ISSN 2229-5518

Analysis of Mechanical behaviour of Bulging Reduction in Coke Drum Used in Petro Refineries

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Abstract— Coke drums are the main part of Coker unit, in which thermal cracking of higher molecular hydrocarbon gets converted to lower molecular hydrocarbons. During the process of decoking the drums undergo cyclic operations typically in the temperature range from room temperature to about 500°C (930°F). The coke drum then separates lighter vapours out of the crude, including hydrocarbon gases. During quenching, the coke drum is inevitably subjected to a rapid drop in temperature because cooling water is injected directly into the coke drum. The temperature profile on the shell surface is uneven and can vary in each cycle of the quenching operation. Such a complicated thermal profile induces large strains in the shell portion of the coke drum, and eventually causes damage like bulging and/or cracking. It is found out that this bulging generally happens at the circumferential welded region. This project deals with the technique for manufacturing coke drums that are bulge resist.

Index Terms— Hydrocarbon, quenching, bulging.

1 Introduction

THE main objective of this paper is to design a coke drum which is more resistant to the bulging phenomenon as compared to the conventional coke drum. And suggest ways to decrease the bulging tendency in the conventional or existing coke drum without any major decrease in productivity. A coke drum is a kind of pressure vessel which utilizes heat and pressure to break higher molecular particle hydrocarbon into usable high review items like gas, diesel, and coke. They are an essential piece of the Coker complex which is destination for the cracking process used in the refinery. Amid this procedure of thermal cracking the coke drum experience a cyclic change in temperature which can extend from room temperature to as high as 700-900°C [1]. One of the principles organizes in the creation of pet coke is extinguishing of the hot VR (vacuum residue) or the crude oil. This would help in cracking of the hot crude. In view of the quenching procedure the coke drum experience high numerous multiple local stress fields both in hoop and axial directions, which causes bulging, and these bulges ordinarily keep on developing. It has been discovered that most bulging occurs circumferentially and happens close to the region of shell and weld seam [2].

As the coke drums or the pressure vessels experience the cyclic and permanent stress amid its persistent working cycle, they experience bulging on the shell part and at the region of the weld seam and the drum part. This bulging gets greater and greater amid the drums working life, which later prompts the development of splits or cracks at the place of the lump part. As the drums holds a lot of very perilous and inflammable hydrocarbons, there would be an odd of spillage of the hydrocarbons from the coke drum. This may prompt genuine calamity to the refinery which holds other oil-based commodities and additionally to the people working there.

2 EXPERIMENTAL

The regular technique for making or planning a shell of coke drum is as indicated by the thickness of the material to the particular required or composed weight. The weight are indicated as in expanding request where least thickness is intended to top of the drum and it increases as we move base of the drum , this is on the grounds that the hot VR is pumped from the base of the drum. These shells are later circumferential welded for the most part by utilizing submerged arc welding process. Later they experience die penetration test or Ultrasonic test for checking any imperfections in them [3]. As the costing of any fabricated material is done based on its weight and thickness, the shells are comprised of various thickness just to remove the cost, this outcomes in a lofty decrease in the thickness of the shells when contrasted with another.

As the coke drums or the pressure vessels experience the cyclic and permanent stress amid its constant working cycle, they experience protruding on the shell part and at the region of the weld seam and the drum part. This bulging gets greater and greater amid the drums working life, which later prompts the development of crack at the place of the lump part [4,5]. As the drums holds a lot of very risky and inflammable hydrocarbons, there would be an odd of spillage of the hydrocarbons from the coke drum. Moreover, as the coke drums are made by welding circumferentially two unique shells, amid its working they experience high nearby pressure fields both in vertical and circumferential weld seam. This would make uneven pressure appropriation which brings about bulging.

