Research Paper Engineering

Failure Analysis of Engine over Heating Issues Observed in Vibratory Compactor Powered by Air Cooled Diesel Engine (Part-01)

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ABSTRACT

Majority of construction equipments run on minimum maintenance requirement because of their remote operation from urban and rural areas under such circumstance it is always preferred by an operator that equipments should not require any special facilities on remote working locations, generally machine which is powered by water cooled engine required to check level of water in radiator to ensure that engine is properly cooled, now a days Construction Equipment manufacturer are preferring air cooled engine in variety of equipments, but there is always constrains on cooling performance of engines in a location where ambient temperature is very high, The paper presents the failure analysis of engine over heating issues observed in a vibratory compactor operating in a locality where ambient temperature is higher than average recorded temperature

Keywords : Over Heating, Failure Analysis, Compactor

INTRODUCTION

Majority of construction equipments prefer low maintenance engines due to following benefits on

Low noise emission, no expensive insulation measures for noise reduction Long maintenance intervals that is 1,000 hours oil change intervals, Low fuel consumption allows savings in operating costs, Low installation costs, Service and user-friendly, Cooling and lubrication with oil avoid corrosion and cavitation,

The simplest type of cooling is the air-cooled or direct method in which the heat is drawn off by moving air in direct contact with the engine several fundamental principles of cooling are embodied in this type of engine cooling. The rate of the cooling is dependent upon the following,

- The area exposed to the cooling medium
- The heat conductivity of the metal used and the volume of the metal or its size in cross section
- The amount of air flowing over the heated surfaces
- The difference in temperature between the exposed metal surfaces and the cooling air

In air-cooled engines the cylinders are mounted independently to the crankcase so an adequate volume of air can circulate directly around each cylinder, absorbing heat and maintaining cylinder head temperature within allowable limits for satisfactory operation. In all cases, the cooling action is based on the simple principle that the surrounding air is cooler than the engine. The main components of an air-cooled system are the fan, shroud, baffles, and fins.

All stationary air-cooled engines must have a fan or blowers of some type to circulate a large volume of cooling air over and around the cylinders. The fan for the air-cooled engine is built into the flywheel. Notice that the shrouding, or cowling, when assembled will form a compartment around the engine so the cooling air is properly directed for effective cooling, In addition to the fan and shroud, some engines use baffles or deflectors to direct the cooling air from the fan to those parts of the engine not in the direct path of the airflow. Baffles are usually made of light metal and are semi-circular, with one edge in the air stream, to direct the air to the back of the cylinders; the fins provide more cooling area or surface and aid in directing airflow. Heat, resulting from combustion, passes by conduction from the cylinder walls and cylinder head to the fins and is carried away by the passing air.

Failure in engine cooling system usually takes place in the form increase in temperature of lubricant oil which is playing as two major roles in cooling system first lubricating all rotating parts and second is dissipating heat which is carried due to its circulation in engine

METHODOLOGY

During on-site study of overheating issues it was observed that heat dissipation of engine is not proper due to flow of cooling air which is getting obstructed by exhaust pipe hence affecting heath exchange rate between ambient air and heated surface of engine, the figure01 shows existing layout where exhaust pipe is shown which is reducing heat transfer between engine surface & ambient air,

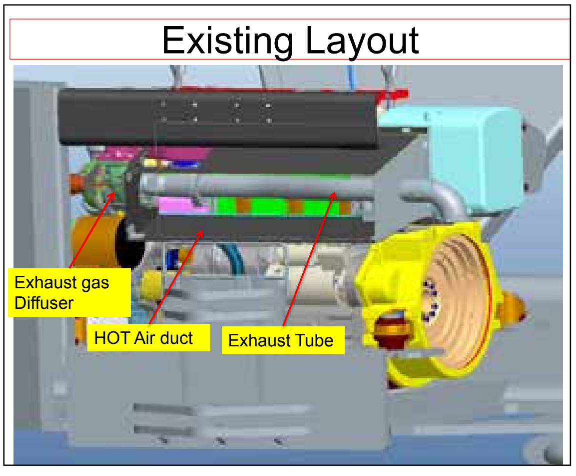


Fig-01; Current layout of exhaust pipe and hot air duct

During the study, the temperature of lubricating oil is recorded as 131^0 C~136^0 C which is above to its permissible limit of green zone temperature 40^0 C~130^0 C as shown in below figure-02

