SOMETHING NEW IN THE PIPELINE

A REDESIGNED BULKHEAD SEALING RING FOR SUBMARINE STEAM SYSTEMS

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ABSTRACT

Stress corrosion in submarine steam pipe bulkhead sealing rings should be avoided with a new design, using finite element techniques, described here.

Introduction

From the beginning of the nuclear submarine programme, the bulkhead sealing rings in the main steam ranges have been a problem. The offending item is by no means a complex piece of engineering; it is simply the fitting used to allow the main steam pipework to pass through a watertight bulkhead. The problems come when, for whatever reason, it requires to be replaced. For reasons which will become clear, this task—very expensive in both repair manhours and operational time—has to be undertaken far too often.

The Existing Sealing Ring

The current design of sealing ring (FIG. 1) is a simple low carbon steel forging (ADSPEC 1100) which is welded to the bulkhead via a thermal sleeve

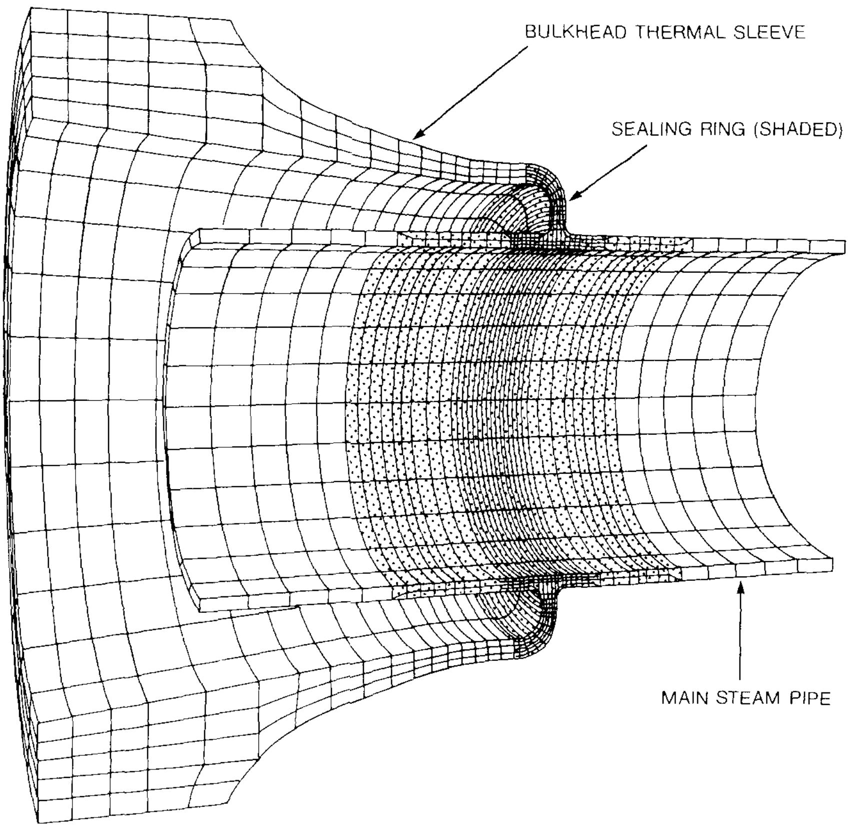

FIG. 1—THE PRESENT BULKHEAD SEALING RING, SHOWN (SHADED) IN A FINITE ELEMENT MODEL

and to the main steam system on either side. It provides for nothing other than a pressure-tight seal to be maintained across the bulkhead on the outside whilst not impeding the steam flow on the inside.

The sealing ring is installed horizontally and, with the two pipe welds either side of the ring offering their services as small 'weirs', it can be guaranteed that during shut-down periods when the system is nominally drained a small puddle of condensate will rest in between these welds, thereby promoting corrosion. Despite many attempts to re-design the system and improve the drainage facilities, some corrosion is almost inescapable. Many design considerations have been explored, resulting in a change in material and chemical treatment of the condensate; none of these, however, has proved entirely satisfactory.

