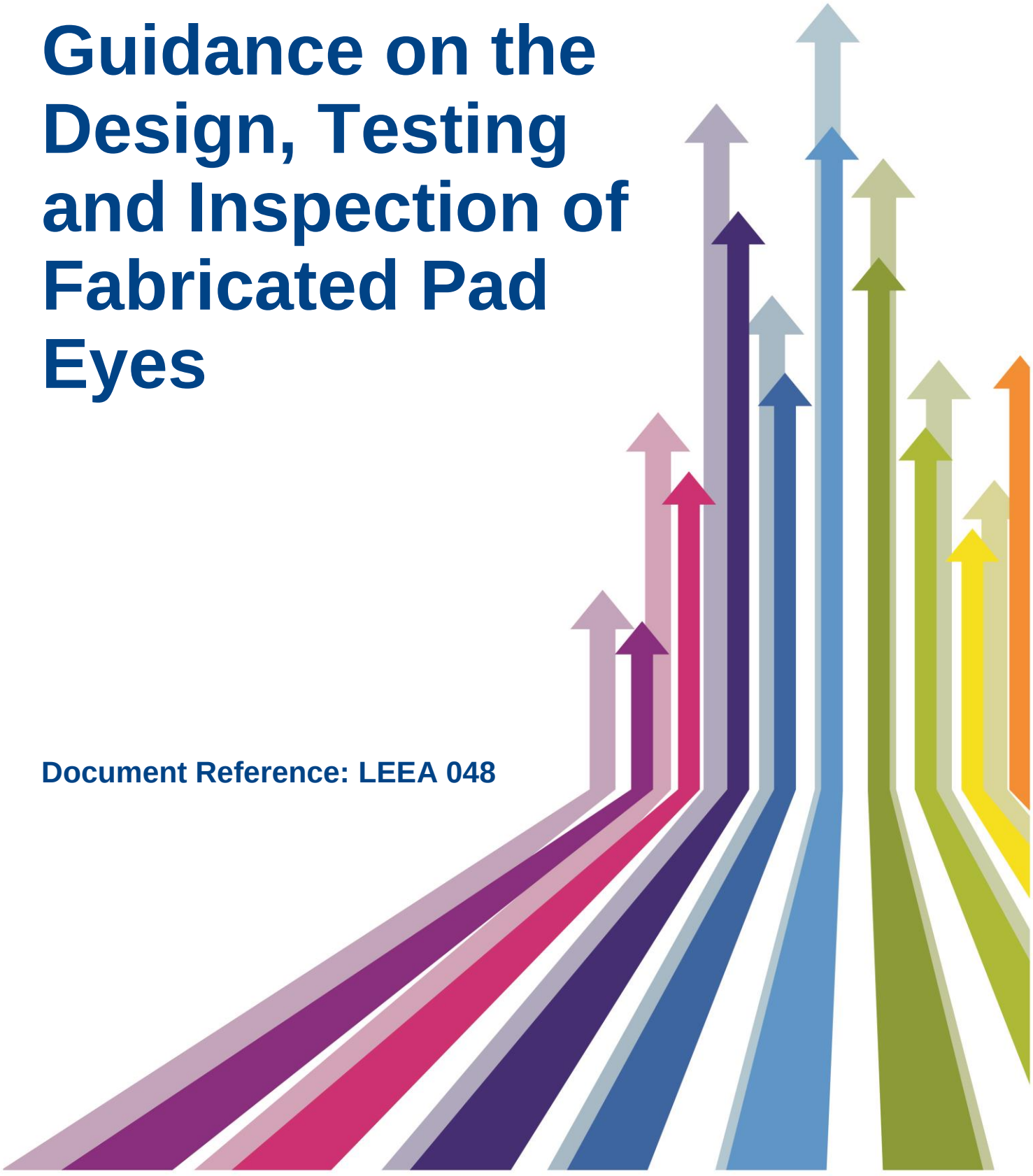
Lifting Standards Worldwide™

LEEA

Guidance on the Design, Testing and Inspection of Fabricated Pad Eyes



Document Reference: LEEA 048

Guidance on Design, Testing and Inspection of Fabricated Padeyes
Document reference: LEEA 048 version 2 dated 22 July 2015

