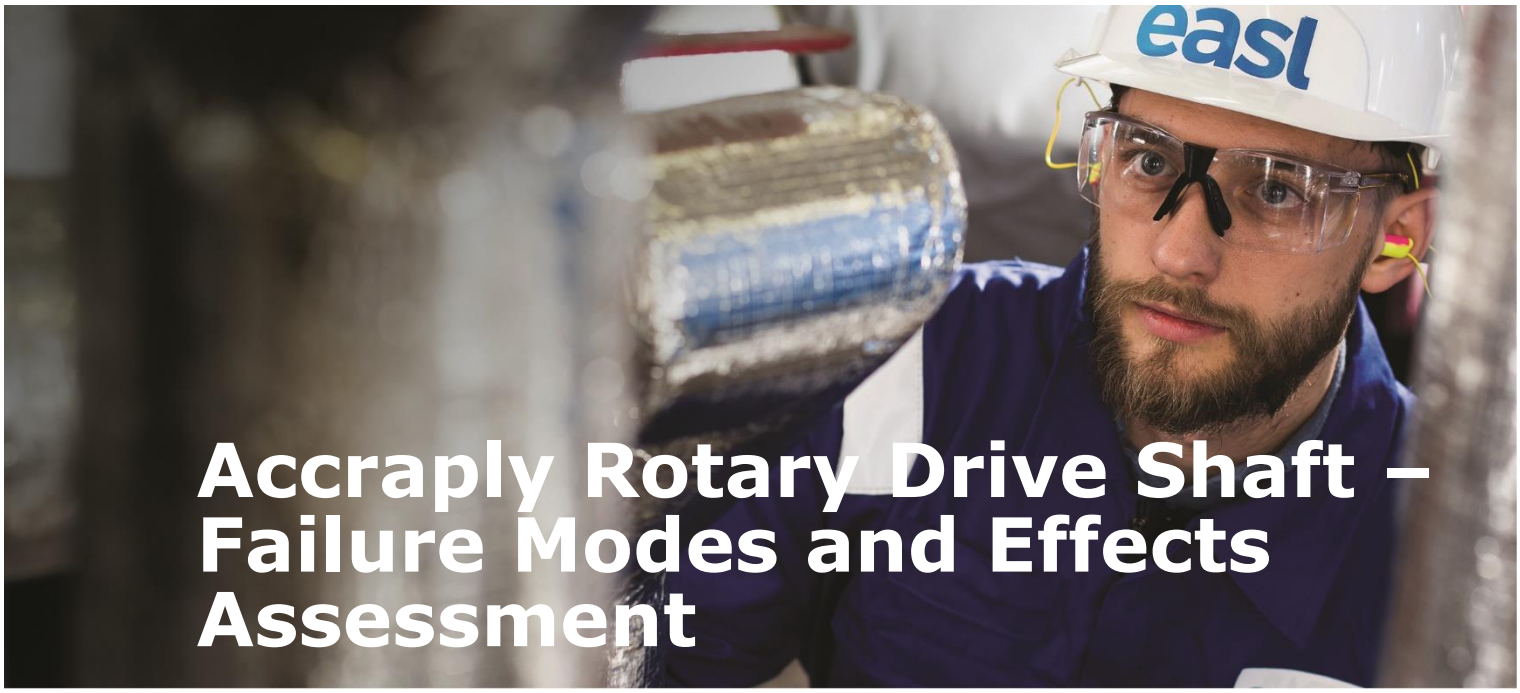

# Accraply Rotary Drive Shaft – Failure Modes and Effects Assessment

## Case study

**Our client designs and manufactures a variety of labelling machines that can be tailored to specific industrial applications. After 5 years of operation on one of the rotary labelling machines, the rotary drive shaft failed whilst running, causing a stop to production for our client's customer. In order to minimise the loss in production and associated costs, EASL were contacted to perform a failure modes and effect assessment to inform the design of the replacement shaft, given our specialties in structural integrity and failure modes investigations.**

## The problem

The rotary drive shaft was initially manufactured in two separate pieces, which were welded together making use of castellations on the shaft that were inserted into recesses on the flange.

