Pak. J. Engg. & Appl. Sci. Vol. 9, Jul., 2011 (*p.* 24-27)

Pin-Hole Leakage in a Thick-Walled Flange

Liaqat Ali[1], Khalid M Ghauri[1] and Gul Hameed Awan[1]

[1] Department of Metallurgical and Materials Engineering, University of Engineering and Technology, Lahore, Pakistan.
Corresponding Author: liaqat_kasuri@hotmail.com

Abstract

Formation of a 'pin-hole' leading to gas leakage, in a thick-walled flange installed on a high-pressure gas line has been investigated to determine the nature and the cause of the leakage. The investigation was carried out by sectioning the flange along suitable planes and tracing the path of leakage with metallographic examination. It was learnt that the 1-inch dia steel flange had been made by forging followed by drilling a hole in the centre by conventional machining. The examination of metallographic sections revealed that during the forging of the component a forging fold had developed which was deep enough to just reach the location of central hole. The leakage through the fold, which took about 6 months to take a start, happened when the oxide entrapped in the fold had been eaten away by the acidic components of the gases.

Key Words: *High pressure gas line, Pin-Hole Leakage, Forging Folds, Metallographic Examination*

1. Introduction

High pressure weld-neck flanges are widely made by close-die forging process. Whereas the large dia flanges are forged such that the central hole is made during the forging process, the smaller dia flanges are made as solid forging followed by drilling the hole by machining. Such flanges are generally thick walled and very suitable for high pressure applications [1].

Components made by forging normally have a sound internal structure and fine grain size, and are thus considered very reliable for high pressure applications [2-4]. Leakages in flanges are very rare, and whenever a leakage occurs, it would usually be associated with some defect in the neck weld or due to any heat-affected-zone cracking. Leakage through a pin-hole in the body has not been reported in the published literature.

The present flange which developed pin-hole leakage six months after its commissioning had been installed on a 1-inch line on a gas sale point at BHP Petroleum. The flange was essentially a blind flange, i.e., no gas was actually flowing through it. However, the pressure of the gas inside the line was 90 bars with an operating temperature of 60-70 °C. The leaked flange and the operating data of pipe/flange were provided by BHP-Petroleum through their consultant [5]. The operating data is summarized below:

2. FLANGE DATA

Flange, Size: 1-inch (25mm)
Smooth Finish
Line operating pressure: 90 Bar
Operating temperature: 60 - 70^{o}C.
Gas composition:

Table 1: Chemical Composition of Gas

Component	**Sales Gas**	**Component**	**Sales Gas**
H2S		Toluene	0.01
CO2	2.6	C8	0.01
N2	21.4	M/P-Xylene	
C1	73.88	O-Xylene	
C2	1.42	C9	
C3	0.28	C10	
iC4	0.1	C11	
nC4	0.09	C12	
Neo Pentane	0	C13	
iC5	0.05	C14	
nC5	0.04	C15	
C6	0.06	C16	
M-C-Pentane	0.01	**Total**	**2.11**
Benzene	0.03	**SG**	**0.6851**
Cyclohexane	0.01	**CGR**	
C7	0.02	**HHV**	**797**
M-C-Hexane			

3. Result and Discussion

3.1 Visual Examination:

A photograph of the Flange taken before it was removed from its location of application was also provided along with the flange. This photograph, given in Figure 1, shows the exact location of the 'pin-hole'.

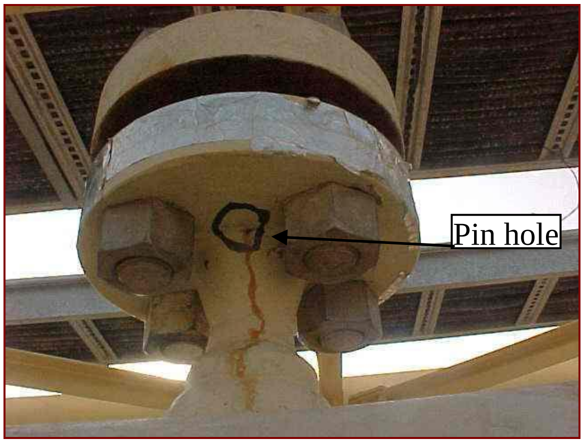

Figure 1 Photograph of the leaked Flange taken before it was removed from its installation

The surface of the supplied flange was covered with enamel-paint, and as such it was found difficult to make any sensible observation. A visual examination of the inner bore of the flange (in the as-supplied condition) also failed to provide any clue. The supplied component was then cleaned by immersing in 25% HCl (Hydro-Chloric Acid) for 15 min., but still no information could be obtained either from the outer surface or from the inside of the bore.

