SUMMARY REPORT

Cost Effective Structural Monitoring

Prepared for:

UK Health and Safety Executive

MEC/99/101/R2

REPORT

Cost Effective Structural Monitoring

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1. SUMMARY

Investigation has begun into a new method of non-destructive testing (NDT) for jacket structures that could have significant advantages over existing methods The new method detects and locates significant changes in the structural properties of a jacket (for example, a crack in a joint), via the changes they cause in elastic wave transmission through the structure. It yields much more information on the presence or otherwise of damage to members than the "modal analysis" method based on forcing by water waves, is more cost-effective than ultrasonic NDT and gives a greater range of operation (fewer sensors) than ultrasound.

Tests on a scale structure have shown the method to have great promise both in detecting the presence of cracks and in locating their position. A crack progressively introduced at a 'K' node (joint) gave corresponding progressive increase in the indication of the damage.

The method can be made insensitive to changes in load supported by the structure.

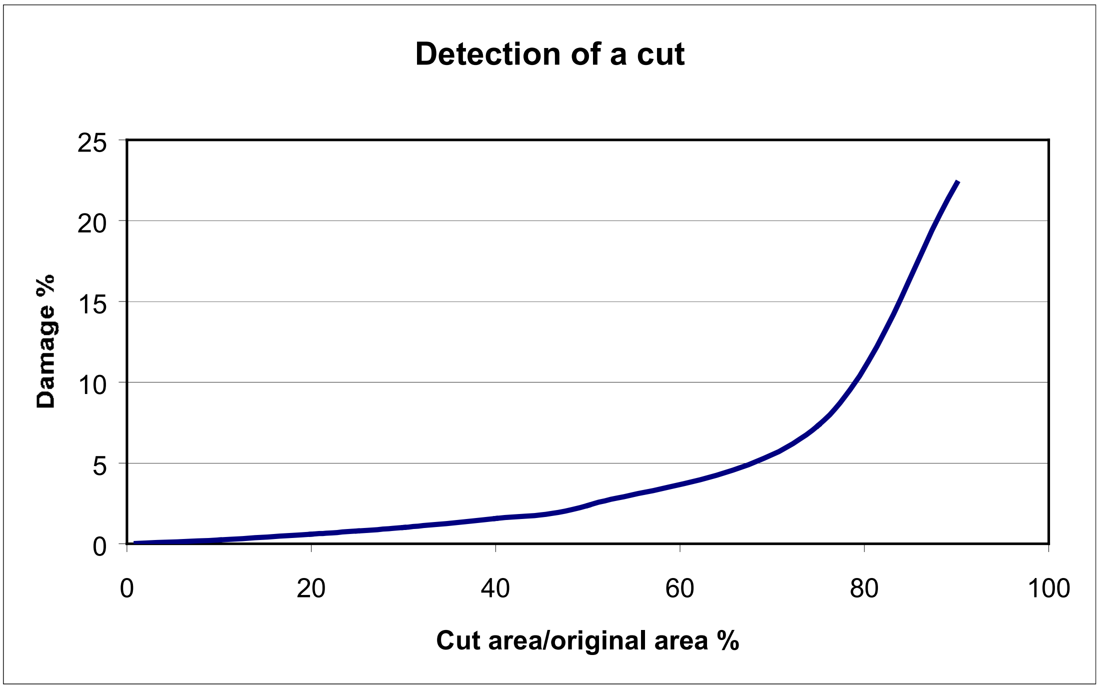
2. EXPERIMENTAL METHOD

The object of the proposed new method is to detect and locate significant changes in the structural properties of a jacket (for example, a crack in a joint), via the changes they would cause in the vibration response of the structure.

Demonstration work was carried out in air on a small-scale, 2D cross-braced frame made of a well damped material. The frame has two main legs with three cross members. One end of one of the cross members was progressively cut to simulate a crack. The frame was instrumented at every node. The response at every node to excitation at one extreme of the frame was analysed in detail, together with its impact on the identification of cracks on a large structure.

Numerical simulation of a single rod with a central collar was used to demonstrate that a crack at the collar could be recognised long before the crack was all the way through the rod. Visual comparison of impact responses before and after cutting part way through the area does not give the best impression of changes that are occurring. If the original uncut rod gives a signal S_1 over a selected time window and the cut rod gives a signal S_2 then the difference $D = S_1 - S_2$. The ratio between the signal D expressed as root mean square (RMS) and original signal S_1 (RMS) gives a measure of the influence of the cut. The influence of the cut is displayed below. These results are promising for detection of cracks that are open.

Figure 1



Sufficient complexity was needed in the model to make it representative but not so much as to increase the cost or extend the testing time. The design illustrated below was used, making the joints carefully so as to include the sort of area changes that occur in offshore K joints.

