Confirmation of Diagnosis

Excess of clearance between piston and liner

***Summary*- This document consists of the failure detection and verification report of a cylinder in a Waukesha P9390 GSI engine with 4000 hours of operation. Windrock engine monitoring was performed, the results were analyzed, detecting an impact at the beginning of the descending effect. The engine was disassembled in order to verify the damage diagnosed, after being repaired, the analysis was repeated to verify the disappearance of the impact.**

I. Introduction

The machine condition analysis is based on vibration and ultrasonic measurements taken with the WINDROCK 6320 PA equipment to the cylinder head and engine frame. The analysis results in the following priority repair recommendation:

Cil 4R It is observed an impact in the beginning of the descending effect after the spark, it could be a symptom of gaps in the piston set, suggesting the check of the same ones.

II. Development

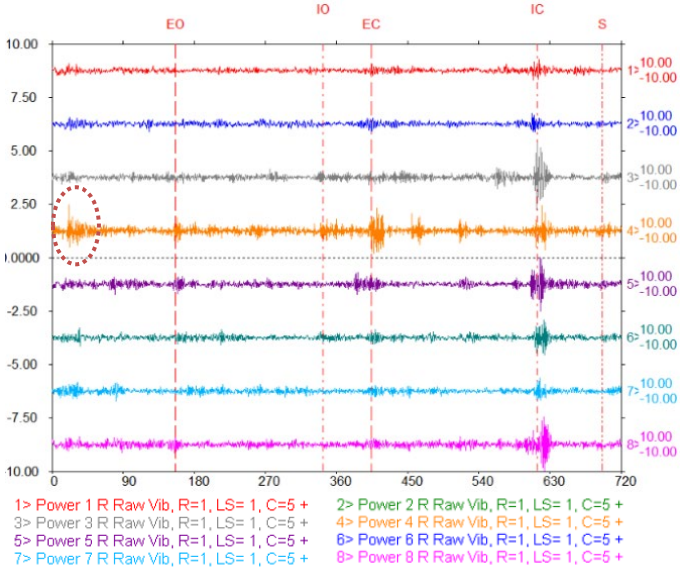
1. Detection.

i. Theoretical references:

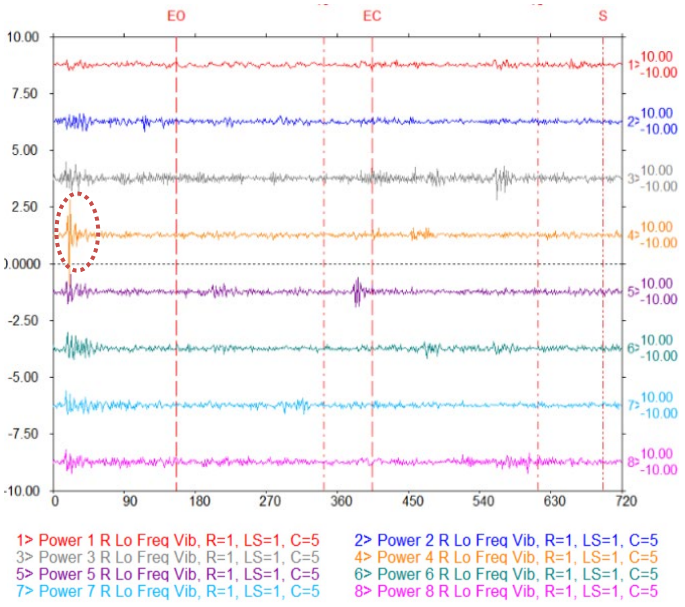
The presence of activity after the top dead center in the combustion stroke reveals two potential problems, detonation or gap problem.

ii. Impact on start of descending effect:

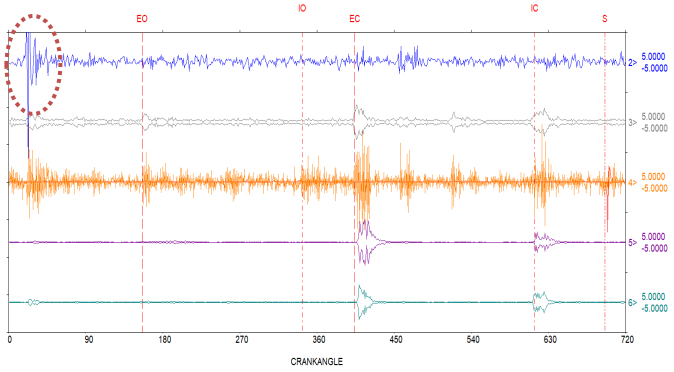
Graphics 1, 2 and 3 are obtained from the measurement done with the WINDROCK equipment on the Waukesha P9390 GSI gas engine.



