TEST FACILITIES FOR FATIGUE AND CRACK GROWTH TESTS UNDER LIGHT WATER REACTOR CONDITIONS

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ABSTRACT

For fatigue and crack growth tests under light water reactor conditions a special test facility has been developed. Main characteristics are an electromechanical loading equipment, vertical sectioned autoclaves with natural circulation and transducers, fitted with welded strain gauges, for load and displacement measurement inside the autoclave. Oxygen contents of 0 and 8 ppm are realized by pressurisation with nitrogen and oxygen or air. For oxygen contents between 0 and 8 ppm a water circulation loop with refreshing equipment is available. The test facility is restricted to a maximum load of 100 kN and a maximum frequency of 1 Hz. Due to these restrictions the benefits are lower costs for procurement, operation and maintenance, as well as by greater ease of operation and lower susceptibility to malfunction, compared with universal test facilities.

KEYWORDS

Autoclave; fatigue test; crack growth test; light water reactor; water refreshing equipment.

INTRODUCTION

During their service life of 40 years the components of light water reactors are subjected to various mechanical and thermal loads. Reliable statements on reactor life considerations can only be made by reference to material parameters which have been determined under representative boundary conditions. Test facilities for carrying out fatigue and crack growth tests under simulated light water reactor conditions are described in the following.

ENVIRONMENTAL EFFECTS

Water may significantly affect the fatigue and crack growth behaviour of metallic materials. This is illustrated schematically in Fig. 1 where, in addition to the chemistry of the water, the type of loading and the temperature are also major factors. However, no universally valid quantitative statements can be made on this correlation. Such quantitative information can thus only be gained from specific investigations.

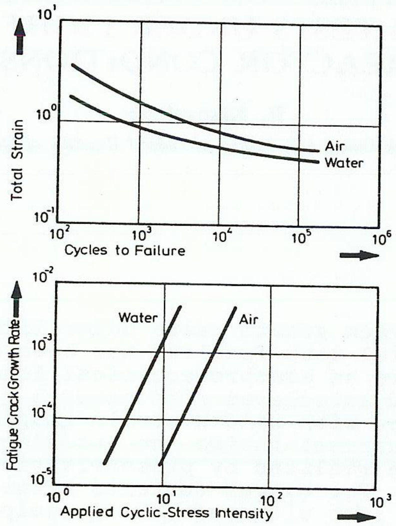

Fig. 1. Influence of water on fatigue - and crack growth behaviour (schematic).

SCHEMATIC SET UP OF EXPERIMENTAL EQUIPMENT

The main components of the experimental facility are as follows:

Loading equipment
Autoclave
Water refreshing equipment
Control system
Data acquisition equipment
Data recording and processing equipment

Each of these assemblies can be designed to meet various principles of construction and operation, as indicated in Table 1, thereby yielding a large variety of types and optimum matching to specific boundary conditions. Our own experience, however, has shown that the universally ideal system cannot in effect be realized.

TABLE 1 Design Variations of Test Facilities

Component	Construction and design principles
Loading equipment	Servohydraulic Electromechanical, one-spindle Electromechanical, two-spindle
Autoclave	Sectioned vertically Sectioned horizontally One port Two ports
Water refreshing equipment	Static with N_2-pressurizer Static with O_2-pressurizer Dynamic with refreshing equipment
Control system	Function generator Computer
Data acquisition (load and displacement only)	Differential transducer Strain gauges
Recording and processing of data	Recorder Computer

Time-proven test facilities for crack growth measurements with servohydraulic loading equipment have already been dealt with in the pertinent literature (Sturm, Loss, and Cullen, 1980; Gerscha, Klausnitzer, and Wieling, 1981). The present report deals with test facilities specially designed for fatigue and crack growth tests under light water reactor conditions. No attempt has been made to cover universal applications.