Figure 2
Node D

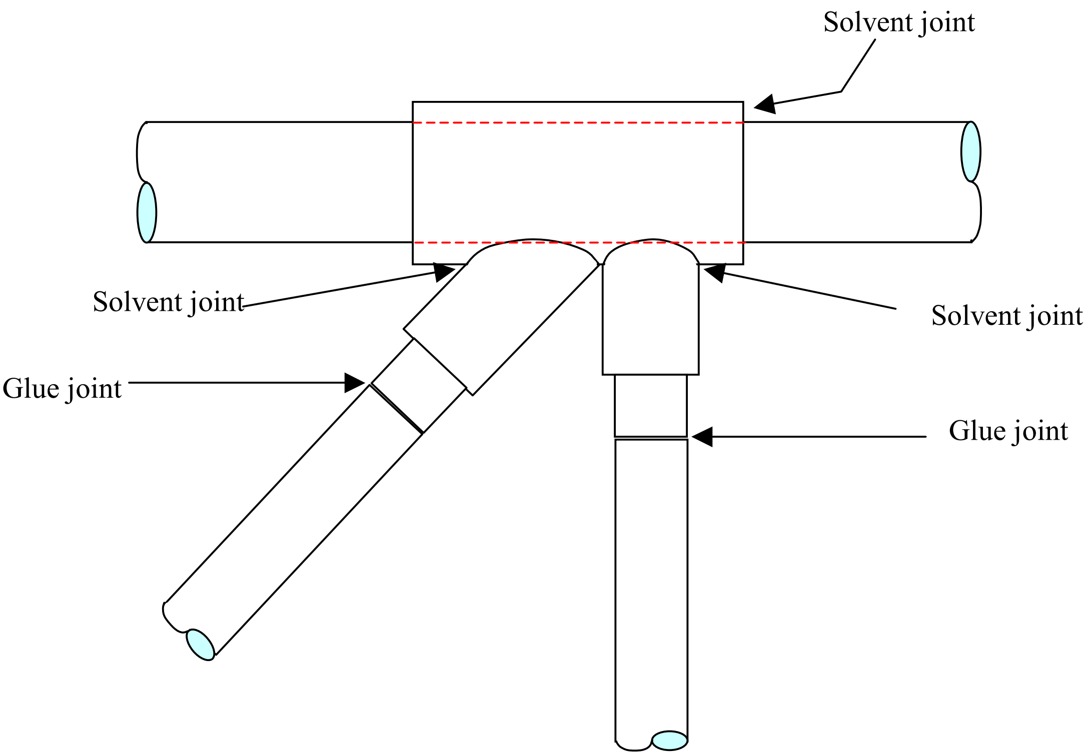
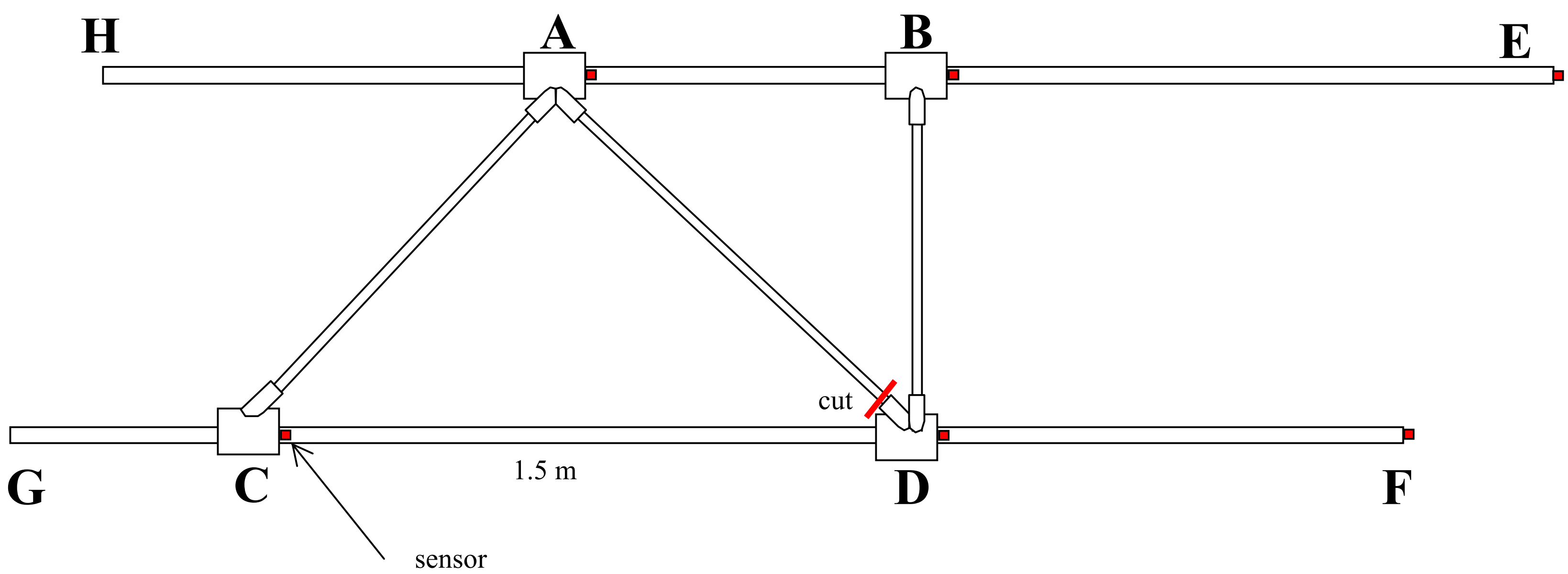