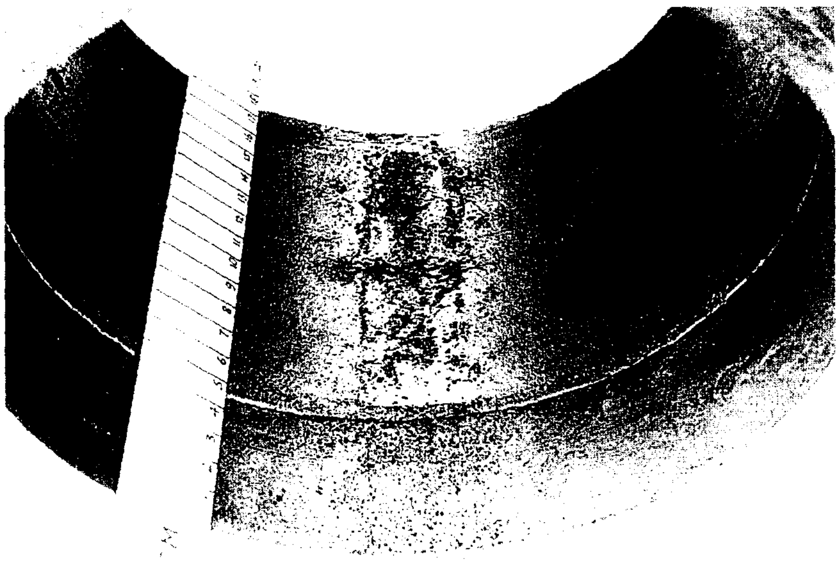

FIG. 2—INTERNAL VIEW OF THE PRESENT SEALING RING, SHOWING STRESS-ENHANCED CORROSION AT THE BOTTOM

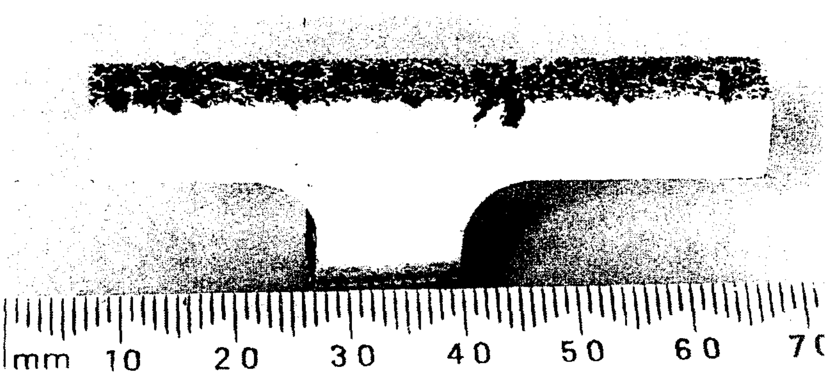

FIG. 3—CROSS-SECTION OF THE PRESENT SEALING RING, SHOWING THE DEPTH OF CORROSION

What has led to the need for an altogether new design approach is that the corrosion rate (FIGS. 2 and 3) is some five times that predicted and experienced elsewhere in the system. Furthermore, this area of maximum corrosion is most difficult to examine. Radiography is the accepted technique, although with this tending to be qualitative rather than quantitative sealing rings are removed from service often before this becomes strictly necessary.

The Finite Element Approach

The much accelerated corrosion rate suggested that other forces were at work, the most obvious being some form of stress. Measuring stress on the inside of the pipe under operating conditions would be difficult and so a Finite Element approach was adopted to estimate the stress field.

