STRUCTURAL INTEGRITY VERIFICATION OF A PRIMARY CIRCUIT PUMP FLYWHEEL FOR THE OPAL RESEARCH REACTOR

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Introduction

The flywheels on nuclear reactor coolant pump motors provide inertia to ensure a slow decrease in coolant flow in the event of loss of power; thus preventing fuel damage due to the reduced coolant flow. During operation at normal speed, a flywheel has sufficient kinetic energy to produce high-energy missiles and excessive vibration of the coolant pump assembly if the flywheel should fail.

The structural integrity of a large steel flywheel to be used in the primary cooling circuit of the OPAL research reactor at Lucas Heights was evaluated according to the requirements of the US Nuclear Regulatory Commission guide RG 1.14. This guide was developed for nuclear power plants where significant over-speeds in pumps are possible. In the OPAL reactor at ANSTO such pump over-speeds are not possible, however, the code was used to demonstrate the incredibility of failure of the flywheel and consequently a guillotine failure of the primary cooling system pipework.

Evaluation Route

- Flywheel material: 100mm thick section AS 3678 Grade 350 plate.
- Mechanical property determinations:
    - Tensile behaviour
    - Ductile-Brittle Charpy transition temperature
    - Fracture toughness via SINTAP, minimum value, master-curve approach.
- Integrity Assessment:

  Revision 4 of the well-validated British Energy R6 defect assessment procedure was used to analyse the critical speed for the flywheel using the two-component failure assessment diagram considering brittle fracture and plastic collapse.