Figure 3
Layout of structure



2.1. SUMMARY RESULTS

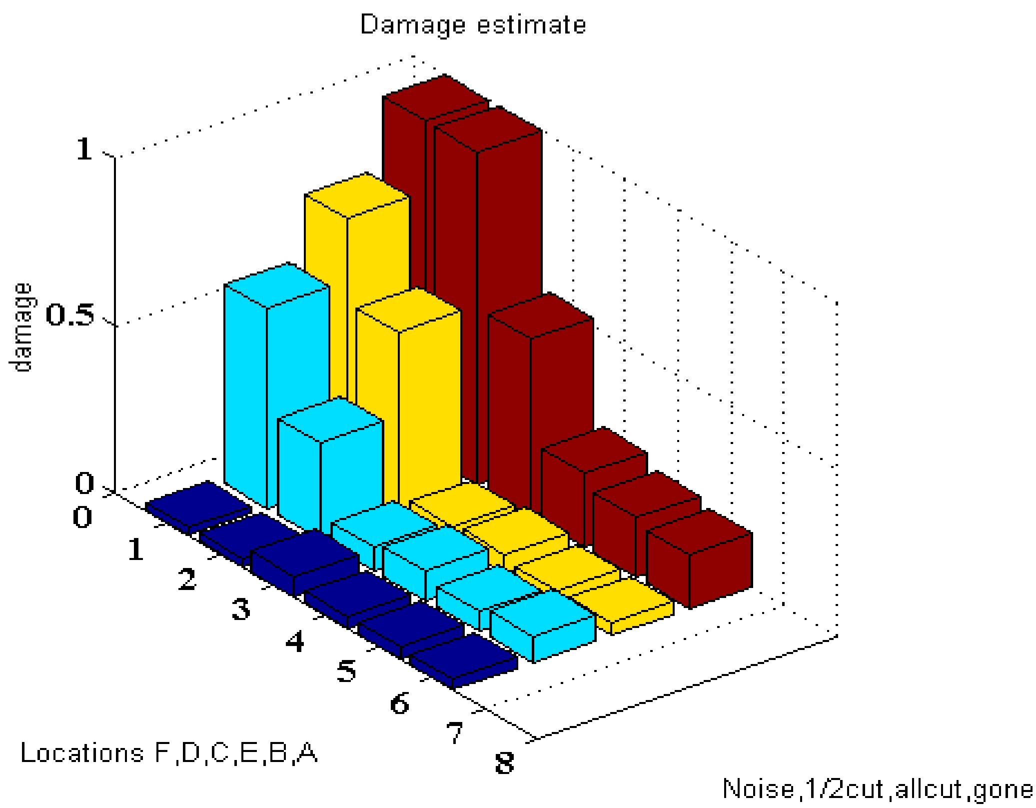
The intact structure was tested first before progressively introducing a cut at node D on member AD as shown in figure 3. The damage involved a 50% cut, cut through but still under compression, and member AD removed. The row described as 'noise' in figure 4 is the random variation between two sets of readings on the nominally unchanged structure. This is displayed to show the changes due to damage are well in excess of random noise.

It is necessary to demonstrate that some measure of the signals changes progressively with damage. Let the original time windowed undamaged signal be S_0, the time windowed damaged signal S_n where the n represents the degree of damage so that S_{50} would be the signal after a 50% cut. Take the root mean square (RMS) of $(S_0 - S_n)$ to obtain the change in the signal and then divide by $RMS(S_0)$ to normalize the result. This is a measure M of the damage detected.

Below we display the histogram of the measure M at the various locations with increasing damage. The increase with damage at locations D and F is clear, together with the jump in the measure at all locations when AD is completely removed.

The measure M is clearly sensitive to the location and extent of the damage.

Figure 4



3. CONCLUSIONS

- A new method of detecting damage to members of a multi-member jointed structure has been proposed and found to have good potential for detecting damage long before it progresses to a complete break.
- The method requires only a small numbers of response sensors and excitation points. On a full-scale rig it may be possible to use roughly one sensor per ten members with excitation at the top of each vertical leg. It is not yet known how tall a structure could be before additional underwater excitation was necessary.
- The method can be made insensitive to changes in load supported by the structure.