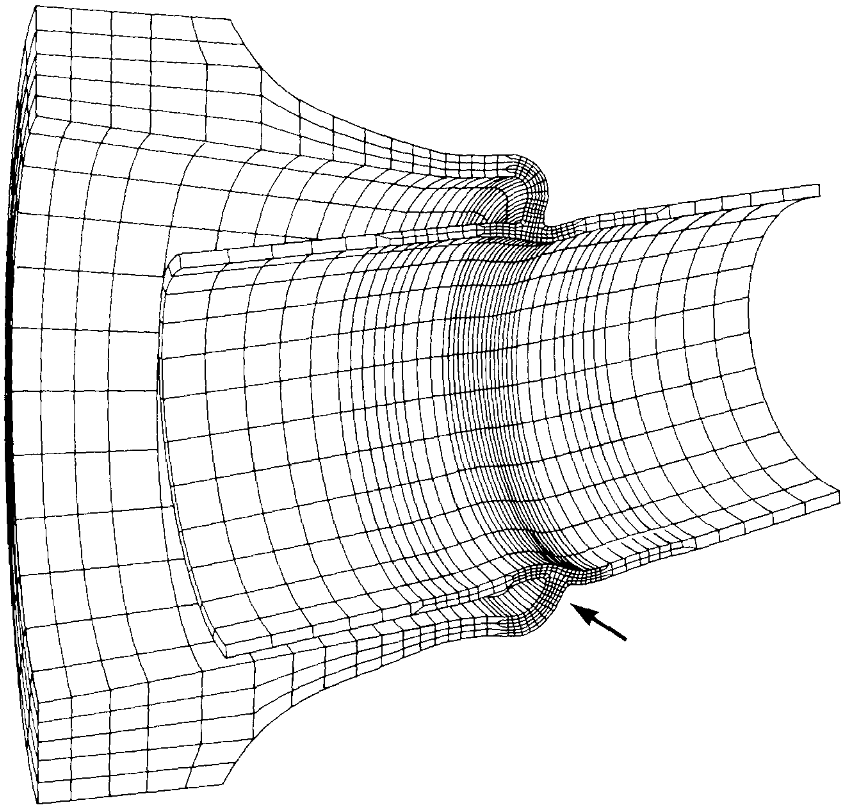

FIG. 4—DEFORMATION OF PRESENT DESIGN UNDER STRESS. THE MAXIMUM DEFORMATION IS COINCIDENT WITH THE MOST SEVERE CORROSION

The network developed (FIG. 4) was subjected to six independent stress regimes:

thermal loads	bending moments
axial loads	torsional loads
internal pressure	transverse shear loads,

and each was analysed separately.

These were then combined to present the overall stress picture of the existing design. Comparisons between the model under stress and the actual sites of excessive corrosion were extremely good, with the maximum stress field lying precisely at the site where maximum corrosion had occured. Using these results a second model could now be built up with an improved geometry and this was then subjected to the same stress fields. This improved geometry indicated not only that overall stress levels could be substantially reduced but, more importantly, that the high stress concentration on the inside (wetted) surface of the existing design could be eliminated. On the

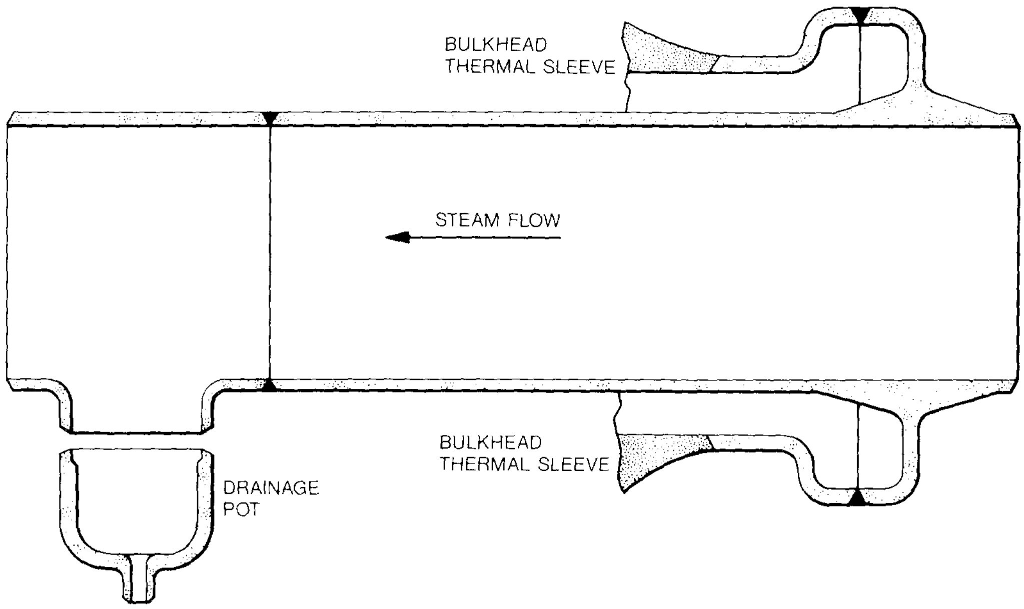

FIG. 5—IMPROVED DESIGN SEALING RING WITH ACCESSIBLE WELDS, IMPROVED FLEXIBILITY UNDER LOAD AND AN INTEGRAL DRAINAGE ARRANGEMENT

improved design (FIG. 5) the areas of highest stress fall on the outside of the sealing ring in an area most amenable to inspection. Pictures of the model deforming under the stress fields (FIGS. 4, 6 and 7) also illustrate well the area of high stress in the existing design and how this has been changed in the improved one.