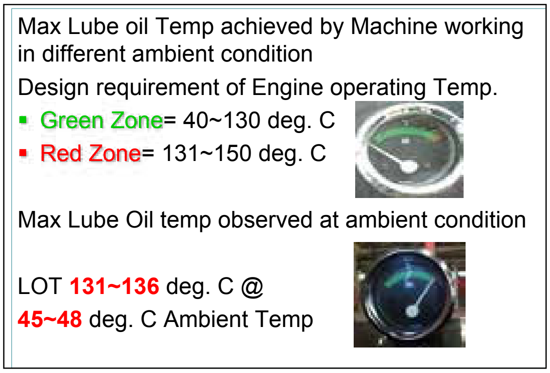


Fig-02; Temperature range and observed value

After detailed study on existing layout an improvement is done in air flow passage by changing existing layout to new layout of exhaust pipe passing in front of hot air duct as shown in below figure-03

Validation of new layout is done using temperature sensor and data logger to check whether the lube oil temperature is reduce to its design requirements

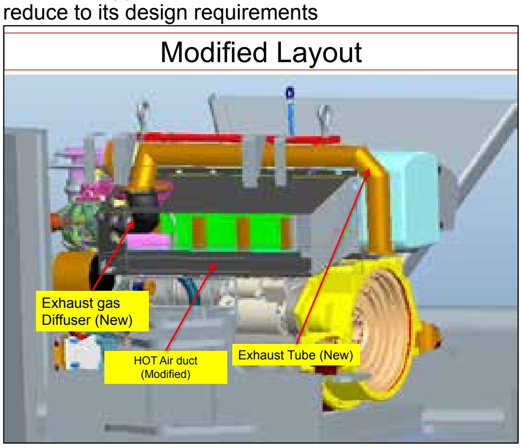


Fig-03; Modified layout of exhaust pipe and hot air duct

Field experimentation and results observed:-
After modification machine with modified layout is allowed to run full day on its all operation to check performance on overheating issues in similar way as it was operating with existing layout as shown in figure-04

Fig-04; Modified layout of exhaust pipe and hot air duct

Temperature sensors are fitted on different ports of machine, example sensor in inlet air, outlet air, lube oil, ambient temperature all these sensors are connected to online data logging system which is attached with a laptop for continuous data recording, below figure-05 shows arrangement of data logging system in actual field experimentation

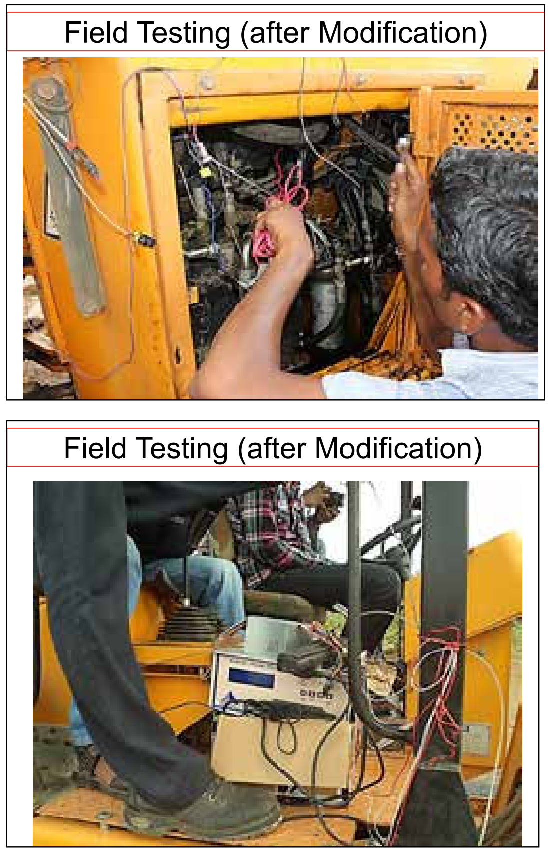


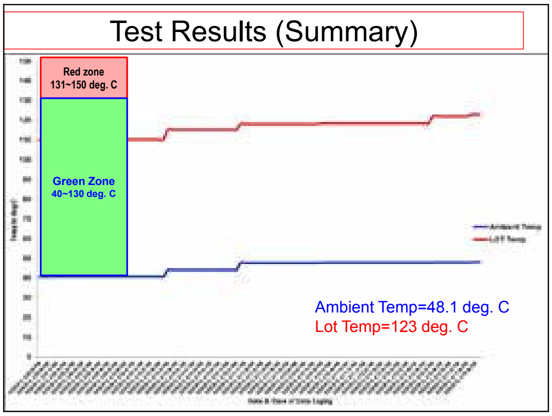
Fig-05; Field testing and data acquisition on modified layout

RESULTS AND DISCUSSION
The test results observed during field experimentation are shown in below table-I,

