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STUDY OF WEAR AND PERFORMANCE FOR BIOGAS FIRED IC ENGINES

Prof Vinod Parashar[1], Ashish More[2], Sujeet Sharma[3]
[1]Professor, [2,3]Student ,Department of Mechanical Engineering, SGSITS Indore, India
, Department of Mechanical Engineering, SGSITS Indore, India
[1]inventeron@gmail.com, [2]ashishvmore@gmail.com, [3]sharma.sujeet.1710@gmail.com

***Abstract*- REVIEW STUDY was carried out to determine the wear of engine components when it is fuelled by bio gas. Wear and corrosion rate of Piston rings, valves and the change in lubrication properties were studied due to Presence of H2S in biogas. Various techniques used to measure the wear rate were studied to plan an experimental program that can determine the allowable limits of H2S in biogas. It was planned to run a biogas fuelled engine for 150hrs and then wear rate and change in lubricating property will be measured to determine suitability of biogas as an engine fuel.**

***Keywords* – Biogas compression, gas storage, gas analysis, engine with biogas as fuel, wear analysis of engine component.**

1. INTRODUCTION

A substantial quantity of **wet** as well as **dry** biomass in various forms is naturally available in the Indian rural areas. Efficient utilization/ recycling of biomass as a fuel is supportive to the growing economic needs for country. Appropriate technologies for waste-to-energy conversion of this resource will go a long way in improving not only the rural economy but also the ecology. Recycling of **moist** biomass such as animal waste, domestic as well as agro-industrial organic waste through **biomethanation** has a universal applicability in energy sector. The biomethane thus generated is a recyclable fuel that would share the burden of global warming that is caused due to fossil fuels.
This conversion process makes available renewable energy in the form of biogas not only for rural sector but for the urban sector too. Wet biomass is largely available in large dairy
clusters, poultry and other animal farms, sewage treatment plants in rural areas and in large hotels, hostels, and food processing industries in the urban area.

Raw biogas contains a substantial proportion of H2S that causes generation of Sulphuric acid when burned with air. If raw biogas as a fuel it would causes corrosive attack on the engine components and would reduce the engine life [2].

Removal of H2S by scrubbing the biogas can reduce the proportion of acid formation [3]. The present research tends to establish the effect of bio gas scrubbing on the wear and life of engine so that biogas can be used on economic and commercial level as engine fuel.

2. COMPARISON BETWEEN RAW AND UPGRADED BIOGAS:

2.1 RAW BIOGAS

• A low Grade fuel (CH4 55-65 % & CO2 35-45 %) with lower percentage of methane.

• Mode of utilization– On site itself or nearby for cooking and for electricity production. The **presence** of CO2 besides being non combustible, restrains its compressibility there by making biogas difficult to be stored in containers.

– For utilization at far off places it must be stored in biogas balloons and taken to the site of utilization or it can be transported by pipelines. [2]

2.2 UPGRADED BIOGAS

• A high grade fuel (CH4 > 90 % and < 10 % other gases) with high percentage of methane.

• Mode of utilization – Methane burns faster hence yields a higher specific output and thermal efficiency compared to raw biogas when used as engine fuel. [2]

– Upgrading, compression and bottling facilitates easy storage and transportation as

• As a vehicle fuel
• As a cooking fuel
• For electricity production

TABLE I

EFFECT OF GASEOUS CONTAMINATION ON ENGINE PARAMETERS: [5-6]

Gaseous contamination in biogas	**Effect on engine**
Presence of CO2 in biogas	– It lowers the power output from the engine; – It takes up space when biogas is compressed and stored in cylinder; – It can cause freezing problems at valves and metering points where the compressed gas undergoes expansion during engine running.
Presence of H2S and H2SO4	The traces of H2S produces H2SO4 which corrode the internals of pipes, fittings etc.
Water particles	Moisture causes corrosion and decreases heating value of the fuel.

