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REVIEW PAPER ON FATIGUE LIFE OF COKE DRUM

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Abstract: ***Coke drums are pressure vessels that are used in refinery processing industries to convert heavy residual oils into lighter more valuable fuel. Coke drum is subjected to cyclic thermal and mechanical loadings. Among these loadings, thermal loads are more conservative and reduce useful life of coke drum in comparison with other equipment's in the refinery. Coke drum is supported by means of skirt which is welded to drum around lower periphery of main cylindrical portion of drum. The failure modes of coke drum include excessive bulging deformation and fatigue cracking.***

Keywords: **Bulges, Coke Drum, Cyclic Thermal mechanical loads, Fatigue**

INTRODUCTION

In an oil refinery, to increase its refining margins, the heavy residual feed stock is up graded by separating the solid coke from the lighter oil. For that the coke drums are used. It is a vertical pressure vessel (cylindrical shell) with spherical (or elliptical) top end and conical bottom. Their dimension may be in order of 25 to 40 meter in height (or length) and 4 to 10 meters in diameter [1, 9]. The coke drums are usually manufactured by welding together a cylindrical shell which is also known as course. The thickness of shell wall may be varying from 20 to 50 mm [1]. Generally thickness decreases from the bottommost course to the top most courses. In order to support coke drum from the base, the skirt support is commonly used. The coke drums are always arranged in pairs (even number), alternating cycles between two (even number only) coke drum are take place [1].

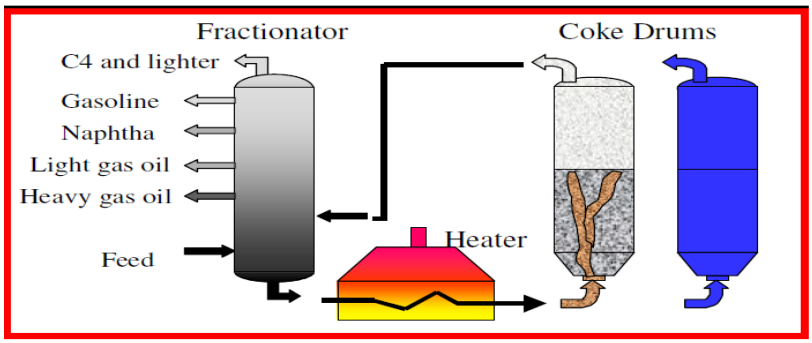

Figure-1 Simple Flow Diagram of delayed coking unit [3]

The operating cycle of coke drum can be divided in to four main stages. This is depicted below.

1) Pre heating (Vapor heating)

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2) Filling stage (oil filling)
3) Cooling stage (Water Quenching)
4) Cutting stage

1) Pre heating: To avoid the harmful effect of thermal shock, the drum is gradually pre heat (warmed) by hot vapor to a temperature of around 350 C. Coke drum is heated from bottom of drum to top [1].

2) Filling stage (oil Filing): the feed material is heated in furnace before sending it in to coke drum. When feed material (heavy oil) entered in to coke drum, a temperature varies within the range from 400 to 500 0C and pressure also varies from 300 to 350 Kpa. During these circumstances thermal cracking process take place and produce light hydrocarbons that are sent to fractionation tower where they are separated into gas, petrol, Naphtha and other higher value liquid product at the end, a concentrated carbon material known as petroleum coke are left within the drum [1].

3) Cooling stage: in this stage, steam is introduced to strip out any remaining oil and then high rate of quenched water is injected in to drum which cools the drum and liquid coke is converted into solid coke as it is being cooled down [1].

4) Cutting stage: When the coke drum has reached to its initial temperature (Temperature before preheating). Solid coke will be cut out by using rotating high pressure water stream. After removing all the coke the cycle is repeated [1].

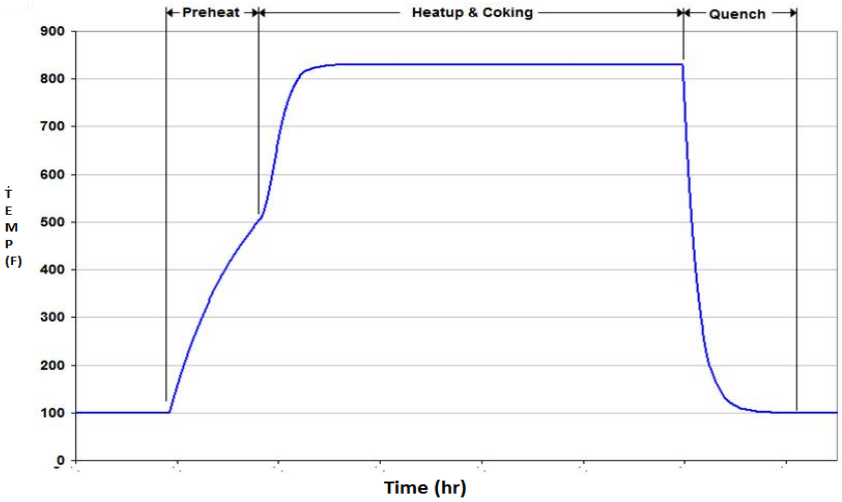

Figure-2 Coke drums operation cycle [5]

Coke drum are generally made from low carbon alloy steel such as Carbon-0.5 Mo, Carbon-1.25 Mo and steel with higher Cr-Mo content such as 1¼Cr-½Mo, 1Cr-½Mo or 2¼Cr-1Mo and internally clad with S.S (SA-240 Type 410 S.S / 405 S.S) or Inconel (N6600 / N6625) [5]. However, drum is subjected to cyclic thermal and mechanical load during operation cycle, which experience shorter fatigue life.