3.2 Sectioning and Metallographic Examination

Since the visual examination with the help of a magnifier as well as boroscope did not reveal any clue about the pin-hole, it was decided to section the component along some suitable planes so as to be able to look at the inside of the bore, without disturbing the region around the 'pin-hole'. The sectioned flange is shown in Figure 2. The location of the 'pin-hole' is marked with an arrow-head.

Although nothing very evident could be seen on the sectioned surfaces as such, when one face of the sectioned flange was metallographically polished and etched, a 'crack' which was later identified as a 'forging-fold' became visible. A photograph of this forging-fold is given in Figure 3. It may be noted that the fold extends up to the inner surface of the bore.

Figure 2 Photographs showing where the Flange was sectioned at, for looking at the inside of the bore.

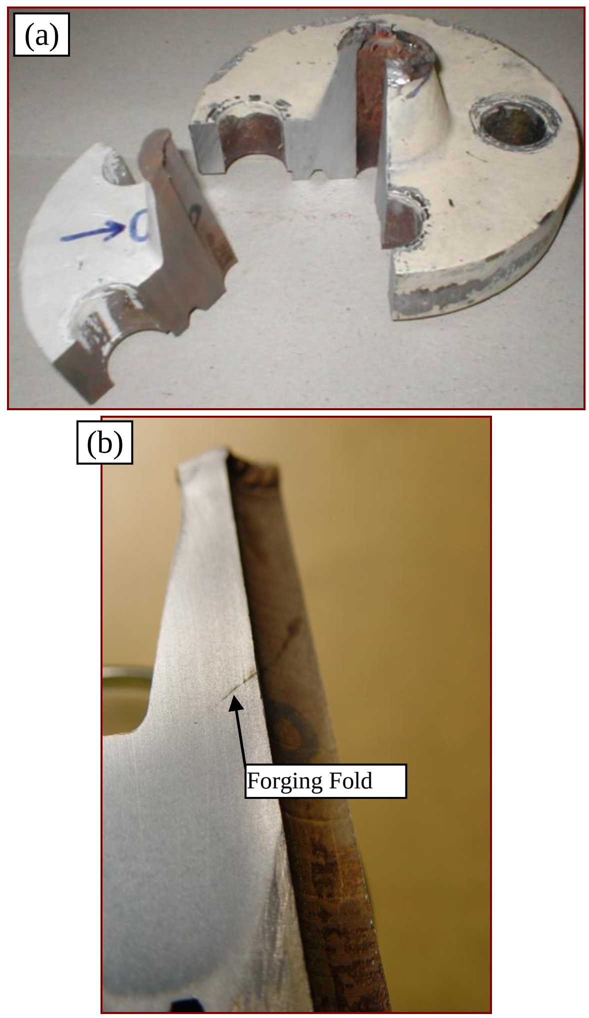

Figure 3 (a) The photograph of sectioned flange. (b) The sectioned face which was polished and etched. A 'crack' that was essentially a 'forging-fold' can be clearly seen in Figure 3b.

Although nothing very evident could be seen on the sectioned surfaces as such, when one face of the sectioned flange was metallographically polished and etched, a 'crack' which was later identified as a 'forging-fold' became visible. A photograph of this forging-fold is given in Figure 3. It may be noted that the fold extends up to the inner surface of the bore.