• The energy density of upgraded biogas is comparatively low at ambient pressure and as a result it must be compressed at high pressures (e.g. 200-250 bar) to allow its sufficient storage in bottles/cylinders.
• reduces storage space requirements,
• concentrates energy content an Increases pressure to the level needed to overcome resistance to gas flow.
• Compression can eliminate the mismatch of pressures and guarantee the efficient operation of the equipment. [5]

3. TECHNICAL PARAMETERS OF BIOGAS FOR ENGINE PERFORMANCE

Technical parameters of biogas are very important because of their effect on the combustion process in an engine.
Those properties are:-

- Ignitability of CH4 in mixture with air: CH4: 5...15 Vol. %, Air: 95...85 Vol. %
- Combustion velocity in a mixture with air at p = 1 bar: cc = 0.20 m/s at 7% CH4, cc = 0.38 m/s at 10% CH4.
- The combustion velocity is a function of the volume percentage of the burnable component, here CH4. The highest value of cc is near stoichiometric air/fuel ratio, mostly at an excess air ratio of 0.8 to 0.9. It increases drastically at higher temperatures and pressures.
- Temperature at which CH4 ignites in a mixture with air Ti = 918K ... 1023 K
- Compression ratio of an engine, 'e' at which temperatures reach values high enough for self-ignition in mixture with air(CO2 content increases possible compression ratio) e = 15...20
- Methane number, which is a standard value to specify fuel's tendency to knocking (uneven combustion and pressure development between TDC and BDC). Methane and biogas are very stable against knocking and therefore can be used in engines of higher compression ratios than petrol engines.
- Stoichiometric air/fuel ratio on a mass basis at which the combustion of CH4 with air is complete but without unutilized excess air.

4. ENGINE WEAR

Sliding contact between solid metallic components of any mechanical system is always accompanied by wear which results in the generation of minute particles of metal. In a petrol engine, the Components normally subjected to wear processes are the piston, piston ring, cylinder liner, bearing, Crankshaft, cam, tappet and valves. Wear of engine valve and seat insert include adhesive wear, Surface fatigue wear, shear strain and abrasive wear [13]. Wear problems are associated with two regions [7]
1.) Within the engine
2.) The combustion zone and the crankcase zone.

4.1 WITHIN THE ENGINE

TABLE 2
ENGINE COMPONENT WEAR SHOWN AS PERCENTAGE MASS LOSS WITH INTRODUCING BIOGAS (900HRS):

Engine component	**%age of mass loss**
Intake value	0.8
Exhaust value	1.2
1st piston ring	4.3
2nd piston ring	2.0
Compression ring	0.1
Connecting rod bearing	0.5

5. COMPARISON DATA OF ENGINE WEAR WITH BIOGAS AS A FUEL:

5.1 ENGINE AND ITS SPECIFICATION:

TABLE 3
ENGINE SPECIFICATION:

Type	**Single cylinder 4stroke air cooled diesel engine**
Model	Kirloskar TAFI model
Bore	87.5mm
Stroke	110mm
Cc	661.5cc
Piston bowl diameter	52mm
Compression ratio	17.5
Power	5HP
Inlet valve diameter	34mm
Exhaust valve diameter	34mm

5.2 PISTON RING WEAR

The weight loss and radial width change for the three compression rings have been recorded. [7-9]

TABLE 4
WEAR OF PISTON RING AFTER ENGINE RUNS (38 HOURS)

Piston ring	Wt. before run (gm)	Wt. after run (gm)	Weight loss	Weight loss in %
Top ring	14.1366	14.0643	72.30	0.51
Middle ring	14.3659	14.2903	75.60	0.53
Bottom ring	14.4141	14.3734	40.71	0.28

TABLE 5
RADIAL WIDTH OF THE PISTON RINGS BEFORE AND AFTER ENGINE RUN (38 HOURS)

Piston ring	Width before run (mm)	Width after run (mm)	Dimensional loss (µm)	Dimensional loss in %
Top	3.157	3.141	16	0.50
Middle	3.319	3.302	17	0.51
Bottom	3.069	3.061	08	0.26

6. VALVE WEAR

The initial measurements of weight and surface roughness of valves were taken after lapping its faces. At the end of Experimentation, the valves were washed by acetone in ultrasonic vibrator in order to remove the deposits (soot, debris particles etc) from the surface of the valves. The measured weight losses of intake valve and exhaust valve have been given in Table-4. [7-9]

TABLE 6
WEAR OF VALVES AFTER ENGINE RUNS (38 HOURS)

Engine component	Weight before engine run gm	Weight after engine run gm	Weight loss mg
Intake valve	79.1923	79.1923	0.4
Exhaust valve	81.1889	81.1858	3.1

7. WEAR METAL DEBRIS:

Wear particles generated from sliding contact of solid surfaces are suspended in the lubricating oil. By analyzing a sample of lubricating oil from the engine after a certain running period, it is possible to Gain information on the operation and condition of the engine. [10]