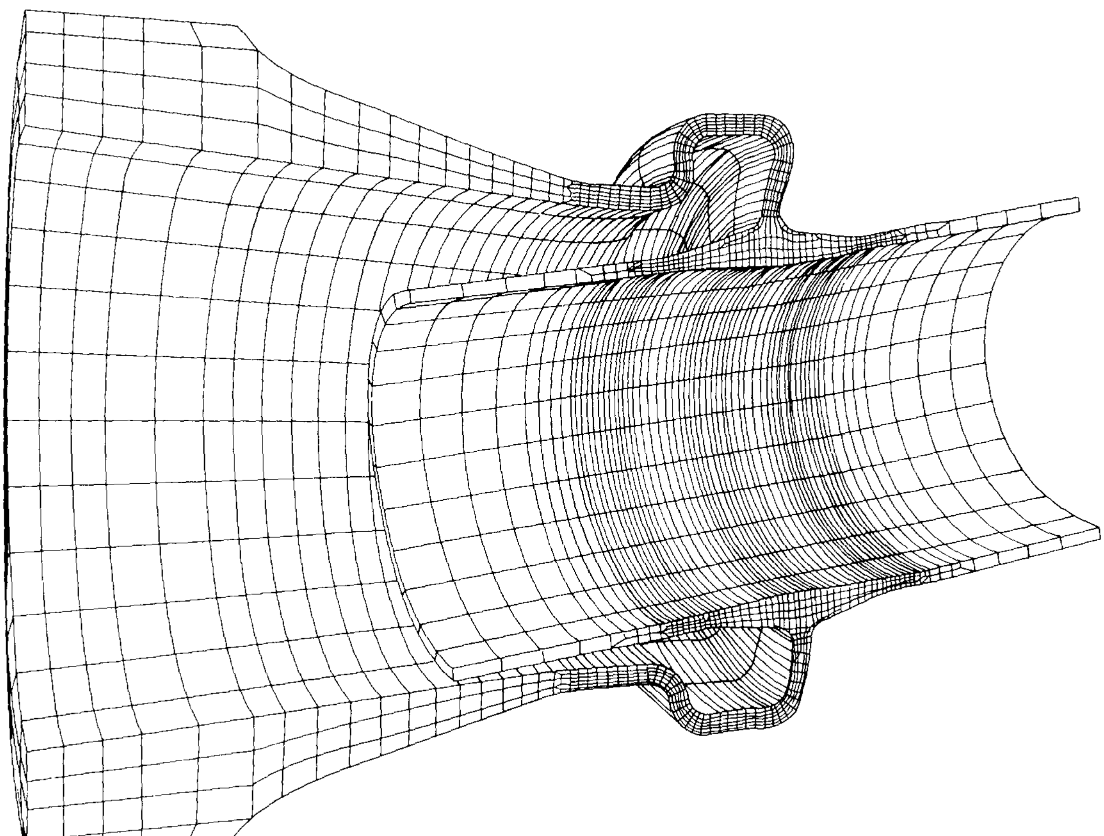

FIG. 6—DEFORMATION OF THE IMPROVED DESIGN SEALING RING UNDER STRESS

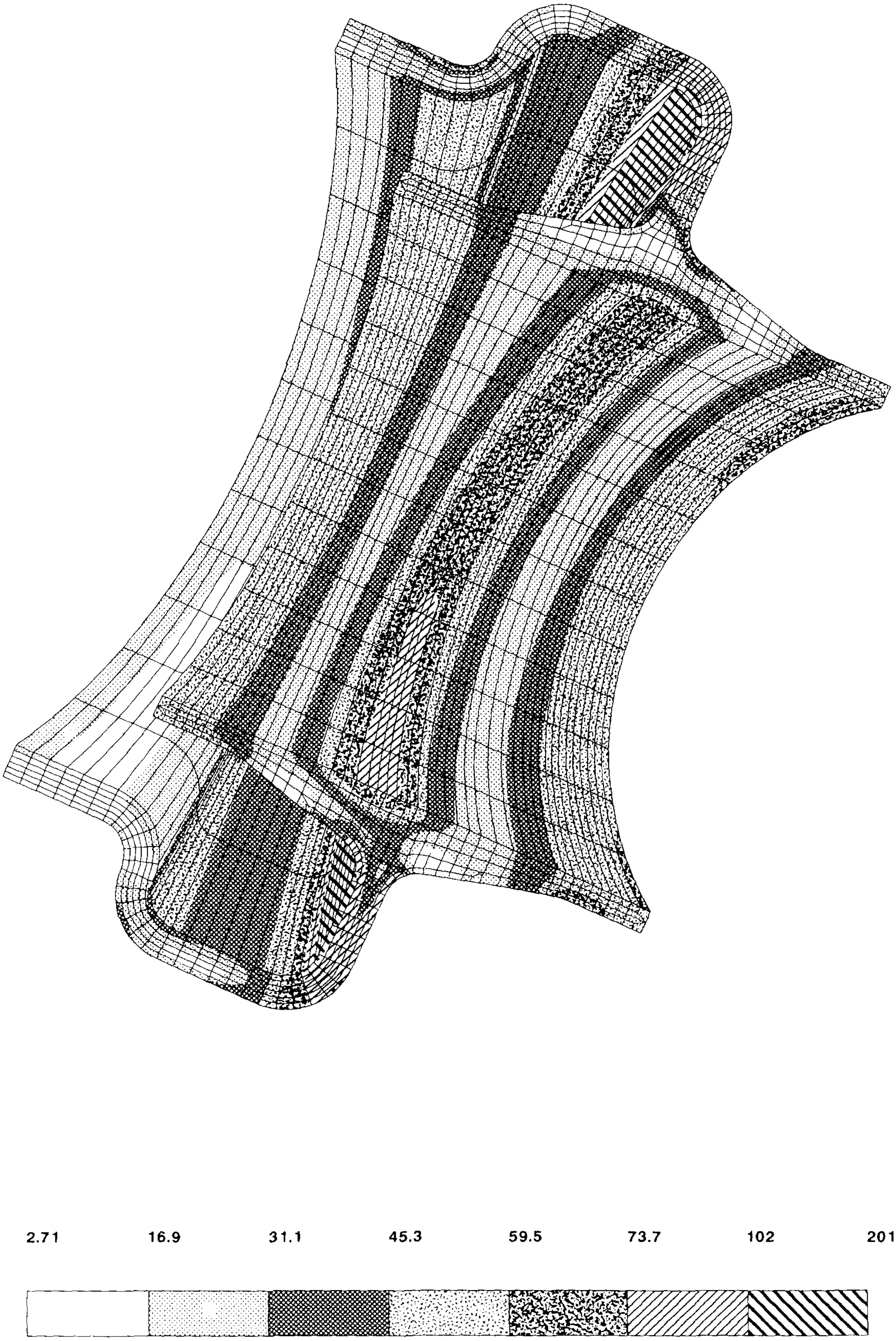

FIG. 7—STRESS DISTRIBUTION IN THE IMPROVED DESIGN UNDER LOAD. THE HIGH STRESS AREA IS NO LONGER ON THE WETTED SURFACE

The Improved Design

The new sealing ring, designed for minimum stress on the wetted surface, will be brought into service and will also incorporate significant secondary improvements. It will be installed at a slope, be longer in order to bring the necessary welds out into accessible sites for inspection, and the design will incorporate a large drainage pot with the condensate unimpeded by weld protuberances. Most significantly, it will facilitate simple non-destructive examination of the more highly stressed areas.

The new design will be introduced at refit. Its performance will be verified by stress measurement using strain gauges on the outside profile, and once again the finite element model will be used to calculate the stress levels on the wetted surface.