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Failure Assessment For Gasifier Shell Due To Thermal Fatigue

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Abstract

The stresses which produce fatigue failure at high temperature do not necessarily need to come from mechanical source. Fatigue failure can be produced by fluctuating thermal stresses under conditions where no stresses are produced by mechanical causes. Thermal stresses result when the change in dimensions of a member as the result of temperature change is prevented by some kind of constraint. Here in this research work we have carried out thermal fatigue analysis at the throat section of gasifier shell using different biomasses to get stresses which produce fatigue failures at high temperature. For biomass babul wood the number of cycle of stress to cause complete fracture of the specimen using coffin-menson equation at throat section has been obtain. We have also assessed the microstructure of gasifier shell at present condition using in-situ metallography test.

Keywords: Gasifier, Thermal fatigue, Coffin-menson equation, Biomasses, In-situ test

Introduction

Gasifier apparatus used to produced gas by using different biomass like wood, coconut shells, Wheat straw pellets, pressed sugarcane, etc Biomass gasification means partial combustion of biomass which produced combustible gases consisting of Carbon monoxide (CO), Hydrogen (H2) and traces of Methane (CH4). This blend is called producer gas. This gas can be used to run both compression and spark ignition engine [1]. Gasifier apparatus having different zones named drying zone, pyrolysis zone, combustion zone and reduction zone. Out of all four zones the temperature of combustion zone is reached around 700˚C to 1000˚C which is highly affected from the operating condition. However, the locations are selected as per the given temperature range.

The stresses which produce fatigue failure at high temperature do not necessarily need to come from mechanical source. Fatigue failure can be produced by fluctuating thermal stresses under conditions where no stresses are produced by mechanical causes. Thermal stresses result when the change in dimensions of a member as the result of temperature change is prevented by some kind of constraint [2].

Metallography is the art to study of the internal structure of material and alloys, and to identify the relation of structure to composition and to study physical, chemical, and mechanical properties of the metals. Many methods have been devised to resolve internal structure, but microscopically examinations have always been among the supplementary important. For most of the history of metallography, they have been carried out by means of the optical microscope. And now a day some advance material characterization techniques are introduced to categorize the internal structure of the metals. Many times a metallographer needs to examine the microstructure of a material without physically destroying the component. However, with the techniques involving in-situ metallography, this task can become a possible. In fact, as one can expertise, to take microstructure at site and microstructure prepared at laboratory are difficult to differentiate [3]. As the components are not destroyed during in-situ metallography, is considered as NDE (non destructive evaluation) technique.

In-situ metallography is most important NDE technique to assessing the conditions and life of the plant components facilities to avoid the damage or failures and ensure healthy, reliable and safe environment of the plants like, petrochemical, power plant, fertilizer plant

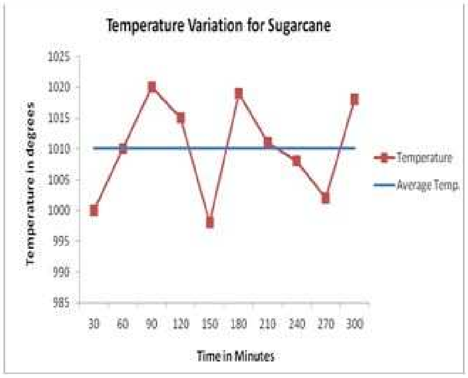

Fig-1 Temperature variation in babul wood bioma

etc. with the advancement and portable equipments the in-situ metallography considered as non destructive technique. Operating condition of components play an important role in failure of the components, some other factors are also involved in the same. Metallography also revels the different properties of material and those are depends on the manufacturing of components [4, 5].

Methodology

A downdraft tube gasifier made up of mild steel has been used for experiment. Since the throat section is highly affected by thermal stress therefore this section of gasifier has to be analyzed for thermal fatigue [6].

A ‘k’ type thermocouple is used to obtained temperature fluctuation at throat section of the gasifier for different biomasses respectively; for which following results were obtain as given in the figures 1 to 5.