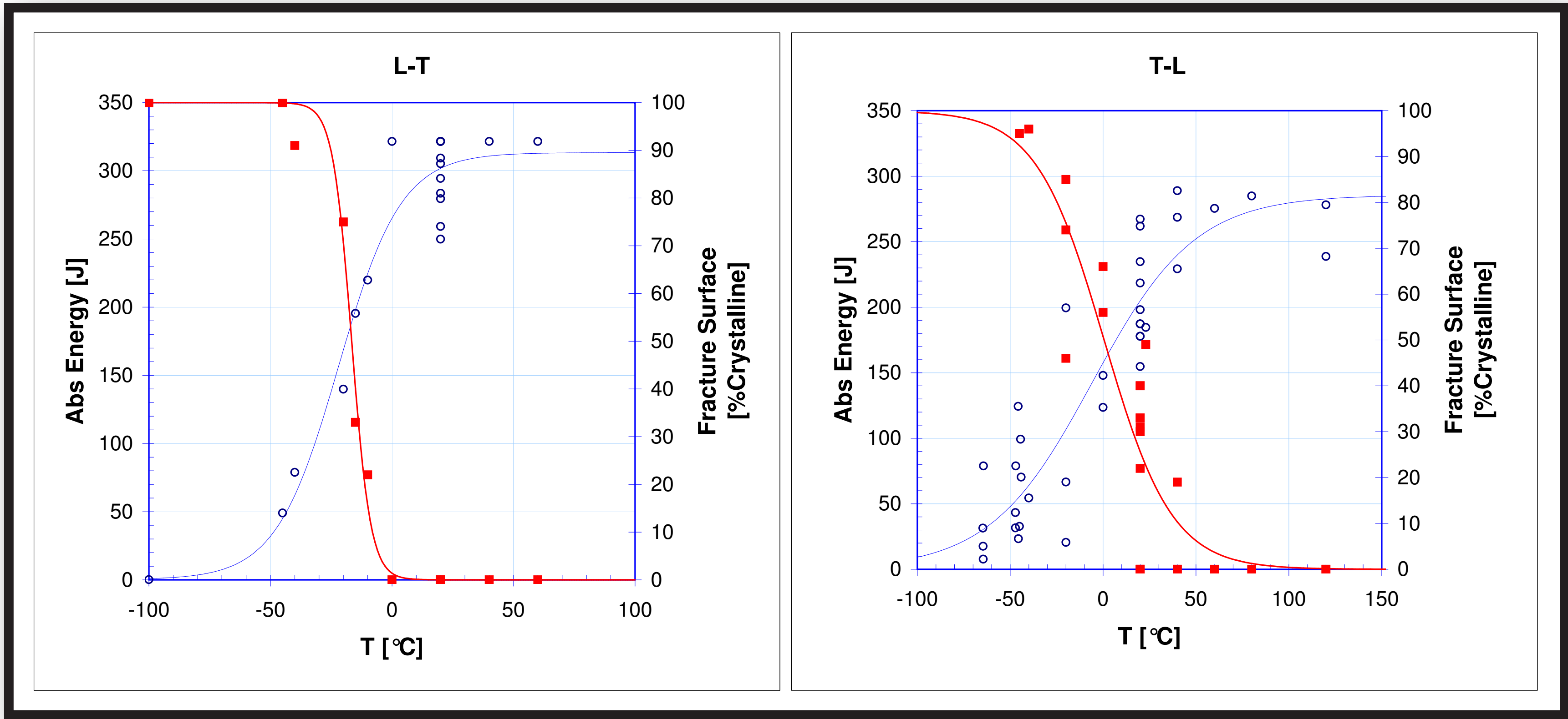

Figure 1.

Charpy impact energy toughness for the plate orientations L-T and T-L. Note the brittle transition behaviour in the T-L direction at 20 °C.

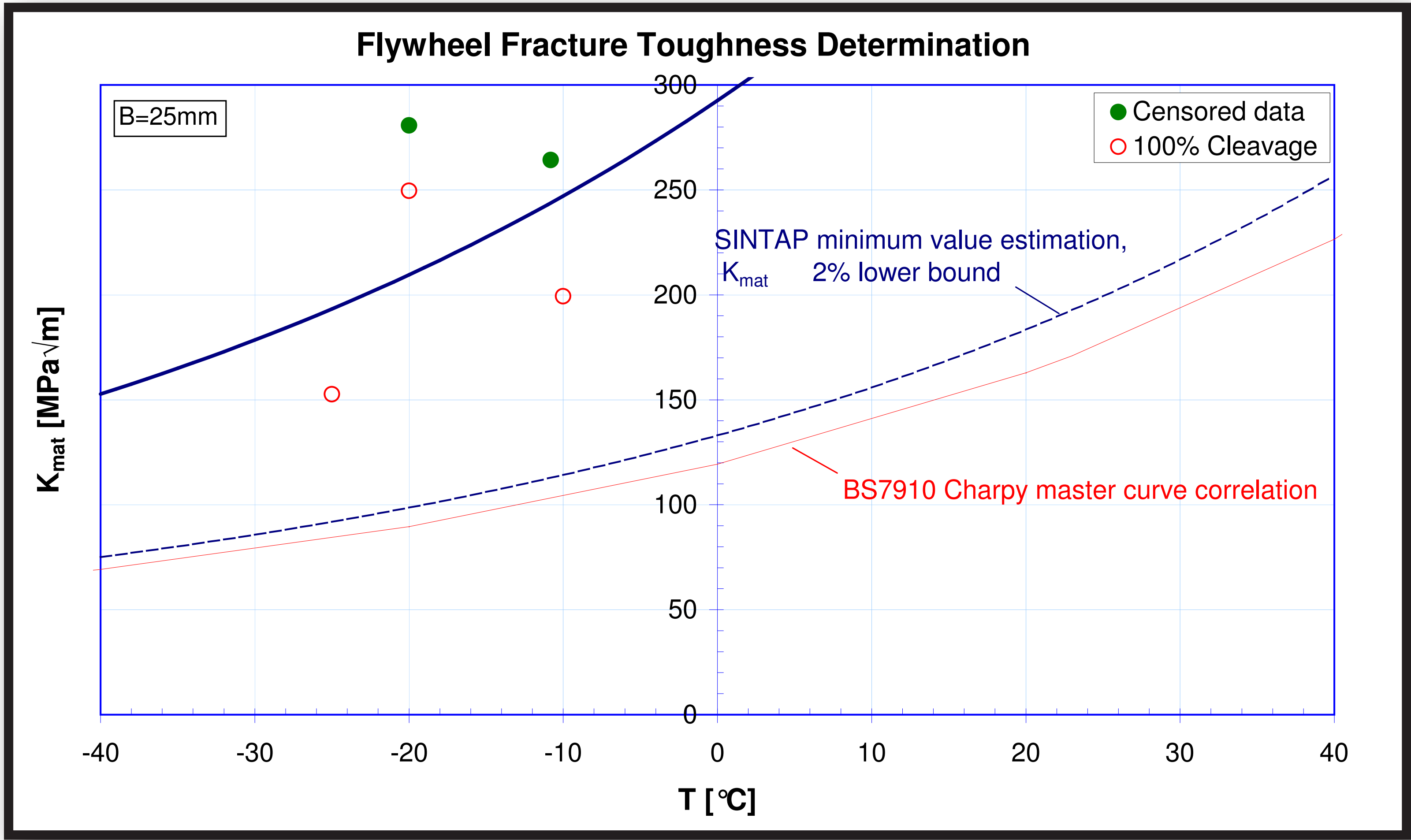

Figure 2.