In order to understand the link of the forging-fold with the pin-hole at the outer surface of the flange, the sectioned portion shown in Figure 3(b) was further sliced very close to the 'pin-hole', a photograph of which is shown in Figure 4. It may be noted in Figure 4 that the forging-fold is oriented in a manner such that it serves as a 'connection' between the inside of the bore and the 'pin-hole' on the outer surface of the flange. Although it was possible to remove another thin slice from the section shown in Figure 4, in an attempt to illustrate the fold actually linking with the pin-hole, it was considered appropriate not to do this for two reasons:

(a) The available evidence, i.e. Figure 4, was quite convincing even as such, and

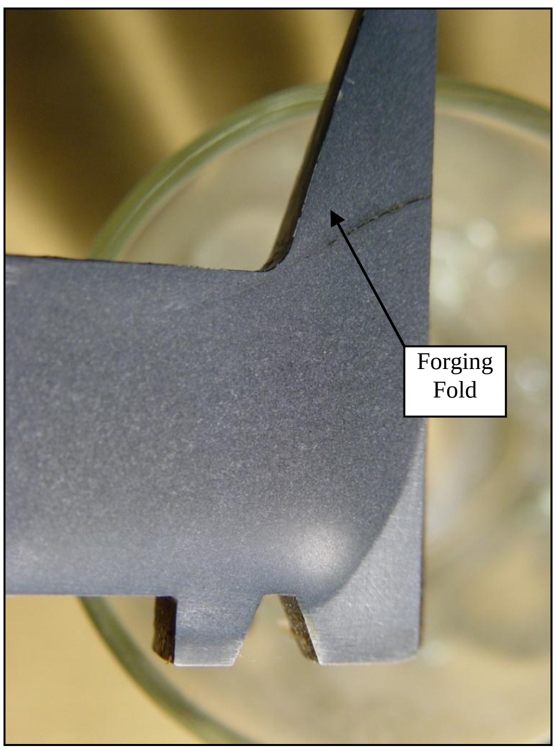

Figure 4 A section taken very close to the pin-hole, showing the orientation and the depth of the forging fold. It can be seen that the fold is serving as a 'connection' between the inside of the bore and the 'pin-hole' on the outer surface of the flange.

(b) The sectioned portion of the flange was to be sent back to BHP Petroleum (and possibly for onward transmission to the manufacturing company in Australia). It was thought appropriate to leave the further slicing (if needed) to the forging company, so that they could carry out the remaining examination from their own point of interest, i.e. how the forging fold could have formed, so as to improve/modify the blocking/pre-forging step.

3.3 Microscopic Examination

As may be noted in Figure 1, the leakage marks on the outside of flange indicate that some kind of liquid (most likely the condensate in the pipeline) has been seeping through the pin-hole. Further, the microphotographs taken from the fold (given in Figure 5) show that the oxide scale inside the fold has been 'eaten away' at some places (Fig 5c), while it is still present at some places, especially in the narrower part of the fold (Fig 5b).

An analysis of the above observations should be conducted in conjunction with the information that the leakage through pin-hole was noticed six months after the installation of the flange. It is logical to believe that the condensate in the gas had caused a slow chemical attack on the oxide entrapped in the fold, and it took about six months for the condensate to eat away sufficient oxide so as to create a leakage path through the fold.

The compositional analysis of the gas given in Section 2 above shows no H2S in the gas, however, the CO2 content was about 2.6 %. The H2S and CO2 are both soluble in water (condensate), and result in the formation of sulphuric and carbonic acids, which are corrosive to iron as well as iron-oxide. In fact the iron-oxide dissolves into the sulphuric or carbonic acid more readily than iron [6-10].

The microstructures given in Figure 5 also show that the entrapped oxide scale is sandwiched between continuous layers of decarburized steel. This observation clearly shows that the oxide seen in Figure 5 is not an intrinsic inclusion, but is the oxide scale that had formed at the surface of hot metal, and had been entrapped inside the fold when (due to inappropriate handling of forging stock) a forging fold was developed during forging. It has to be remembered that when a stock is being heated in a furnace prior to being forged, the surface scale as well as a decarburized layer always forms on the surface as it is exposed to atmospheric oxygen. It is therefore clear that the oxide layer seen in Figure 5 had its origin in the forging fold, and that the oxide had been gradually attacked by the acidic condensate in the gas eventually resulting in the leakage.