Published by the
LIFTING EQUIPMENT ENGINEERS ASSOCIATION
3 Osprey Court, Kingfisher Way
Hinchingbrooke Business Park
Huntingdon PE29 6FN
United Kingdom
Tel: + 44 (0) 1480 432801 Fax: + 44 (0) 1480 436314
E-mail: mail@leea.co.uk Website: www.leeaint.com

CONTENTS

1.0 Introduction

Fabricated pad eyes can be used as anchor points on structures from which lifting equipment can be suspended or as attachment points on loads. LEEA members are sometimes asked to test and certify existing pad eyes or to design and fit new pad eyes. There are no national or international standards specifically for pad eyes. However, there is a wealth of relevant information which can be applied directly to the design, testing and inspection of fabricated pad eyes. LEEA has reviewed and pooled together this information into this best practice guidance.

Note 1: for the purpose of this document the definition of a fabricated pad eye is a flat steel profiled plate with a single hole to accommodate the pin and body of a shackle. To pad out the jaw of the shackle some pad eyes will have cheek plates or other spacers fitted.

Note 2: all references to standards and legislation made in this document are to the most current version.

2.0 Legislation

Pad eyes are generally classed as a part of the load and therefore are not within the scope of the Supply of Machinery (Safety) Regulations, which implements directive 2006/42/EC in the UK.

In terms of supply, applicable legislation in the UK is the Health and Safety at Work etc. Act (HSWA). Section 6 of HSWA requires the equipment designer, manufacturer, importer or supplier of pad eyes;

1. To ensure, so far as is reasonably practicable, that the pad eye is so designed and constructed that it will be safe and without risks to health at all times.
2. To carry out or arrange the carrying out of such testing and examination as may be necessary for the performance of the duty imposed on him by point one.
3. To take such steps as are necessary to secure that the persons supplied with the article are provided with adequate information about the use for which the article is designed or has been tested and about the conditions necessary to ensure that it will be safe and without risk to health at all times.

For pad eyes associated with offshore containers the manufacturer should also refer to EN 12079.

Once in service pad eyes fall under the Provision of Use of Work Equipment Regulations (PUWER). However, when used with lifting equipment the Lifting Operations and Lifting Equipment Regulations (LOLER), must also be referred to.

3.0 Design

The pad eye, in the first instance, is often designed around a shackle, which is most commonly attached to the leg of a sling. In this instance it is considered best practice to ensure that the pad eye is positioned such that the line of force acts in the plane of the pad eye. Otherwise bending stresses will be induced to the pad eye and will result in damage to the shackle. Figure 1, below, shows the correct and incorrect loading on a pad eye.

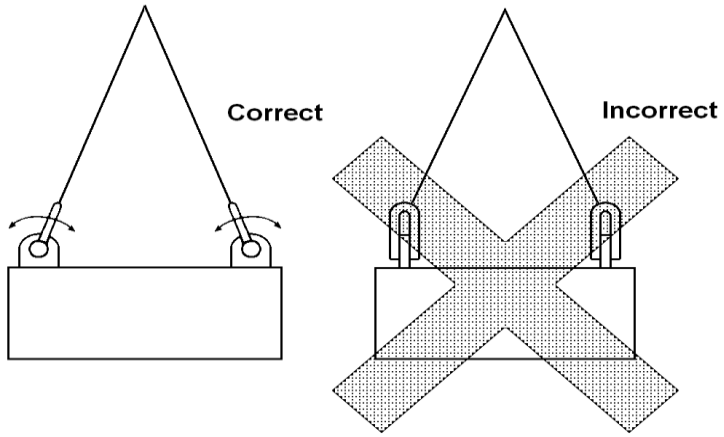


Figure 1: Examples of correct and incorrect pad eye load cases.