Lower-bound flywheel toughness (thickness dependant), derived from J-integral and Charpy measurments.

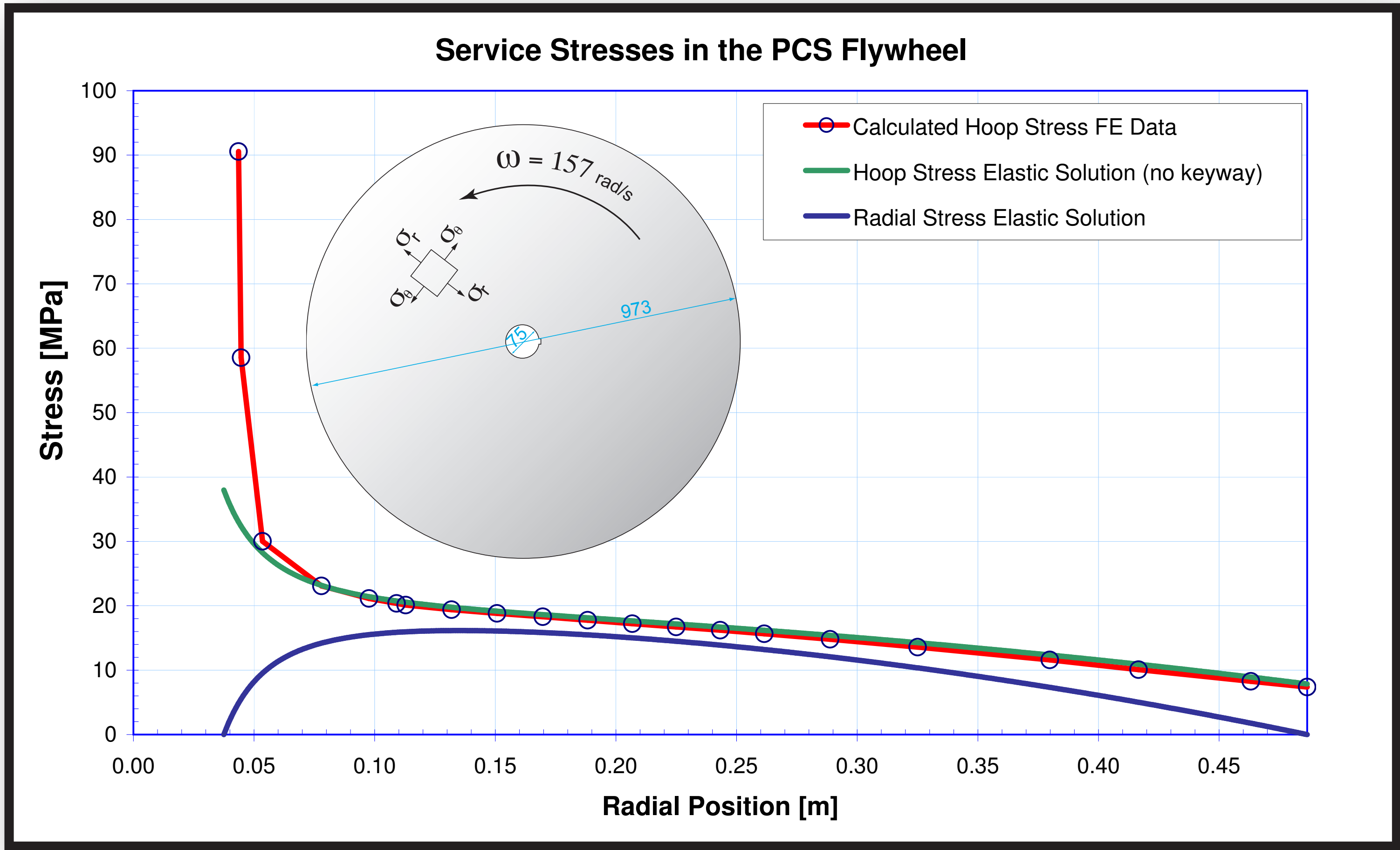

Figure 3.

