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Fatigue analysis of bolted flange joints of a rotary dryer

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ABSTRACT

This paper describes the fatigue failure of a rotary dryer in a chemical plant. The process conditions required the dryer to be rotated continuously at a speed of about two and half revolutions per minute. The shell structure of this large drum is formed by combining segmented shell parts using bolted ring flange joints. Because of the gross weight of the dryer in operation time, each joint was subjected to bending moment. In the first two years in service, micro cracks were occurred by fatigue. The failure was analyzed using the fatigue curves given in ASME Boiler and Pressure Vessel Code Section VIII Division 2 and EN 13445 Unfired Pressure Vessels Part 3 Codes. Finally, flange joints were removed from the drum and new cylindrical parts adapted to the drum using butt welding after reaching better results in FEM and fatigue calculation.

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1. Introduction

1.1. Background

Fig. 1 is a schematic diagram of a rotary dryer in a chemical plant. The rotary dryer consists of a 3.7 m diameter and 28 m long rotary cylindrical shell. Due to its inclination (1°18′) and a lifter flights system, it makes the product drive along its inside mixing it with hot gases about 130 °C. In this way, the material gets dry slowly and the gases full of humidity leave the dryer being vacuumed by the fan.

The dryer shell was made of 18 mm thickness mild steel plate in accordance with ASTM A 285 Grade C FBQ, being its construction welded and divided in three parts joined by flanges. All joints in each segmented shell butt-welded to ASME Sec. IX with full penetration. The shell under the riding rings and the girth gear is of greater thickness. The concentricity of the shell, after complete assembly, was within the range of plus or minus 5 mm throughout its length. The shell structure is to be supported by two sets of tires and rollers positioned approximately one-fifth of the total length from either end of the shell. A pair of axial-contention thrust rollers keeps the rotary body in the correct longitudinal position. Driving is made by means of a pair of girth and pinion gears. The girth gear ring was to be constructed of cast steel having machined out teeth and was to be connected to the shell by mild steel linked arms.

In the case of large dryers, it could be necessary to use divided shells which flanged later. The average gross weight of the dryer when it was operating was about 160 t. The drum rotates at a speed of about two and half revolutions per minute. This means that bolted ring flange joints were subjected to cyclic bending moment of the cylindrical shell.

We can see that if the drum is rotated through 180° the stress in the welds will be reversed. If the drum is rotated by another 180°, the stress will return to their initial values. This means that, with each revolution, the stresses in the welds will undergo a complete cycle of fatigue loading. The total number of fatigue cycles N experienced by welds during the period of operation is

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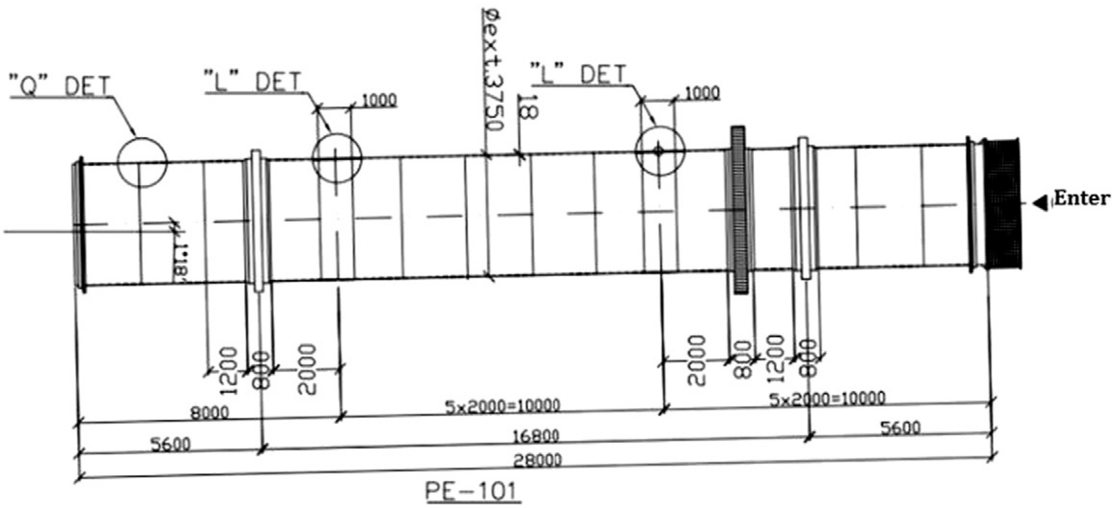

Fig. 1. Schematic side elevation of the chemical vessel.

given approximately by: $2.5 \times 60 \times 24 \times 365 \times 2 \times 0.9 = 2.4 \times 10^6$. The drum was in continuous use for about 90% of the time and this is allowed for by the 'utilization factor' of 0.9. This is a large number of cycles and the welds presumably failed by high-cycle fatigue [1].

1.2. Details of construction

Fig. 2 is related to details of the ring flange joints used in this rotary dryer. Segmented shells were welded to ring flanges by the manufacturer before arriving the chemical plant. At the assembly phase of the drum at the plant, segmented shells were bolted to each other and finally seal welded.

Ring flange joints are used in all cases where application tubular sections or components are to be positively connected with each other. They represent an alternative if welds are not suitable due to technical or economic criteria. This ring flange joints are exposed both in static and in dynamic ways extreme loads.

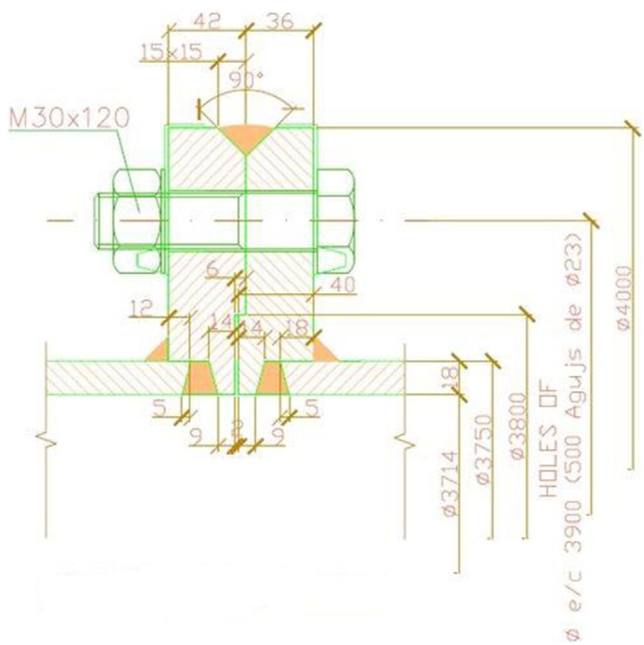

Fig. 2. Schematic side of the bolted ring flange joint ('L' detail of Fig. 1).

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