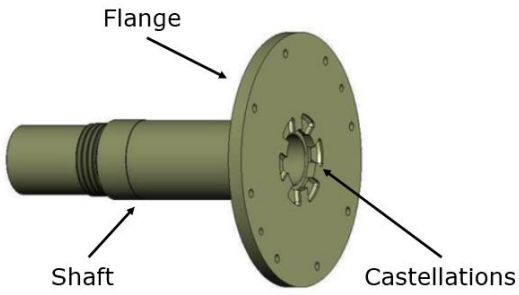


*Figure 1 3D model of the rotary shaft assembly*

The shaft failed after 5 years of operation (~12.5 million cycles), with the failure surface axisymmetric and different failure modes apparent from the shape.

*Figure 2 Failure surface of the shaft*

There was evidence of a crack of ~3 mm depth and the part had been post-weld heat treated. As a result, the failure modes considered were:

- Tensile failure from a combination of shear, bending & torsional loading;
- Fatigue crack initiation & crack growth;
- Fracture; and
- Resonant vibrations from breaching fundamental frequency.

# The solution

Each of the failure modes were investigated, making use of design code based calculations where appropriate.

As the failure surface was axisymmetric, it was judged that the principal loading influence must also be axisymmetric. Therefore bending was not considered a significant mode of loading.

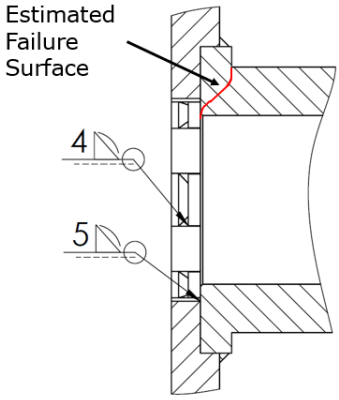


*Figure 3 Estimated through wall direction of failure surface*

To determine the collapse failure mechanism, an ASME code allowable torsional shear stress was determined and compared to the maximum operational equivalent, taking into consideration a safety factor applied to the maximum torque of the torque limiter in the wider assembly.

For the fracture assessment, the type of crack was deemed a mode III crack initiating from torsional loading. The crack depth was assumed at ~3 mm and to be fully circumferential. The stress intensity factor (SIF) at the crack tip was calculated and evaluated against the material fracture toughness to determine proximity to fracture.

To investigate the fatigue crack growth, the largest torsional moment range was determined, the motor running on and off, and the maximum subsequent crack growth was calculated for the operational cycle lifetime. This was then evaluated against the maximum allowable crack size associated to the maximum SIF for this crack type.

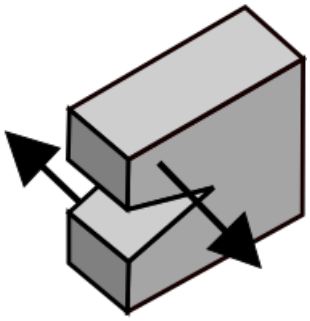

*Figure 4 Mode III crack*

The shaft resonance was lastly considered by calculating the shaft fundamental frequency and evaluating this against the operational frequency.

# The outcome

The failure modes and effects assessment demonstrated that the revised design of creating the shaft from a single billet of material would result in the design code allowable stresses being well in excess of operational stresses and the other noted failure modes not being of concern in future operation. In addition, the design recommendation of increasing the shoulder radius in the region of the previous failure from 0.5 mm to 2 mm would result in an increase in fatigue life by a factor of 80.

This information was used as part of the design update to the rotary shaft, in order to continue operation on site.

# Other applications

**This study was used in a design update to a rotary shaft to substantiate continued operation.**

**Why not see if EASL can help you? Give us a call.**


**engineering analysis services ltd.**

2 Edward Court, George Richards Way, Altrincham, WA14 5GL

0161 923 0070 www.easl-stress.co.uk