Modelled flywheel hoop and radial centrifugal stresses at 1500 rpm. The effective stress concentration of the keyway can be observed from the FE results for the dominant stress in the hoop direction.

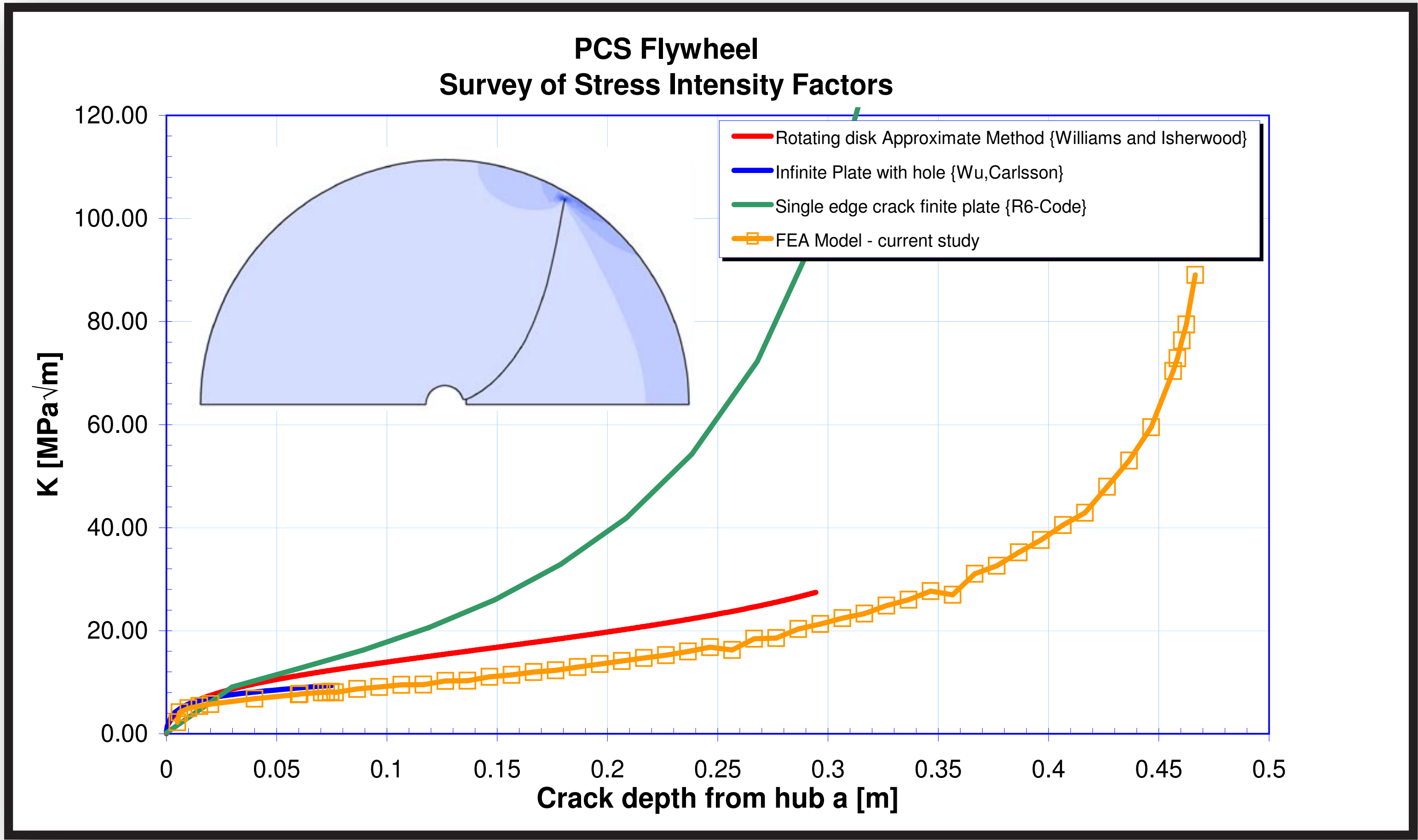

Figure 4.