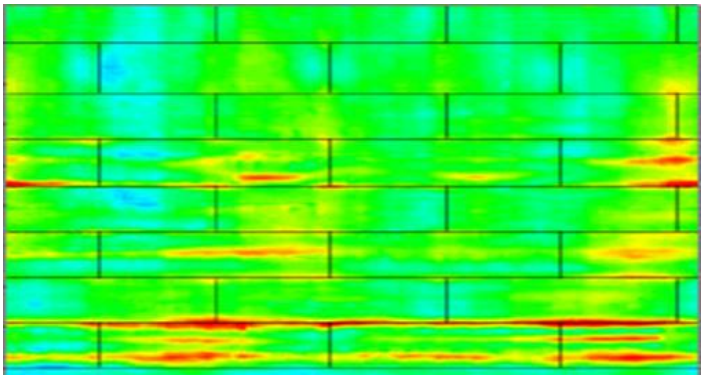
The least difficult strategy for weld break assurance is visual or colour penetrant test from within the drum or Ultrasonic examination from the outside of the drum. In any case, since an average coke drum has more than 500 to 1000 feet of between plate welds, 100% review of welds for breaking can be unrealistic or dreary [6].

3 Results & Discussion

The following results were obtained during the inspection of a coke drum during its later stages of its working life. Here one can clearly see that the stress concntration at the vicinity of the weld seams and concentrated at circumferential welds

[Fig 5(a)].

At the last stages of the drum, one can see that the tension of the stess is maximum, and they cover the most of the drums shell. This makes the drum prone to cracking and can cause the hydrocarbon to leak [Fig 5(b)].



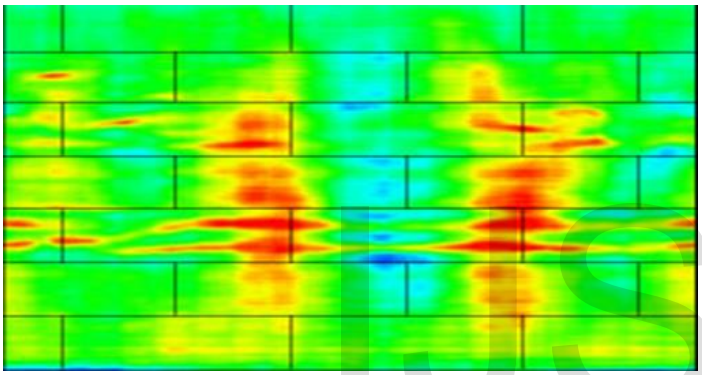
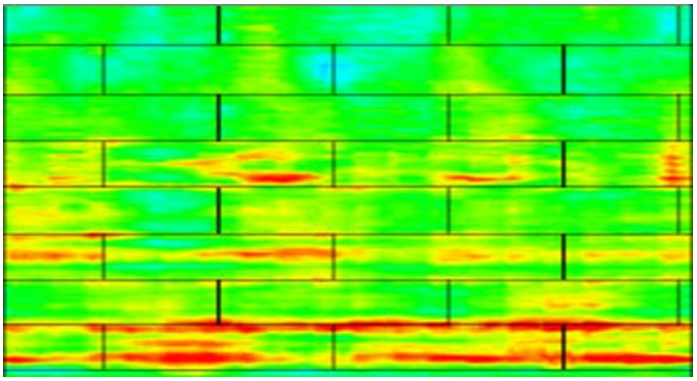


Fig. 1 Mid life stage coke drum

Considering the examinations directed on the bulged coke drums, it was seen that high quenching rates are one reason that produce high thermal gradients as of - 12.22°C for every inch, while bring down quenching rates can create less angles which give fewer swelling impacts on drums.