ELECTROMECHANICAL LOADING EQUIPMENT

By comparison with servohydraulic loading equipment, electromechanical systems are cheaper both to procure and operate (no cooling water needed, lower energy requirement, less maintenance), are less sensitive to electrical interference, are quieter and require less space (no hydraulic unit). One disadvantage which should be mentioned, however, is the restriction of the maximum possible test frequency to approx. 1 Hz, although this would only affect high-cycle testing. Furthermore, tests must in any case be performed at frequencies <1 Hz, otherwise the influence of the medium will not be detected.
As a basic rule, only electromechanical loading equipment with clamp-mounted ballscrews should be used, this ensuring playfree passage through zero load. It should be noted that twospindle systems provide improved guiding. This can be of particular

importance in tension and compression tests involving high plastic deformation. Single-spindle systems are sufficient for crack growth measurement on the CT specimens normally used.

AUTOCLAVES

Our own experience has shown vertically sectioned autoclaves with only one port to be the most suitable. Their major advantage is that the lid of the autoclave is used only for sealing purposes and has no mechanical guide function. Closing the autoclave is therefore made considerably simpler and quicker. Heating is provided by external heating jackets. The autoclaves are fitted with feet which rest directly on and are bolted to the base plate of the loading system. All ports and lines are fitted in the body of the autoclave, also in order to facilitate opening and closing.
Fig. 2 shows two autoclaves of different size, one being for crack growth tests and the other for fatigue tests up to 320°C and 220 bar.

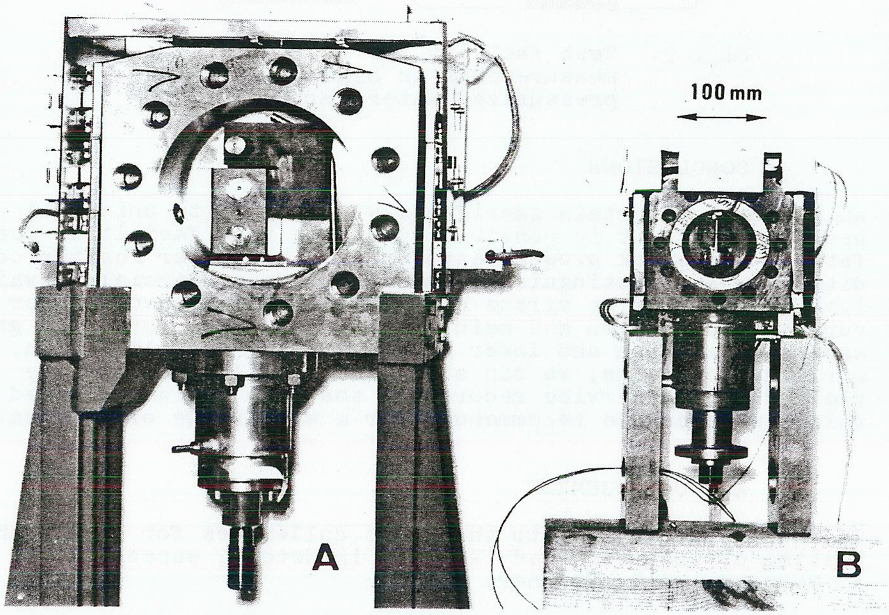

Fig. 2. Vertical sectioned autoclaves.
A: For crack growth tests
B: For fatigue tests

WATER REFRESHING EQUIPMENT

It is not always necessary to operate the autoclaves in conjunction with a refreshing system. Pressurized water reactor conditions with 0 ppm oxygen can also be simulated in static autoclaves. The opposite extreme is that of oxygensaturated water with 8 ppm oxygen. Both cases are readily implemented, as shown in Fig. 3. Natural circulation is sustained by the circu-

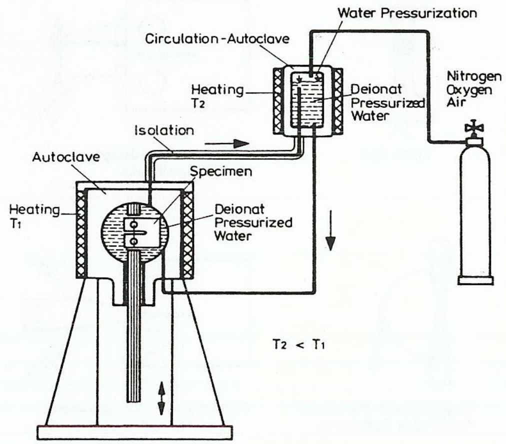

Fig. 3. Static autoclave with natural circulation.

lation autoclave, operating at a lower temperature. This configuration also makes it possible to increase the ratio of the water flow to the surface area of the specimen without any need to employ larger autoclaves. The required pressure is maintained by means of a nitrogen cushion (0 ppm O_2) or a cushion of oxygen or air (8 ppm O_2). The work involved in monitoring the water chemistry is limited to control measurements performed at relatively long intervals.