A survey of stress intensity factors and the SIF calculated from a FE model of the flywheel. The crack propagation path was modelled using the FRANC 2D code emanating from the keyway at the bore as shown.

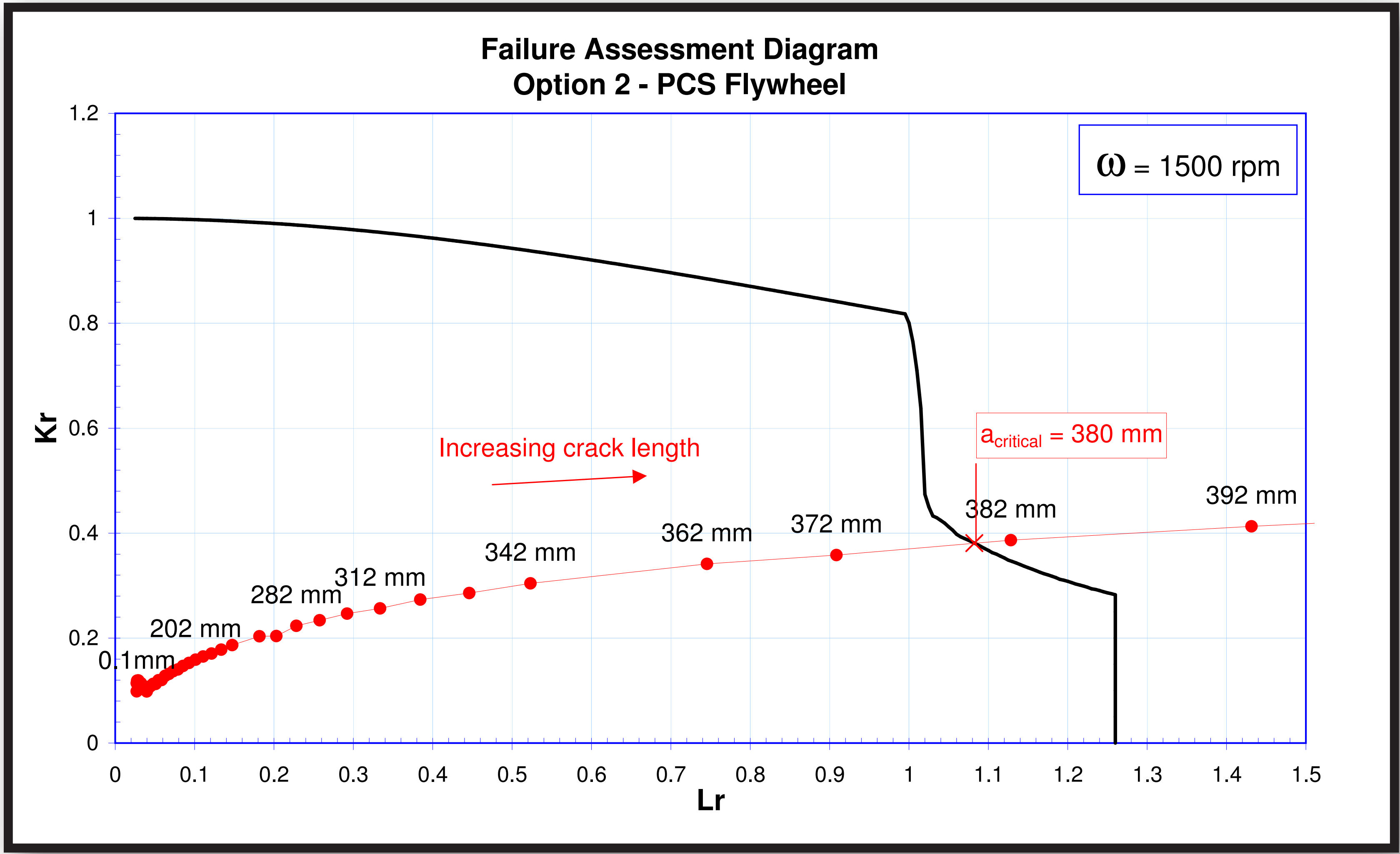

Figure 5.

R6 failure assessment diagram showing the critical crack length required for failure at the design speed. Note the large reserve factor even at a defect length of 202 mm.