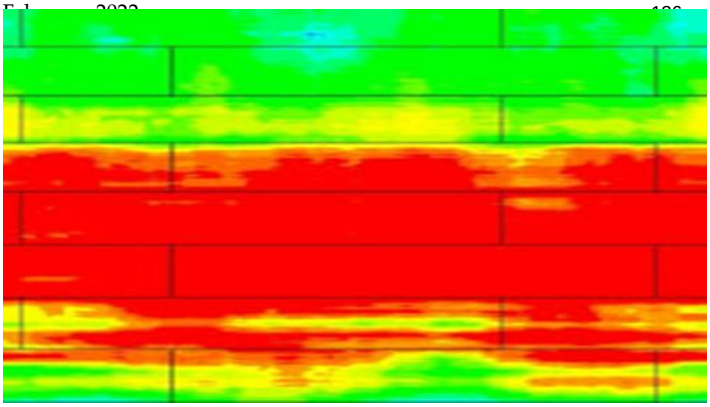


Fig. 2 Last life stage coke drum

To gauge this impacts a "unit quench factor (UQF) "[Table 1(a)], which is the ratio of 'water quenching time in minutes to the coke capacity of the drum in tons. Utilizing these readings, it was determined that if the UQF ≥0.5, the drum bulging would be insignificant or minimum and if the UQF is more prominent than 0.8 the bulging won't happen. Along these lines the estimation of UQF is proportional to the rate of the amount of water injected during the quenching of hot VR or crude oil. So, if the quenching is slower the one can get a higher UQF which converts into less bulging. Yet, this would influence the decoking cycle which thus influence the production.

TABLE 1
UQF CALCULATION

Comparison of quenching methods and severity of bulging during various coking				
Unit number	Water quenching time, min	Coke capacity tons	Unit quenching factor, min	Relative severity of bulging distortion
1	80	370	0.21	Severe
2	100	380	0.26	Severe
3	90	380	0.23	Severe
4	125	180	0.69	Negligible
5	130	170	0.76	Negligible
6	135	170	0.76	Negligible
7	160	180	0.88	Absent
8	190	180	1.05	Absent

Distortions in the shell courses point to zones of past material yielding and conceivable progressing over stress conditions. Checking vessel development after some time enables operators to compare their drums with common industry averages and focus in on regions of concern. Early manual examination strategies for finding and describing drum distortions,

performed after scaffolding within the vessel, have to a great extent between supplanted by remotely controlled laser profiling.

CIA Inspection Inc. (CIAI) works a laser surface profiling framework that can profile coke drums from inside amid the brief span time frame between coke cutting and refilling, taking out the need to sit tight for a turnaround to perform interior estimation. More than 300 inward examinations of postponed coke drums have been directed with CIAI's framework which utilizes a remotely controlled sensor bundle joined to the coke drum's drill stem.

Correspondent with the appropriation of remotely controlled inward laser profiling, remote visual assessment of coke drums has to a great extent supplanted coordinate visual review from interior framework. A shading camcorder with high goals zoom focal point allows an itemized perspective of within the drum equalling the abilities of the exposed eye in distinguishing surface blemishes, for example, cladding absconds or early weld breaks. Contingent upon the tidiness of the drum, splits or imperfections can frequently be related to this gear giving the proprietor significant data on break inception destinations. Remote video investigation has the extra favourable circumstances of arrangement amid the period between coke cutting and refilling, disposing of the need to sit tight for turnarounds, and constant chronicle alongside computerized engraving of area data.

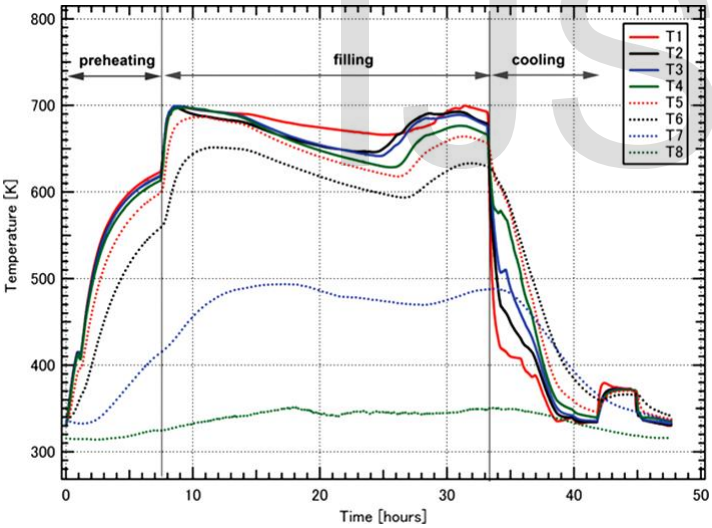


Fig. 3. Temperature time curve

Here we can see there is a exponential increase in the temperature of the drum during the preheating process and remains in a small range during the filling of the hot VR in the drums. During the cooling process the drum experiences a sharp decrease in the temperature this leads to the formations of bulges and later leads to cracking of the drums.