A. Fatigue [8]

Fatigue is a phenomenon subjected to variable loading such as cyclic stressing or straining of a material. When metallic components subjected to variable loading get fatigue, which leads to their premature failure under specific conditions. Fatigue Failure is the failure of components under the action of repeated fluctuating stress or strains. It may be defined as a process in which there is progressive, localized, permanent micro structural changes occurring in a structure when it subjected to boundary condition which produce fluctuating

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stress and strain at some material point or points. These micro structural changes may culminate in the formation of cracks and subsequent growth to a size which cause final fracture after sufficient number of stress and strain fluctuations.

Under the cyclic loading, various parts or component of machineries are subjected to failure. When stresses are exceeding the elastic limit of material used. For designing and analysis of these parts, accurate prediction of cyclic deformation occurs during every cycle is necessary because small crack inside the material leads catastrophic failure. Even for parts that are design within the elastic limit, plastic zone is formed ahead of discontinuities and crack is initiate in plastic zone.

From the literature as well as operation of delayed coking unit, Coke drum is subjected to cyclic thermal and mechanical loading during its operation cycle. Hence; thermal-mechanical fatigue is most common cause of deformation (bulging) and cracking in coke drum. There are vast number of models and methods for estimating the thermal-mechanical fatigue life of engineering component subjected to thermal and mechanical loads. Here, we focus on some commonly used method.

1) Uniaxial and Multi axial Fatigue Damage Models: Uniaxial damage models can be used to predict the development of a crack on the surface of a material. The low-cycle fatigue life of materials is estimated with uni axial damage models. These models may incorporate damage evolution, crack nucleation, and the growth of cracks into a single function. A material can be subjected to two types of fatigue: high cycle fatigue (HCF) and low cycle fatigue (LCF).

2) High cycle fatigue: HCF is associated with local cyclic stress which are of sufficiently small magnitude so that they produce predominantly elastic straining, and hence resulting fatigue life exceed by 104 cycle. Example: it is found in most rotating and vibrating member.

3) Low cycle fatigue: LCF is associated with local cyclic stress which are of sufficiently large in magnitude so that sufficient cyclic plastic straining occur, and resulting fatigue life are less than 104 cycle. Example: nuclear reactor component, gas turbine, petroleum refinery equipment etc.

Figure below illustrates the difference between HCF and LCF when viewed as stress amplitude – life (S-N) diagram.

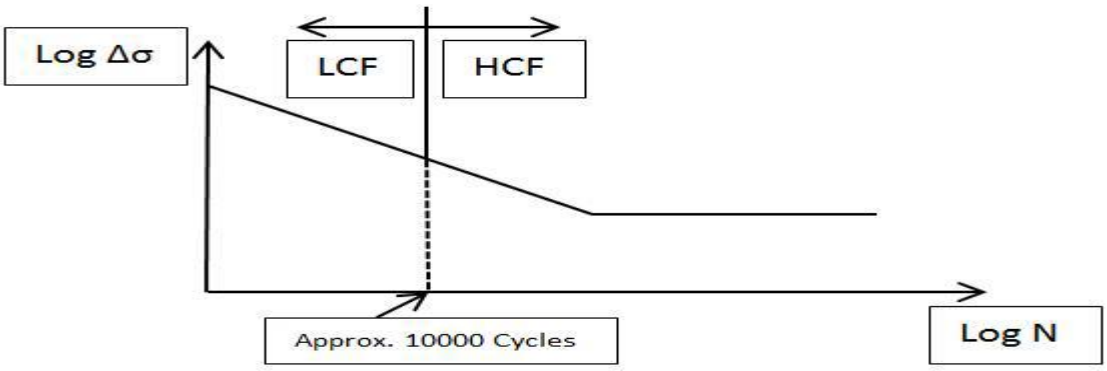

Figure-3 S-N Diagram

However, researcher Masaaki oka, Ambarita and Hiroyaki fujiki[1] conclude that no significant equivalent stress found during pre heating and filling stage and it is found significant during cooling stage at lower cylindrical shell which has been above the yield strength that can initiate permanent deformation or bulges. Jorge Penso and Radwan

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hazime[3] determine fatigue life of coke drum, it is found that minimum life cycle is occur near skirt to shell attachment junction and study creep effect on fatigue life and it was found negligible. However, quench rate have a significant effect on fatigue life, and also conclude that slower quenching rate gives better fatigue life. Jie chen and Zihui Xia [4] conclude that the cracks were first initiated and propagated rapidly near HAZ zone.

CONCLUSION

From literature, it is conclude that coke drum is subjected to low cycle fatigue under cyclic loading and permanent deformation is caused in first operational cycle and may be accumulated in subsequent cycle during cyclic heating and cooling operation and reduce useful life of coke drum. It also concludes that crack were first initiated and propagated rapidly near the heat affected zone. Hence, minimum life cycle is occurs near skirt to shell attachment junction. However, it is also conclude that higher initial temperature and slower quenching rate increase life while creep has a negligible effect on fatigue life and service life of coke drum from isothermal fatigue test are in accurate to measure.

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