IRON

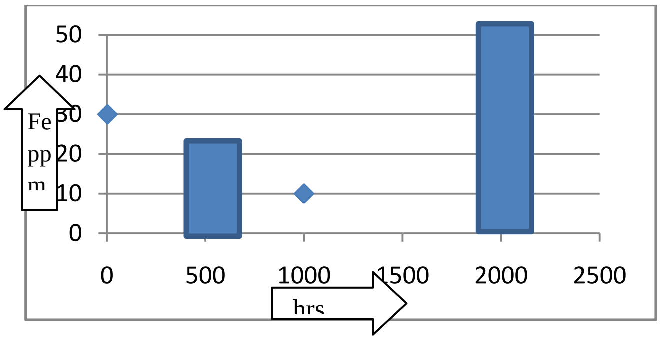


Fig. 6.1 Iron particles on valve after running hrs

COPPER

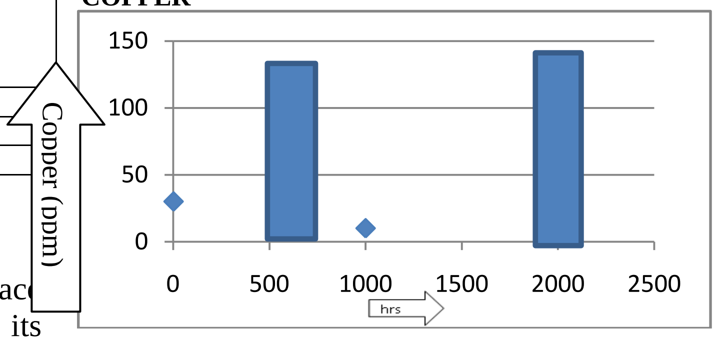


Fig. 6.2 copper particles on valve after running hrs

ALUMINUM

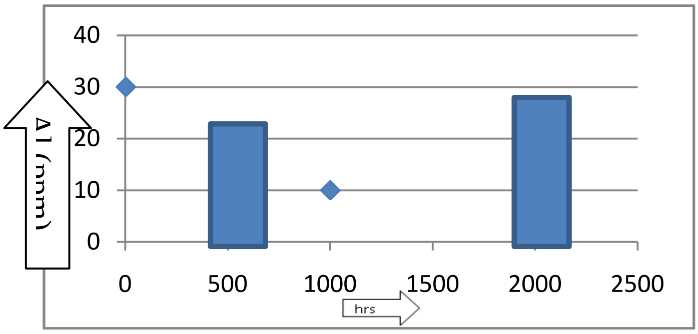


Fig. 6.3 Aluminum particles on valve after running hrs

8. CHANGE IN LUBRICATING OIL PROPERTY:

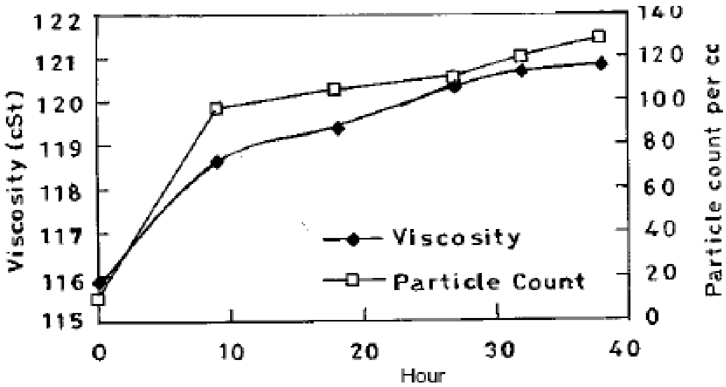
The lubricating properties of engine oil change with running time were due to the effects of oxidation, thermal degradation, reaction with sliding surfaces, contamination by engine blow-by and additive Depletion. During engine operation, a small amount of fuel may be diluted in the lubricating oil. [10]

TABLE 5
CHANGE IN PROPERTIES OF LUBRICATING OIL WITH OPERATION TIME

Property	Test method	Fresh lubricating oil	900 hrs	2000hrs
Kinematic viscosity(cst)	ASTM D 445	14.59	11.34	7.36
Oxidation stability(min)	ASTM D 2272	249	71	86
Acid no.	ASTM D 664	3.57	3.80	3.56