CONTROL, MEASURING AND RECORDING EQUIPMENT

The complexity and cost of control, measuring and recording equipment are considerable, since long-time tests need computer-assisted systems. The hardware and software required are more or less all commercially available and, consequently, need not be discussed here in any greater detail.
However, as already reported (Gerscha, Klausnitzer, and Wieling, 1981), various load and displacement transducers for use in the medium have been developed and tested in our own laboratories. These are all transducers fitted with welded strain gauges. As shown in Fig. 4, simple, cylindrical rods are used for load measurement and bending springs of different forms for dis-

placement measurement. The results are accurate to ± 1 %. This degree of accuracy is sufficient if viewed in the context of scatter and other possible sources of error. The advantages are its relatively low cost and the possibility of performing repairs in one's own laboratory. Corrections performed for pressure differential and friction losses become superfluous for load measurement in the autoclave.

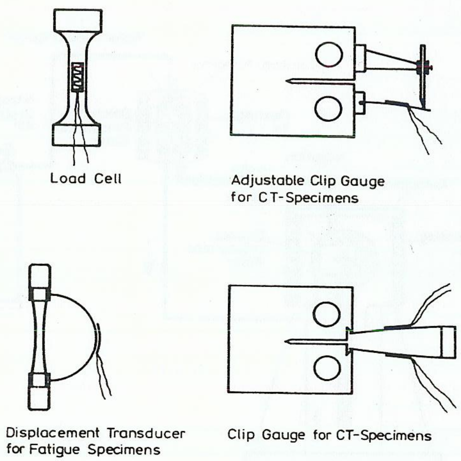

Fig. 4. Load and displacement transducers, instrumented with weldable strain gauges, for use up to 350 °C - water.

DESIGN EXAMPLE

Bearing in mind the above-mentioned considerations, KWU Erlangen created a test facility for performing crack growth measurements on CT 50 specimens. It comprises two test set-ups, operated independently of each other, with all variations of water refreshing equipment. Although the specimen size is restricted to CT 50 and the frequency to < 1 Hz, there are cost savings of more than 50 % when compared to universal servo-hydraulic equipment.

The complete test facility is displayed graphically in Fig. 5.

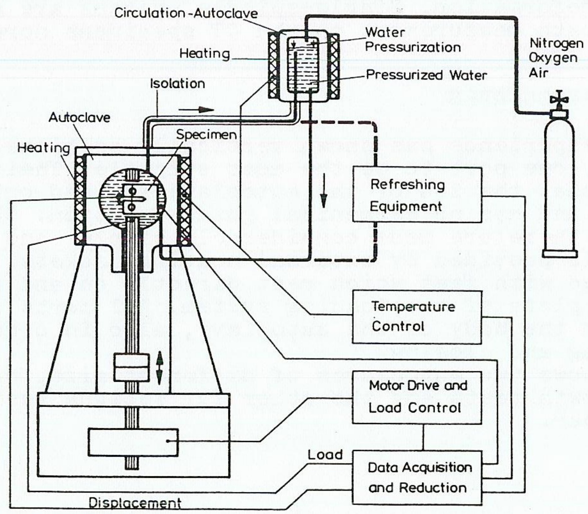

Fig. 5. Test facility for crack growth measurements in high-temperature, pressurized water (schematic).

CONCLUSIONS

Whilst making certain sacrifices with regard to universal applicability, it is possible to create test facilities for fatigue and crack growth tests under light water reactor conditions which distinguish themselves from commercially available facilities by virtue of the lower costs involved for procurement, operation and maintenance, as well as by their greater ease of operation and lower susceptibility to malfunction. From our own experience, we can state that the facilities have yielded a good service record and that the design selected for this report can be recommended for a wide range of applications.

ACKNOWLEDGEMENT

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