The geometry of the pad eye must take into account the geometry of the shackle. Therefore the designer must consider the shackle dimensions in terms of the following design constraints:

1. The pin – it is recommended that for pad eyes for use in the offshore industry that the shackle hole diameter shall be no more than plus 6% of the nominal pin diameter. This would also be considered as good practice for all other types.

2. The dimension from the centre of the hole to edge of the plate at which the shackle is to be functional, must allow sufficient clearance for the adjoining component, see figure 2.

3. The jaw width of the shackle – To avoid eccentric loading of the shackle, spacers should be used to pad out any space between the pad eye and the shackle body. This is often achieved by welding cheek plates concentric to the pad eye hole. Note that such plates are not considered as not having any structural strength and therefore, are not considered when calculating the pad eye strength. The cheek plates must be of sufficient thickness so as to leave a small gap between the shackle body and cheek plate to ensure free movement and fitting of the shackle. However the gap should not be too large so as to allow movement along the pin and result in eccentric loading.

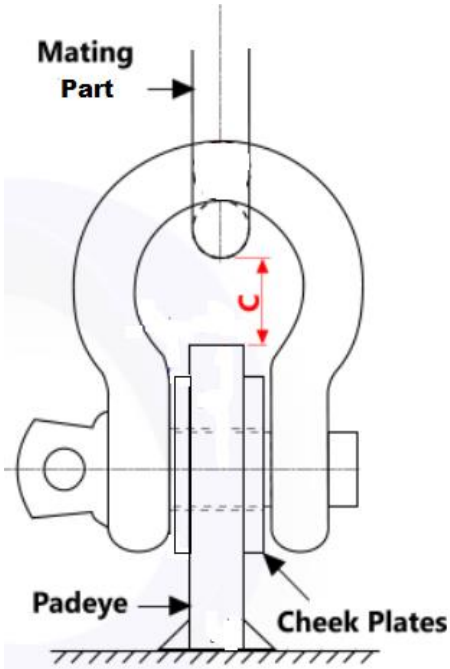


Figure 2: Drawing of a typical pad eye and shackle assemble, showing cheek plates, clearance between pad eye and shackle body and the clearance for adjoining component. Note C is a variable dependant on the size of the adjoining component, but must be sufficient to allow free movement.

Once the general geometry has been determined the designer can then analyse the strength of the pad eye. Depending on the outcome of the verification the designer may choose to optimise the design by increasing or decreasing the thickness or radius of the plate. In order to do this the designer must consider the following load cases:

1. Bearing stress – this is a compressive stress that occurs on the surface of contact between two interacting members. In the case of the pad eye, this would be the shackle pin against the load bearing surface of the hole. All stresses are considered as a force over an area and in this case the bearing area is the projected area of the pin multiplied by the thickness of the pad eye, see figure 3.

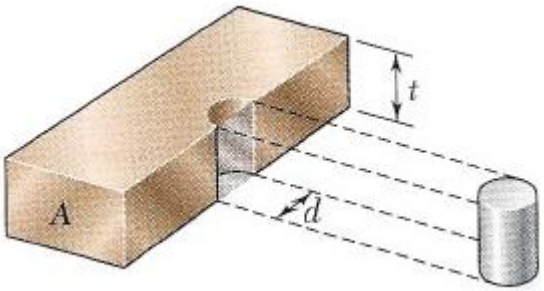


Figure 3: Example of a pin bearing area on a hole in pad eye A.

2. Tensile tear out stress – As the name suggests this is a tensile failure which can occur if the thickness of the steel either side of the hole is too thin, see figure 4.

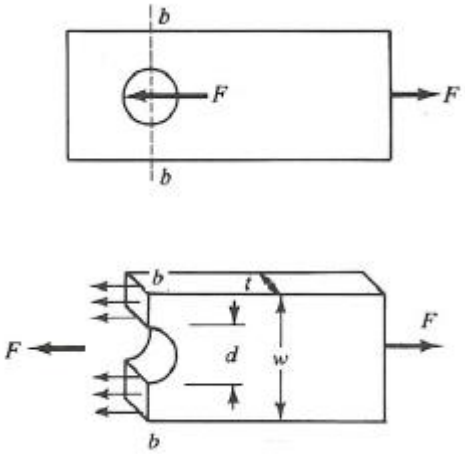


Figure 4: Example of a tensile tear out failure.