8.1 LUBRICANT ANALYSIS

Lubricant analysis shows that after the engine test (38 hours) viscosity has increased about 18%. The viscosity variation and debris/contaminants generation with passage of time have been plotted in Fig.4. In the present analysis of biogas-based engine, the viscosity and particles rise are significant even for 38 hours run only. Viscosity of oil is expected to increase if soot is not adequately dispersed. The oxidation of oil is other reason for lubricant's viscosity rise. The test is carried out on [12] Cummins M11 (246kW) diesel engine for 200 hours and found that the viscosity of lubricating oil remains constant around 15 cSt (at 1000C). In the light of discussion of article [9], the rise in viscosity in present study is very significant. [12]



9. WEAR MEASUREMENT TECHNIQUE: [11]

Corrosive attack is the primary cause of engine wear when bio gas is used as fuel. Acid formation during combustion due the presence of H2S has corrosive wear on the piston, piston ring, bearing, Crankshaft, cam, tappet and valves.. Wear problems are associated with two regions within the engine, the combustion zone and the crankcase zone.

Table 1: Wear measurement methods and typical units for wear quantification

	Measurement Methods	Units of Wear	Units of wear rate
Mass loss	• Direct measurement by a precision balance. • Calculated from volume loss for known density material.	μg g	μg/m, g/m, μg/N, g/N, μg/(N·m), g/(N·m).
Volume loss	• Calculated from depth, width, wear profile and/or other dimensions data of a wear track. Surface profilometry or microscopy techniques can be used for the measurement. • Calculated from mass loss for known density material.	mm^3	mm^3/m mm^3/N $mm^3/(N·m)$,
Linear dimension	• Direct measurement by surface profilometry, microscopy and other dimension measurement techniques.	μm mm	μm/year mm/year

10. CORROSION IN SI ENGINE COMPONENTS:

Corrosion in gasoline engines is generally believed to be due to sulphuric acid formed by the combination of sulphur carried in low-grade fuels and oils with water that enters or is generated in the engine. Much of this trouble occurs in winter and may be traced directly to the action of water that condenses on the inside of the cylinders and crankcase when a cold engine is started. The water destroys the oil-film and comes into direct contact with metal of the pistons, cylinders and other parts, causing them to rust. If this occurs and the lubricating system does not supply more oil to the surfaces immediately upon the restarting of the engine, scored cylinders and pistons are likely to result, or, if the engine is stopped before it is warmed up, condensation and rusting will be rapid and will result in excessive wear. [13].

Measurement technique:

10.1 PERCENTAGE WEIGHT LOSS AND CORROSION RATE

Corrosion rate was calculated assuming uniform corrosion over the entire surface of the coupons. The corrosion rate in mils per day was calculated from the weight loss using the formula: [13]

$$CR = \frac{W}{(D \times A \times t)} \times k$$

Where:
W = weight loss in grams
k = constant (22,300)
D = metal density in g/cm^3
A = coupon area (inch^2)
t = time (days)

10.2 VISUAL INSPECTION

Visually inspecting for corrosion with your own eyes is the simplest method of all. If you have only a small amount of pipes or tubes, it may be the cost-effective approach as well. However, for the large systems home to most stainless steel tubes and pipes, visual inspection becomes the least cost-effective approach due to the enormous amount of labor required. In addition, you can't visually inspect what your eyes can't see furthermore, the human eye has proved notoriously inept at detecting stress corrosion cracks, which can start out incredibly small. Relying solely on visual inspection is almost always not recommended.

1. Metal piece are visually inspected, dried and re-weighted, and then photographed once more to indicate surface status.
2. Each corrosion coupon is pre-weighted to an accuracy of four decimal places

11. CONCLUSION

In this research study a biogas fuelled engine was run for 38, 900hrs and analysis is done on engine components such as valves, piston ring and change in lubricating property , a sustainable wear is noted on engine components at minimum run of 38 hrs, so on the basis of above study carried out our objective is to:

1. Examine the wear rate of engine at minimum run of 50hrs and max of 150 hrs with both scrubbed and unscrubbed biogas.
2. 1st and 2nd piston ring and intake, exhaust valve are more prone to corrosion attack, measuring the wear of these component indicate the presence of corrosive element in the burned gases.
3. Running engine for 38hrs, a measurable wear rate and oil property is noticed, however run hrs increase to 900hrs wear rate is also increase.
4. Visual inspection is carried out to identify the corrosion attack on engine components.
5. Hence 150 hrs of run of the engine was planned to observe the corrosive attack due to the presence of H2S in biogas.
6. Determine the life of the engine with scrubbed biogas as a fuel.

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