S no.	Time of recording	Ambient Temperature in ^{0}C (Average Value)	Lube Oil Temperature in ^{0}C
1	9.00 AM	33.5	110.6
2	9.30 PM	34.1	112.1
3	10.00 AM	35.0	115.4
4	10.30 AM	35.8	116.6
5	11.00 AM	36.9	117.4
6	11.30 AM	37.8	118.9
7	12.00 PM	39.6	119.2
8	12.30 PM	41.2	119.7
9	1.00 PM	43.5	120.6
10	1.30 PM	44.7	121.2
11	2.00 PM	46.8	121.7
12	2.30 PM	47.0	122.8
13	3.00 PM	48.1	123.0
14	3.30 PM	48.0	123.0
15	4.00 PM	47.7	122.7
16	4.30 PM	47.5	122.2
17	5.00 PM	46.3	122.0
18	5.30 PM	45.1	121.6
19	6.00 PM	44.6	120.2
20	6.30 PM	41.5	118.5
21	7.00 PM	39.3	119.3

Table I; Record of Temperature during field testing

A graphical correlation between lube oil and ambient temperature is shown below which is within acceptable range



THEORITICAL ANALOGY OF THE ISSUES

This issues is related to convective heath transfer process in which the transfer of heat from one place to another is done by the movement of fluids, further elaborating this problem is closely associated with forced convection process, according to newton's law "the rate of heat loss of a body is proportional to the difference in temperatures between the body and its surroundings"

Newton determined that the heat transfer/area, Q/A, is proportional to the fluid solid temperature difference T_s-T_f. The temperature difference usually occurs across a thin layer of fluid adjacent to the solid surface. This thin fluid layer is called a boundary layer. The constant of proportionality is called the heat transfer coefficient, h.

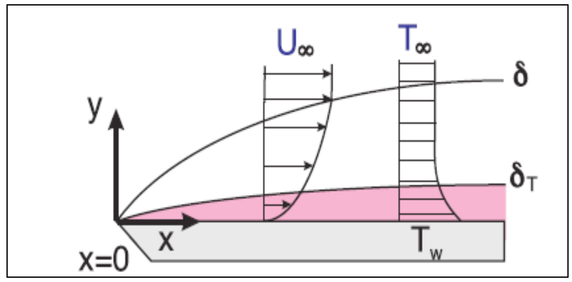
Newton's Equation: Q/A= h (T_s-T_f)

The heat transfer coefficient depends on the type of fluid and the fluid velocity.

Convection type	Description	Typical value of h (W/m2K)
natural convection	fluid motion induced by density differences	10 (gas) 100 (liquid)
forced convection	fluid motion induced by pressure differences from a fan or pump	100 (gas) 1000 (liquid)
boiling	fluid motion induced by a change of phase from liquid to vapor	20,000
condensation	fluid motion induced by a change of phase from vapor to liquid	20,000

Table II. Convective Heat Transfer Coefficients

Increasing the flow rate of air will increase the heat transfer coefficient. Then from Newton's law of cooling Q_{conv}=h A_s (T_s-T_{fluid}) it becomes obvious that for a fixed amount of power, the temperature difference between the surface and the air will decrease. Therefore, the surface temperature will decrease. The exit temperature of the air will also decrease since Q_{conv}=m_{air} c_p (T_{out}-T_{in}) and the flow rate of air is increased.



In this case velocity of air in existing layout was lower compared to modified layout, since flow of air has increased due to change in layout design which is in-turn has improved heat transfer from engine surface to atmosphere

The heat transfer coefficients H_{fm} due to forced convection is given by

$$Hf_m = \frac{k}{D} Nu_m (W/m^2K)$$

where:

k = conductivity of the air (Wm-1K-1)

D = diameter of the cylinder (m)

Nu_m = Average Nusselt number (Dimensionless)

An empirical formula can be used to calculate the Nu_m

$$Nu_m = 0.3 + \frac{(0.62\,Re^{0.5}\,Pr^{0.33})}{(1+(\frac{0.4}{Pr})^{0.66})^{0.25}}(1+(\frac{Re}{282000})^{0.5})\ \text{dimensionless}$$

From SW Churchill and M Bernstein "A Correlating Equation for Forced Convection from Gases and Liquids to a Circular cylinder in cross flow". Journal of Heat Transfer, 99:300-306 (1977). where

Re = Reynolds number = U_c D / v (dimensionless)

Pr = Prandtl number for air (dimensionless)

U_c = Corrected air velocity (m/s)

Corrected air velocity U_c = 1.22 U_a (m/s)

CONCLUSIONS

After new layout and successful field trial, structural analysis of the modified parts is required to ensure that they are capable of withstanding vibration of machine in actual field operation which mentioned in part-2 paper presentation

Heat transfer coefficients H_{fm} is also related to Air velocity since after modification mass flow rate of air has increased which has shown signification results in cooling performance of engine, Hence new layout is finalized for all regular machines in productions

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