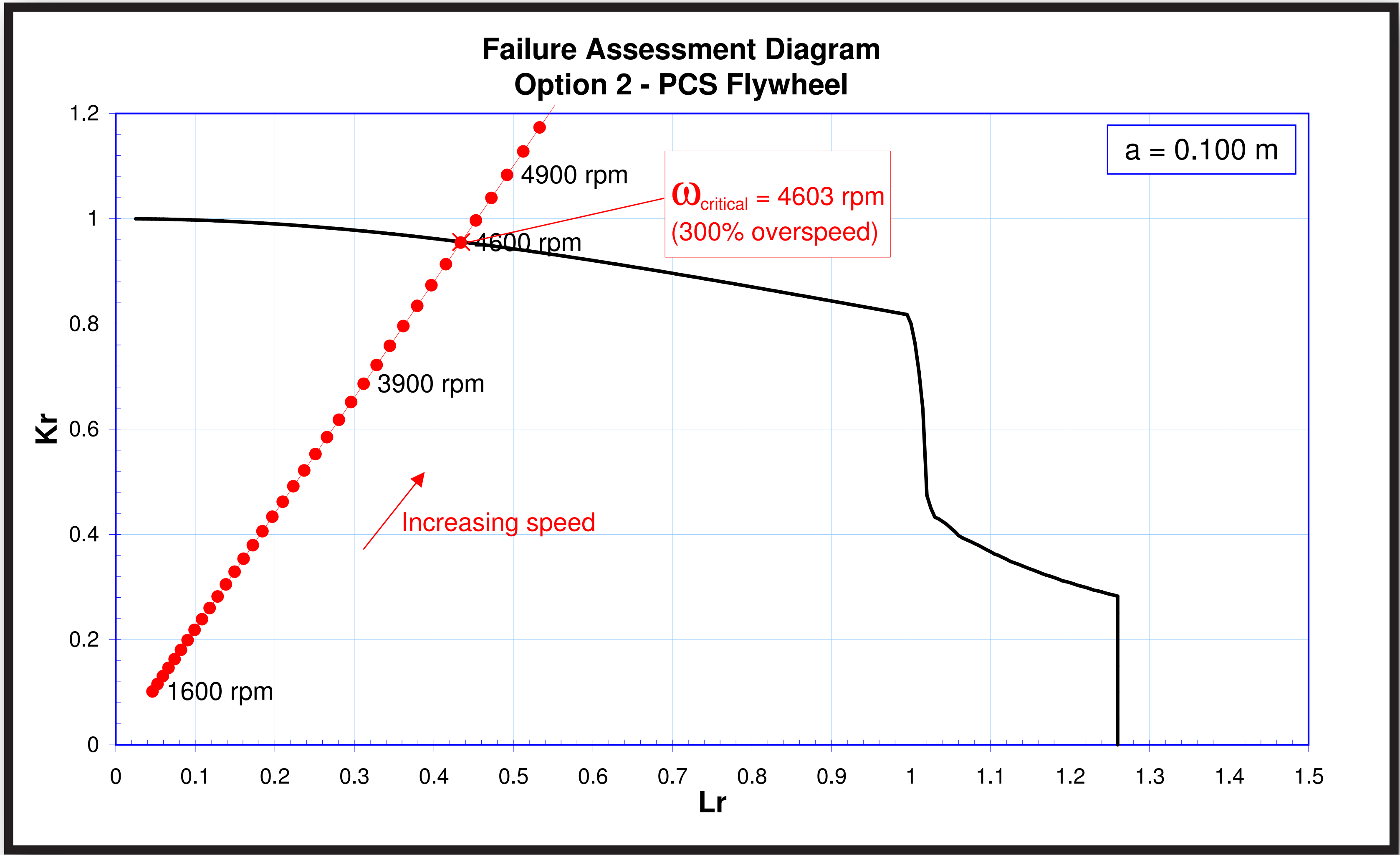

Figure 6.

R6 failure assessment diagram showing the limiting speed for a 100mm defect emanating from the bore. A speed of 300% of the design speed is required before failure.

Conclusions

- Failure has been demonstrated to be incredible by brittle failure or plastic collapse for the worst case defect emanating from the keyway.
- The over-speed necessary for failure is in excess of 300% of the design speed.
- There is a large operational safety margin, shown by the calculated critical crack length of 380 mm.
- The results of the assessment illustrate the evaluation route by which the safety of critical components can be demonstrated for research reactors.

Acknowledgments

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