3.1 FEA PERFORMED ON BULGED DRUM

From the above stress and thermal analysis, we can conclude that using the conventional method of designing coke drum that is by using circumferential seam weld huge amount of Stress concentration at the vicinity of the weld seams and concentrated at circumferential welds.

As the coke drums are made by welding circumferentially two unique shells, amid its working they experience high nearby pressure fields both in vertical and circumferential weld seam. This would make uneven pressure appropriation which brings about bulging. This makes the drum prone to cracking and can cause the hydrocarbon to leak.

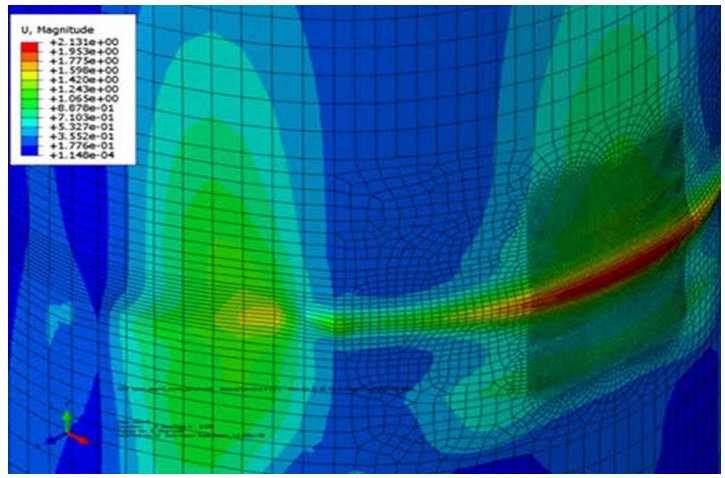


Fig. 4 stress analysis magnified 5x times

3.2 VERTICAL PLATE COKE DRUM ANALYSIS

Delayed coke drums are typically designed and built to the ASME "Boiler and Pressure Vessel Code" Section VIII, Division I. They are designed for the pressures resulting from a pressurized cover gas (typically 60 psi) and the hydrostatic pressure due to the weight of the coke charge. The vessel material and wall thickness are selected based on the calculated pressures at the elevated temperatures expected in operation. This traditionally results in horizontally arranged courses varying in thickness from the bottom of the drum to the thinnest plates at the top. Even though they are used in a temperature cycling duty, coke drums have not been generally designed to low cycle fatigue criteria.

Several drum sets have recently been designed and built using a methodology which features uniform thickness walls of high yield strength plate, matched yields between plates and welds, and flush weld caps. These features are intended to minimize stress concentrations during the quench cycle and hence delay the onset of bulge initiation and extend the useful life of the vessel.

Also recently, a novel construction technique has been pioneered, where course plates are arranged vertically in the drum wall. Since the low cycle fatigue stresses due to the quench cycle are axial, fatigue cracking invariably initiates in circumferential welds. A new repair/replacement technique has been introduced which eliminates the circumferential seams altogether in concern. Orienting the shell plates with their long direction vertical accomplishes this, providing an increased (up to more than 40 feet) shell length without a girth seam. This section of the vessel can be in the areas that experi-

ence the most severe thermal cycles.

From the stress concentration analysis of conventional and vertical plate coke drum it was found out that vertical plate coke drum has fewer patches of stress concentrated areas as compared to the conventional design of coke drums.