3. Shear tear out stress – this failure occurs in the opposite plane to the tensile failure above, refer to figure 5.

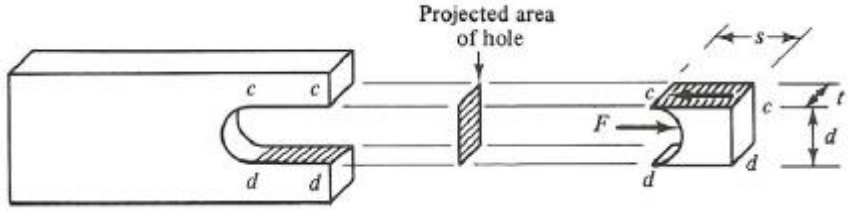


Figure 5: Example of a shear tear out failure.

In all cases the calculated stress is, in basic terms, the resultant sling or other applied force divided by each of the above areas. However, the designer must also take into consideration the stress raiser arising from the change in section at the hole. The accepted method of doing this is to introduce a stress concentration factor into the equation. Such a factor can be devised through tests for specific materials, but fortunately, stress concentration factors are available in graphs and empirical formulas from a wide variety of sources, refer to figure 6. In addition to this the factor, in our case referred to as 'K', is dependant only on ratios of geometric parameters and is independent of member size and material. The equation to calculate each of the above is shown in the following equations.

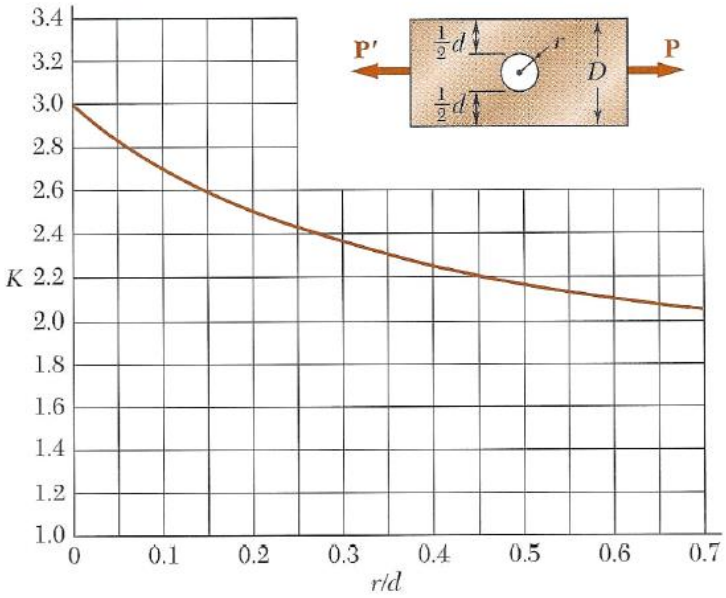


Figure 6: Stress concentration factors for given pad eye sections.

It is important to note that standards concerning offshore lifting equipment use a stress concentration factor of 3.

For all of the above stresses the following equation is recommended by LEEA:

$$\sigma = K\left(\frac{F}{A}\right)$$

Where: σ = the resulting stress
K = Stress concentration factor
F = the design load
A = the area under consideration

For general pad eye design LEEA recommends that the actual resultant sling load is multiplied by a factor of 2 and the subsequent calculated stress is within the elastic range of the material to be used.

4.0 Material
If the pad eye is to be attached to the structure or load by welding, the material selected must be compatible with that of the structure or load.

