at
the safety aspects of the system. Each axis has physical limit switches as well as software
limits to avoid overshooting of the movements. Similarly, there are sensors installed to detect
the presence of the piston as well as proper centering of the piston.

Further interlocks between the IPC, PLC and the ECT electronics ensure that the system is
running in proper synchronization.

The operator panel consists of a start button, emergency stop button and an acknowledge
button. The acknowledge button is used to acknowledge NOT OK pistons.
Further, a rejection bin is placed beside the system. A rejected piston must be placed into
the rejection bin, which will activate a magnetic sensor to enable the operator to start the
next cycle. This is a poke-yoke check to avoid NOT-OK pistons being added to the lot of OK
pistons.

Tower lamps and LEDs serve as indications for test results in addition to the software
display.
7. Testing In The Production Line

Since the evaluation will be done online, during the manufacturing process, it is important that the process is simple and swift.

Below illustrates the process:

1. Operator will manually load the piston into the test table
2. The start button is pressed and the safety door shuts automatically
3. The floating mechanism will perform a centering operation to ensure the centering of the piston. The piston is clamped from the bottom and held firmly in position on the
rotary platform

4. The Z-axis, Y-axis and alpha axis of the arm holding the probe moves to the start position of the test. At this point, the pencil probe touches the horizontal surface of the piston bowl, at its start position.

5. Piston starts rotating

6. The probe is manipulated along the contour of the piston bowl, with the help of simultaneous movement of the axes.

7. The test ends with the probe in a vertical orientation when it has reached the end of the bowl rim

8. If no defects have been found during the eddy current evaluation, then the safety door will open and the operator will unload the piston. The operator will insert the next piston.

9. If defects are found, then a pen marker is activated to mark the piston. The operator will have to acknowledge the NOT OK result by pressing a button on the panel, which will open the safety door. The piston will be placed in the rejection bin, which will activate a sensor to start the next test cycle

10. All the above steps are completed within 23 seconds.

8. Conclusion

Using the Statograph ECM and a specially designed pencil probe, the system is able to detect 0.3mm surface defects on the piston bowl rim. The repeatability of the master piston was verified by noting a difference of maximum 2 degrees in the flaw placement in the Cscan and a tolerance of 3% in the defect signal amplitude. The complete test cycle is quick enough to be used in a piston production line.