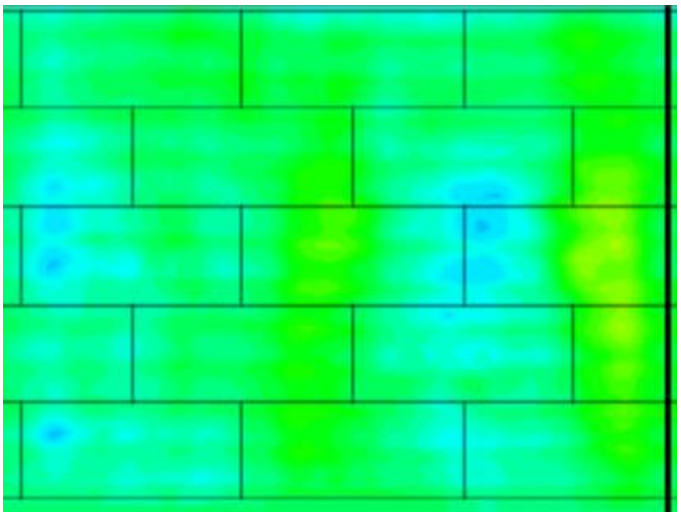


Fig. 5 Drum with Conventional Design

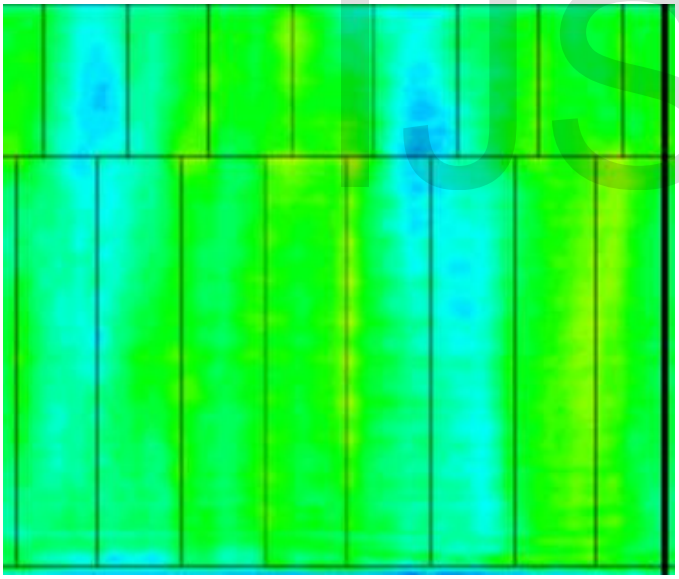


Fig. 6 Drum with Vertical Plate

One can see that the circumferential welded areas are the areas that experience the most uneven stress concentration, whereas vertical welded region experiences the least.

At the point when BP expected to supplant harmed coke drums at its Carson, California refinery, McDermott reacted with another and creative arrangement. Two coke vessels at the Carson refinery had started swelling and breaking following long periods of serious warm cycling. BP had beforehand supplanted a 20-foot segment of each drum and now intended to supplant two extra 20-foot segments of every vessel. Notwithstanding, that arrangement would have left circumferential seam in the segment of the drum where the protruding and splitting issues were generally articulated. In the wake of inspecting our new vertical plate idea, BP adjusted its arrangement and chose to retrofit everything except the best nine feet of each drum shell with two vertical plate courses—one that would be 40 feet long, and another that would be 23.5 feet long. Vertical weld creases have been appeared to be less helpless to warm cycling, aside from where the vertical creases converge circumferential welds.

The outcome is a sturdy vessel that keeps going longer than customary coke drums. The BP venture would be McDermott's first establishment of its new vertical plates, however the client was sure that we had the ability for the activity.. The plates were then transported to Carson. At the venture site, our team cut the old circumferential areas from the drums and evacuated them utilizing an altered rail framework connected to the structure. The new vertical plate segments were then set into place, and an expansive spout in the best head and segments of the skirt were additionally supplanted. McDermott specialists at that point performed post-weld heat treating and hydrostatic testing. They finished the whole venture in 28 days at an expense not more noteworthy than conventional strategies.

The task was successful to the point that the client requesting that we supplant shells on an extra four coke drums at the Carson refinery. Refer the figures below.

4 CONCLUSION

Coke drums are the main part of Coker unit, in which thermal cracking of higher molecular hydrocarbon gets converted to lower molecular hydrocarbons. During the process of decoking the drums undergo cyclic operations typically in the temperature range from room temperature to about 500°C (930°F). The coke drum then separates lighter vapours out of the crude, including hydrocarbon gases. During quenching, the coke drum is inevitably subjected to a rapid drop in temperature because cooling water is injected directly into the coke drum. The temperature profile on the shell surface is uneven and can vary in each cycle of the quenching operation. Such a complicated thermal profile induces large strains in the shell portion of the coke drum, and eventually causes damage like bulging and/or cracking. It is found out that this bulging generally happens at the circumferential welded region. Thus by elimination of the circumferential welds and the methods of quenching the bulging tendency can be reduced and we can reduce the chances of a huge disaster taking place at the complex.

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