Graph 1: Vibrations Raw (unfiltered) in drive heads R, cylinder 4 (yellow), sensor in vertical direction respect to piston displacement direction.



Graph 2: Vibrations Low Freq in cylinder banks R, cylinder 4 (yellow), sensor in horizontal direction respect to the movement of the piston.



Graph 3: Side impact on 4R cylinder, low frequency vibration (blue).

As the analysis of crank-angle-referenced 4R cylinder signals exhibits abnormalities in the combustion stroke after the top dead center, the parameters of combustion, carburation and ignition advance are verified without observing any abnormalities, it being ruled out that the fault were coming from detonation, in consequence it is supposed that the problem is coming from excessive piston/liner diameters clearances.

There is also widespread wear on all pistons/liners set, resulting from an overload in the use of the engine (since it was charged from the start of its operation above 103% of its rated power).

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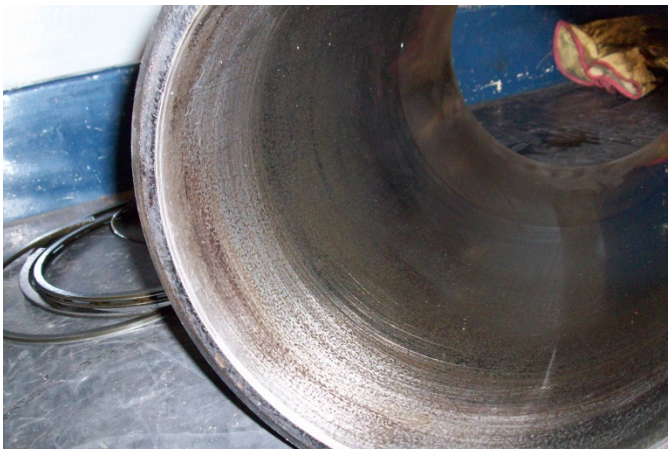
2. Testing & checks

The assembly was disassembled with the following findings: The liner shows a wear pattern of abrasive character and the cylinder head and piston cap with blows signs.



Picture 1: Liner internal piston and rings path.

It may be noted that the cylinder liner suffered damage throughout the stroke of the piston, indicating that at some point a foreign body was present in the combustion chamber.

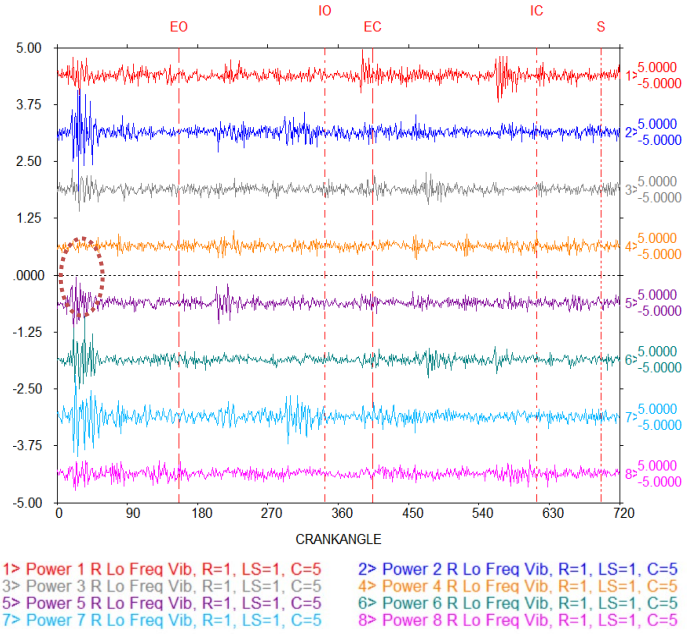
Picture 2: Piston cap

Picture 3: Liner and piston

On this opportunity it is easy to check that the diagnosis obtained from the measurements made and the corresponding predictive analysis was adequate.

3. Repair

Piston, liner and rings were changed and the condition analysis of machinery was carried out again to verify the reduction of the impact signal after the repair.



Graph 4: Vibrations Low Freq in cylinder banks drive R

A comparative and significant improvement is presented in the Cil # 4R, after the change of liner and rings.
In addition, abnormal vibrations in the rest of the cylinders are remaining advertising the need of their maintenance/inspection and, from now, limiting the use of the engine to the maximum allowed power supplied by the manufacturer.