For some applications it may be necessary to use material with through thickness properties. This is due to the fact that rolled steel does not have a homogeneous structure. This is a result of the rolling process that squeezes the alloy grains in the microstructure such that they overlap by becoming long and thin in the direction of rolling. In most applications the principal stresses and strains imposed on a steel product will be in this beneficial lengthwise direction. Occasionally, however, loads will be imposed in the transverse “through-thickness” or “Z” direction. Then the ability of the grains to adhere to each other is crucial.

The situation when the through-thickness properties of the steel are most likely to be important is in heavily-welded “cruciform” type joints. This is because when welds shrink on cooling the locally imposed strains can reach yield and the parent material must be ductile enough to redistribute these strains. This requires the steel to have an appropriate “Z-quality”.

For further guidance refer to the steel industry guidance note at the following link:
http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&ved=0CCcQFjAA&url=http%3A%2F%2Fwww.steelconstruction.org%2Fcomponent%2Fdocuments%2F%3Ftask%3DdownloadDocument%26doc%3D47815%26file%3D47815&ei=8uGHVf3KF4OQsgGu85noAg&usg=AFQjCNEG_PHkKS2woCwmQy4i-dnh9z74hg

To avoid initiation of brittle fracture the steel should possess adequate fracture energy. This can be verified by the Charpy impact (V-notch) method according to EN ISO 148-1 Metallic materials; Charpy pendulum impact test. *Note: EN 12079-1 specifies the requirement for offshore containers and is appropriate for other applications in a similar environment.*

5.0 Fabrication
The external profile of the pad eye components will generally be flame cut. Freehand manual flame cut components should be finished by grinding to remove irregularities. Automated flame cutting using a pattern may produce an acceptable finish but the finish should be inspected and any irregularities ground smooth. Automated laser cutting using a pattern should provide an acceptable finish. The hole for the shackle pin should always be machined to size.

6.0 Load Testing
The pad eye should be tested with a static test force of 2 x WLL.

Prior to the application of the test load the pad eye should be inspected. To satisfy himself that the item is suitable for the test load the inspector may use supplementary testing, such as NDT, to support the inspection.

The load should be applied in a manner which simulates the method of use, i.e. at the angle or range of angles required. If there is the possibility that the accuracy of the angle or range cannot be guaranteed, a tolerance should be assumed e.g. ± 10º.

7.0 Examination following a load test
Following a load test the pad eye and connection to the supporting structure should be visually examined for any defect. All welds should be checked by an NDT method appropriate to the section of weld. The relevant standards are:

Magnetic Particle: EN ISO 17638 Non-destructive testing of welds. Magnetic Particle testing

Dye Penetrant: EN ISO 3452-1 Non-destructive testing. Penetrant testing. General Principles

Ultrasonic: EN ISO 17640 Non-destructive testing of welds. Ultrasonic testing. Techniques, testing levels and assessment.

Radiography: EN ISO 17636-2 Non-destructive testing of welds. Radiographic testing. X-and gamma-ray techniques with digital detectors.

8.0 Marking
Pad eyes should be marked with the following information:

A unique ID
SWL
Angle or range of angles of the line of pull

For pad eyes attached to the supporting structure by welding, this information may be displayed on the supporting structure adjacent to the pad eye. If the pad eye is attached to a container, then the container may carry the safety marking. For pad eyes attached by bolts, the information should be marked on the pad eye.

9.0 In-service inspection of Pad Eyes.
Pad eyes are considered as work equipment and therefore must be inspected in accordance with regulation 6 of PUWER at regular intervals. The periods between inspections is derived from a risk assessment taking into account the likelihood of deterioration due to such things as use or environmental conditions for example.

Some existing so called ‘pad eyes’ which members are asked to test, are little more than a piece of steel plate crudely cut to shape with a gas torch and welded into place. Pad eyes of this quality should never be used for lifting purposes. The best course of action is to remove and scrap them.

Pad eyes and their welds should be checked for wear, distortion, damage, nicks, gouges, cracks, corrosion, etc. If any of these defects are found then it is up to the competent person to assess their importance in relation to the continued safety of the pad eye.