Engineering Failure Analysis 31 (2013) 394–411

Contents lists available at SciVerse ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Analysis of the catastrophic failure of a dockside crane jib

Francesco Frendo *

Department of Civil and Industrial Engineering, University of Pisa, Largo Lucio Lazzarino, 56122 Pisa, Italy

ARTICLE INFO

Article history:
Received 11 December 2012
Received in revised form 12 February 2013
Accepted 15 February 2013
Available online 4 March 2013

Keywords:
Crane
Structural integrity
Fatigue design
Welded joint
Failure analysis

ABSTRACT

The catastrophic failure of a crane jib is discussed in the paper. The final failure was determined by an existing crack, which had propagated up to a considerable part of the cross section of one of the main tubular elements, which constituted the jib frame. The crack originated from a seam weld, which was used to join a stiffener on top of the tubular element where some cracks were found few years before the failure and that, actually, resulted to be a misguided attempt to strengthen the jib structure at that point.

A stress analysis of the crane jib is firstly carried out, in order to analyse the stress levels nearby the failure region and to discuss the fatigue design with reference to current standards. In the second part of the paper, a crack-growth model is developed in order to achieve an estimate of the propagation period and a simple collapse model, based on beam theory, is used together with the material properties determined by experimental tests, to determine whether the final failure was determined by fracture or by plastic collapse.

The analyses conclude that the fatigue design requirements were not satisfied and that the final failure was determined by plastic collapse of the critical cross section, after a relatively long stable propagation period. Some considerations about the necessity of scheduled and qualified inspections are also drawn.

1. Introduction

The catastrophic failure of dockside crane jib is analysed in the paper. As shown in Figs. 1 and 2, the failure occurred nearby the connection to the standing tower. The visual inspection of the fracture surfaces revealed the presence of a large pre-existing crack, which originated from a seam weld and propagated through one of the main pipes constituting the crane jib, in a plane orthogonally oriented with respect to the pipe axis.

The jib consisted of a space frame, made of x52 steel pipes with different cross sections joined by welding. The technical literature on fatigue analysis of welded structures is really extensive (see for example [1–8]). Even if the subject is widely treated, the analysis methods are different depending on the model and parameters assumed in the stress analysis and there is not a unified approach. The analysis methods can be broadly grouped into categories [1,2,4]. In nominal stresses methods, which are typical of standard codes [13–16], the nominal stress amplitude acting on the joint is evaluated and then compared to the nominal *S*–*N* curve, taken as reference for strength evaluation. This method can be considered robust if based on a statistically representative experimental data basis, such as in case of the joint classes provided by standards. At the same time this method presents some drawback, such as in cases where the nominal stress cannot be meaningfully defined, or when there is no direct correspondence of the component which has to be analysed with the joints classes that are covered by standards.

* Tel.: +39 050 2218074; fax: +39 050 2218069.
E-mail address: frendo@ing.unipi.it

1350-6307/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.engfailanal.2013.02.026

Fig. 1. Pictures of the catastrophic failure.

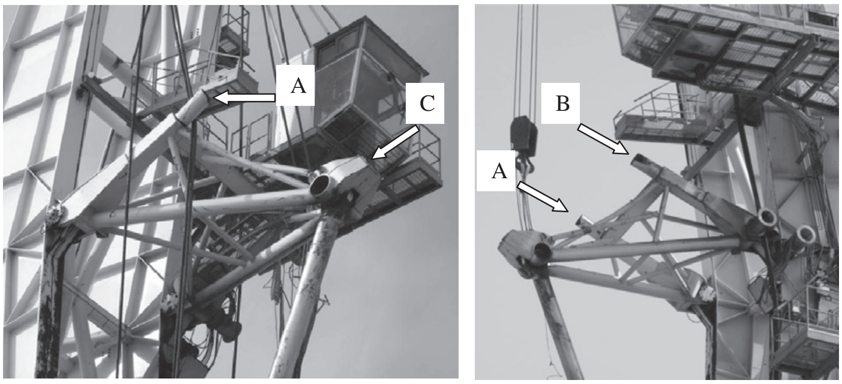

Fig. 2. Detailed views of part of the jib structures, near the connection to the standing tower, where failure occurred. A–C indicate the failure sections of the three main tubular elements of the jib frame.

On the opposite side there are methods in which the local stress acting at the weld toe or root is evaluated [2–4]. Due to the singularity of the elastic stress field, this has to be done following different assumptions. When the maximum stress at the weld toe or root is considered as the limiting parameter a finite radius is introduced, following the original idea of Neuber, and a notch stress can then be defined and used for the analysis. Another possible way of bypassing the singularity of the elastic stress–strain solution is the use of a notch stress field parameter, typically the ‘‘Notch Stress Intensity Factor’’ (N-SIF) [5,8]; this is based on the fact that the local stress field in the neighbourhood of a weld toe is similar to the stress field in the neighbourhood of a V-shaped sharp notch having the same opening angle as the severe V-notched geometry of the weld.

More recently some methods based on the average (integral) value of a stress component, such as the maximum principal stress, or of the strain energy evaluated in a small volume, in the surrounding of the critical zone, have also been proposed (see e.g. [9,10]).

In the ‘‘local stress’’ approach there is not a unified definition of the weld toe or root radius to be used and several assumptions of the ‘‘worst case’’ or of a ‘‘fictitious notch radius’’ have been proposed [2,6]. The so called ‘‘structural stress’’ method [2–4], among which there is the well-known ‘‘hot spot’’ method, try to overcome the difficulties encountered in defining the notch radius. According to this method the so called ‘‘geometric stress’’ acting at the weld toe is evaluated considering the effect of the joint geometry, while any local effect due to the weld geometry itself is not taken into account. The structural stress acting at the weld toe, to be considered for the fatigue analysis, is numerically computed by finite element (FE) analysis or experimentally obtained by strain gauges measurements.

The different approaches to the fatigue design of welded joints and components are also covered by the recommendations of the International Institute of Welding, which, since 1996, periodically releases updated procedures. The recommendations embrace all the current methods of verification of welds and try to describe the fatigue behaviour and assessment on an