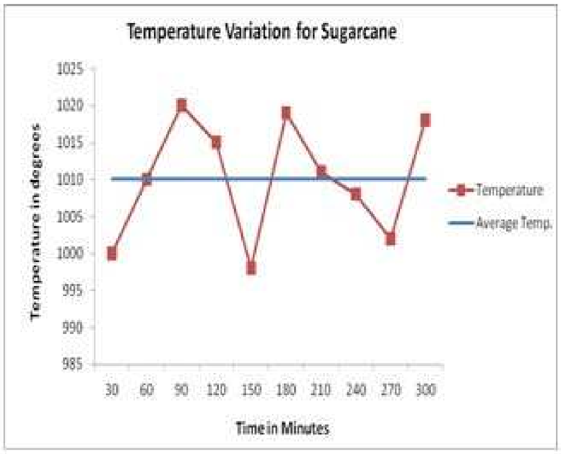

Fig-2 Temperature variation in Sugarcane biomass

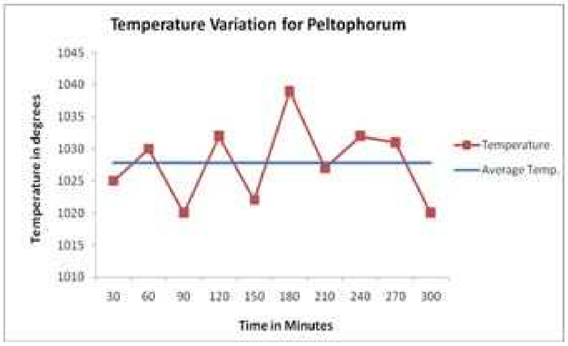

Fig-3 Temperature variation in Peltophorum biomass

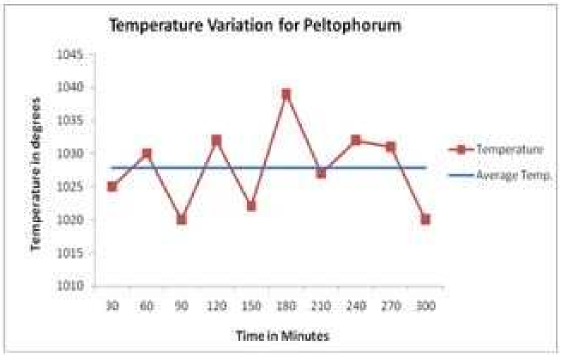

Fig-4 Temperature variation in 50% Pltophorum & 50% babul wood biomass

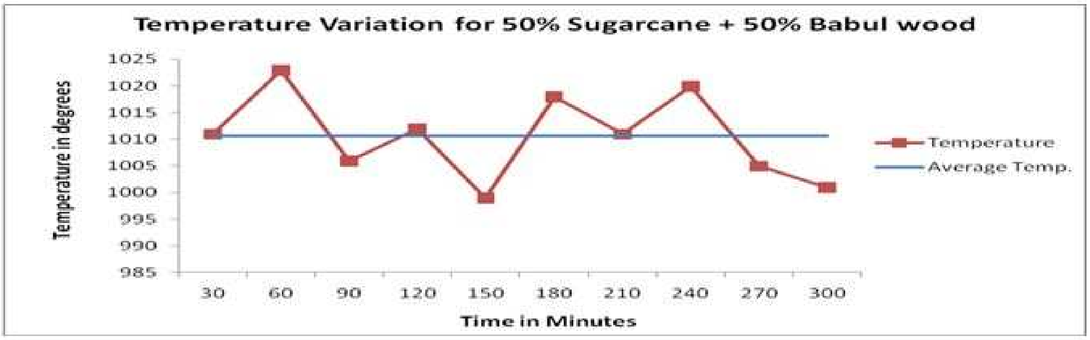

Fig 5
Temperature variation in 50% Sugarcane &50% Babul wood biomass

Sr. No	Biomass	Frequency of Temperature variation	Average Temp (˚C)	Maximum Temp(˚C)	Minimum Temp(˚C)	Temp Difference (˚C)	Calculation for thermal stress (Mpa)
1	Babul wood	5	1016.7	1026	1000	26	60.06
2	Peltophorum	8	1027.8	1032	1020	12	27.72
3	Sugarcane	5	1010.1	1020	998	22	50.82
4	50% Peltophorum +50% Babul wood	6	1020.8	1033	1000	33	76.23
5	50% Babul wood + 50 % Sugarcane	7	1010.6	1023	999	24	55.44

Table 1 Calculation of thermal stresses and temperature value for different biomass

Result

Now to calculate thermal stresses following relation $\sigma = \alpha E \Delta T$ where , E young modulus for mild steel is $2.1*10^{5}$ Mpa , α is linear thermal coefficient of expansion $11*10^{-6}$ K [7], ΔT temperature different for which results has been obtain which is shown Table no.1

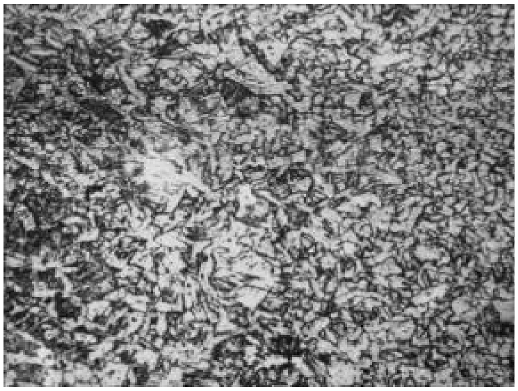

Fig 6 Location Weld/HAZ 100X

Location: include weld metal, heat affected zone and parent material
Material: Mild steel
Operating temperature: 1100˚C (combustion zone)
Enchant: 2% Nital

Fig 6 shows the microstructure of HAZ/weld portion and Fig 7 shows microstructure of parent material. Weld microstructure shows dendritic structure of ferrite and carbides, Whereas at HAZ microstructure shows fine-grained ferrite and pearlite structure. Parent metal microstructure shows fine-grained ferrite and pearlite structure. In-situ spherodization of pearlite is observed at the grain boundaries.