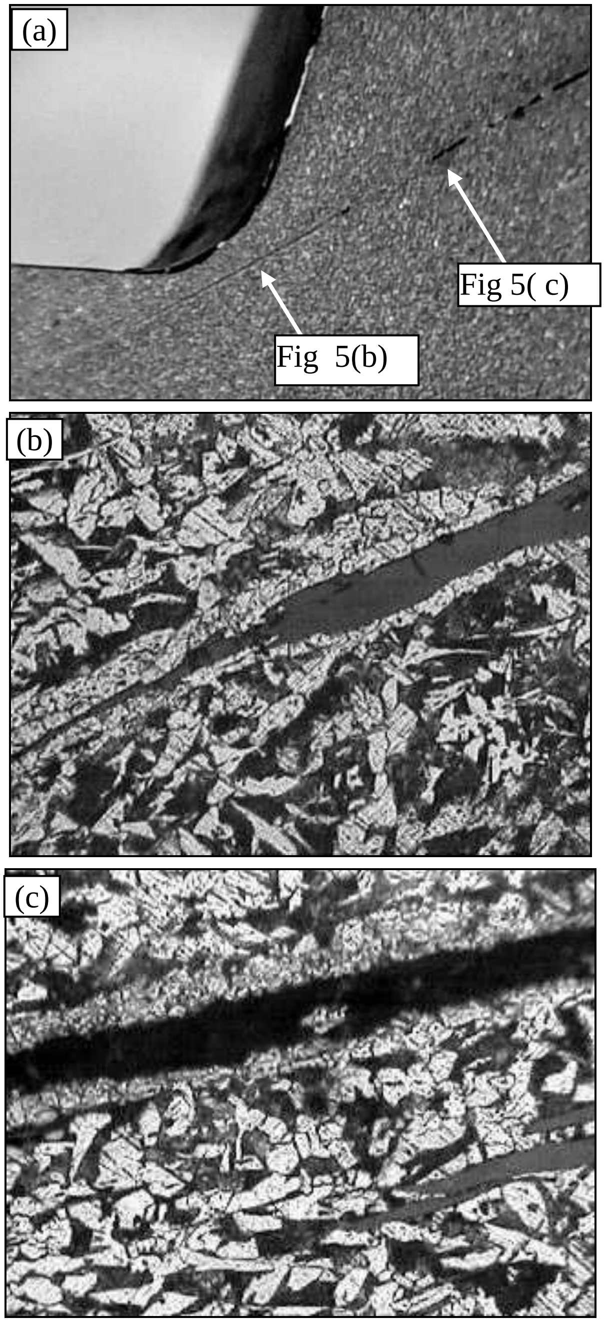

Figure 5 (a) A macroscopic view of the fold, (b) micrograph showing that the oxide entrapped inside the fold, (c) another micrograph indicating that the oxide has been eaten away at some locations in the fold, thus providing a leakage path to the gas / condensate.

4. Conclusions

The leakage through the flange wall had occurred through a manufacturing defect. This defect was a forging fold which was so deep that it had reached the central hole that was drilled through the center of the flange forging. The oxide scale entrapped in the fold had been gradually attacked by the acidic condensate in the gas, eventually leading to leakage.

References

[1] "Designing to codes and standards" Materials Selection and Designe, Vol. 20 ASM International 1990.

[2] G.F. Vander Voorts, Metallograghy principles and practice, McGraw-Hill, 1988.

[3] J. Schey, Manufacturing Process and their selection, Material Selection and Designe, Vol. 20, ASM Hand Book, ASM International, 1997. P 687-704.

[4] W. D. Callister, Jr, Materials Science and Engineering. An International 3rd Ed. Wiley, 1994.

[5] Private communication: Dr. F. Hasan, October 18, 2010.

[6] "Corrosion Cost and Preventive Strategies in the United State," FHWA-RD-01-156, supplement to Materials Performance, Vol. 3, July 2002.

[7] "Corrosion of Metals and alloys-Corrosively of atmosphere-Classification," ISO 9223: 1992.

[8] "Corrosion of Metals and alloys-Corrosively of atmosphere-guide line values for the corrosivity categories," ISO 9224: 1992.

[9] "National Air Quality and Emission Trends Report, 2003 Special Studies Edition," U.S Environment Protection Agency, 2003.

[10] Corrosion Doctors: "Rupture and fire near Carlsbad New Mexico August 19, 2000." Available at http://corrosion-doctors.org/Pipeline/Carlsbad-exp...; accessed November 27, 2010.