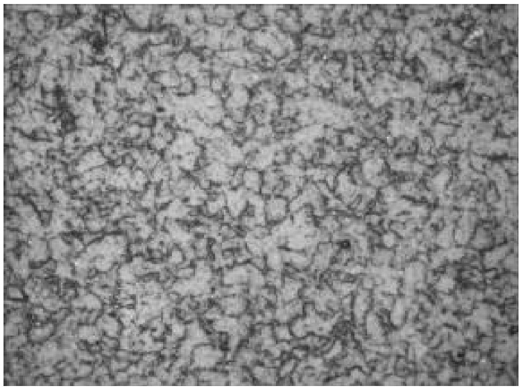

Fig 7 Location Parent Material 400X

Results obtained after solving Coffin-Menson Equation

Thermal fatigue is a form of failure that occurs in components subject to alternate heating and cooling. Under thermal fatigue, crack can initiate, propagate and eventually failure occurs. The reason for crack is due to the temperature change in the material that induces thermal expansion (or contraction). If surrounding material or external constraints hinder this expansion, thermal stresses arise. These cyclic thermal stresses cause fatigue similar to that of mechanical stresses.

Coffin and Manson established that the plastic strain-life data could also be linearised with log–log coordinates. The equations of Basquin and Coffin–Manson hold the stress-based and strain-based fatigue properties, respectively. The summation of these equations is known as Coffin–Manson equation:

$$\frac{\Delta\varepsilon}{2} = \frac{\sigma_f^{'}}{\mathbf{E}}(2N_f)^b + \varepsilon_f^{'}(2N_f)^c$$

E= $2.1*10^5$
B= -0.12 [2]
C= -0.7 [2]
$\sigma_f^{'}$ = 95 N/mm^2
$\varepsilon_f^{'}$ = 0.1886
$\Delta\varepsilon = \alpha\Delta T$ $11*10^{-6} *25 = 2.74*10^{-4}$

By solving coffin Manson equation for babul wood biomass (Trial and error method) we found the N_f (Number of cycle for failure) is 1.1 x 10^5

Conclusion

Based on the experimental work carried out on gasifier the following conclusions may be derived.

1. Using ‘k’ type thermocouple temperature fluctuation at the throat section of gasifier has been found as mentioned in fig 1 to 5.
2. Based on the result obtained on temperature fluctuations, thermal stresses has been calculated accordingly as shown in table no 1
3. Using in-situ metallography microstructure of specimen at throat section has been obtained, results reveals the initial stage of degradation in thermal fatigue.
4. In order to prepare microstructure at laboratory and at in-situ metallography both give quantitative and valuable characteristics of the specimen at microstructure level. Because, The gasifier shell is mainly made of carbon steel or mild steel. In-situ metallography is useful to find out certain failure mechanism like, graphitization, degradation of pearlite, creep mechanism, decarburization, grain coarsening (grain growth), stress corrosion, inter granular corrosion , thermal fatigue, sigma phase identification etc.
5. Finally using coffin-menson equation for biomass babul wood the number of cycle of stress to cause complete fracture of the specimen was 1.1 x 10^5

References

[1] Anil k. Rajvanshi, Published as a Chapter (No. 4) in book “Alternative Energy in Agriculture”, Vol. II, Ed. D. Yogi Goswami, CRC Press, 1986, pgs. 83-102

[2] George E. Dieter, “Mechanical Metallurgy” SI Metric Edition, McGraw- Hill Series in Materials Science and Engineering, Edition-III, pp.390-392, 1988

[3] A.R. MARDER,” Replication Microscopy Techniques for NDE” ASM Handbook, Volume 17: Nondestructive Evaluation and Quality Control ASM Handbook Committee, 52-56

[4] Virendra K. Bafna and Paresh U. Haribhakti, In-situ metallography for the plant health assessment study and failure investigation. 4th Middle East NDT conference and exhibition, kingdom of bahrain, dec 2007

[5] S.Jana,” Non-destructive in-situ replication metallography” Journal of Materials Processing Technology 49 (1995) 85-114

[6] *[1]Karan Joshi, [2]Rajendra Patil, [3]Dr. Alka Agrawal, “Assessment Of Microstructure Degradation For Gasifier Shell Using In-Situ Metallography Test” International Journal of Emerging Technologies and Application in Engineering, Technology and Science. ISSN: 0974-3588, July ’12 - December ’12, Volume 5: Issue 2

[7] Vailant. J.C, Vanderberghe. B, Zakine. C, The T92/ P92, book, Vallourec & Mannesmann tubes.