

TRUEFLAW FLAW PRODUCTION TECNOLOGY

1 INTRODUCTION

Trueflaw produces natural in-situ grown cracks to ready-made samples. Flaw production technology is based on controlled thermal fatigue damage mechanism. Representativeness of produced flaws to real, service-induced flaws is based on the measured flaw characteristics. Produced flaws are realistic simulations of thermal fatigue and mechanical fatigue cracks, and good simulations of most stress corrosion cracks, based on the comparison of the flaw characteristics of the produced and service-induced flaws.

2 TRUEFLAW TECHNOLOGY

Trueflaw produces defects using controlled natural thermal fatigue damage process. The defects are grown in much the same way as could occur during service conditions. However, the growth is accelerated to make production times practical and controlled to enable predetermined flaw parameters. Flaw production is done in-situ to ready-made sample. Cyclic thermal fatigue loading is induced locally by alternating heating and water spray cooling, as described by Kemppainen [1]. Loading is based on pure thermal loading and there is no welding, machining, or mechanical treatment applied. No artificial initiators of any kind are used and the material microstructure is not disturbed in the process. More detailed information on the properties and use of produced cracks has been presented earlier [2–5].

2.1 Characteristics of the growth procedure

Thermal fatigue loading technology used by Trueflaw solves many of the problems traditionally associated with artificial crack production. Manufacturing of real cracks has traditionally been restricted to simple component shape and small components. Providing the stress for crack growth mechanically becomes impractical when the sample geometry becomes more complicated. Also, accurate control of induced stress in complex shapes during crack growth is very difficult and it is not possible to limit the stress only to desired areas where defects are needed. In contrast, thermal loading can be applied to local areas in complicate sample geometries. Since only a limited area is stressed at any given time, the needed equipment is relatively light. Furthermore, the ability to locate and control the stressed area enables accurate control over crack growth location and crack parameters.

2.2 Confirming essential flaw parameters without supplementary NDE inspections

Often, the dimensions and other characteristics of the cracks must be known. Some of the parameters, like surface length, can be readily measured. However, for many important defect parameters, defect depth in particular, this is not possible from the final sample. In Trueflaw technology, these parameters are known through destructive validation. When there is no experience on the specified crack, the intended crack is first produced to a representative validation sample. This sample needs to have similar material and similar local geometry, but can be simplified and smaller compared to the actual test sample. This validation crack is destructively examined to reveal the true crack depth and other specified parameters (e.g, crack opening, surface roughness etc.). Then, using the same procedure, a similar crack can be produced to any number of actual test samples repeatably.

The Trueflaw technology has been available on the market since 2001. During that time, the technology has been developed immensely. It has been applied to numerous different materials and component geometries. It has been used to solve various problems requiring information about response of cracked components in nuclear and conventional energy production, as well as in aerospace and railroad industries. It has been tried and tested. Most of the applications to date have been on inspection training and qualification samples. There has also been several application cases for using such cracks in developing existing and new NDE techniques (see, e.g., [5]).

3 SPECIMEN

Flaws are produced to ready-made specimens without any welding or machining. Basically, no changes are caused to the specimen other than the realistic cracks.

Flaw production is based on known and controlled crack growth of the material in question. There are tens of different materials where cracks have been produced. Crack production to these materials have been validated to adjust the production process parameters for the material in question. When such validations are accepted, a recipe is written for the crack production.

However, if the material in question is not in the current Trueflaw list of known materials, a destructive validation procedure is applied. Furthermore, as the geometry of the sample may have marked effect on the crack production, a specific geometry, which has not been validated earlier, will undergo a destructive validation process. See paragraph 5 for more detailed description of the validation process.

The process is sensitive to the material properties that affect crack growth in the material. For some materials there is much wider applicability range of the same production parameters, while some materials are very sensitive to any change of the material properties. Typical materials among the first group are austenitic stainless steels, while some ferritic steels clearly belong to the latter group.

4 FLAWS

Flaws are produced in-situ to the specimen with controlled thermal fatigue loading based on validated recipes. The flaw location is affected by the local material properties and if the sample contains marked inhomogenities or stress risers, the cracks grow in to the natural weakest locations. The crack location must be reachable with the production tools used at the same surface where the surface opening flaws are produced.

Specification	Value
Tolerance for depth	±1 mm
Tolerance for length	±1 mm
Tolerance for location	±2 mm

Table 1
Tolerances for the crack production.

Tolerances given above are based on results of a number of destructively tested validation cracks used as basis of the recipe. Given tolerances for the recipes are applicable to all the materials and crack sizes produced, if not differently specified.

5 VALIDATION PROCESS

When a destructive validation process is required, an additional specimen, made of similar material and respective shape to the actual one, is used. In the process the ownership of this specimen is transferred to Trueflaw on reception for archival in Trueflaw quality records.

Validation work is, by nature, development work done for the client specific needs. Hence, the action plan is always defined together with the client before starting the work.

In the validation process the specifications are first set for the produced crack together with the client. Secondly a crack is produced to the validation sample with production parameters planned to be suitable for the specific case. Before destructive testing, client has the possibility to do inspection for the sample to gather NDE response of the cracks. Then the produced cracks are destructively tested and flaw characteristics determined. Here, it is possible to measure all essential crack characteristics if a cross-sectional sample is used (normal procedure is to bend open the crack to reveal its depth).

6 LIST OF MATERIALS

In the Table 2 a list of materials are given where Trueflaw technology has already been applied. This list does not cover all the materials, but those that are most common and to which a valid recipe exists. The list contains materials where different crack sizes have been validated, however, crack sizes are not similar to all materials, and exact sizes has to be checked from Trueflaw. Furthermore, Table 3 shows expanded list of materials where Trueflaw technology has been successfully applied, though there may not be a currently valid recipe for the materials.

Material	Depth range validated
Austenitic stainless steel base material	1.5–10 mm
Austenitic stainless steel weld HAZ	1.5–4.5 mm
Ferritic base material (different grades)	1.0–5.0 mm
Inconel 600	1.5–4.7 mm
Inconel 690 (SG-tubes)	0.2–0.6 mm
Inconel 182	1.9–3.6 mm

Table 2
Trueflaw current list of validated crack depths in most common materials.

Material
Austenitic stainless steel base materials
Austenitic stainless steel weld HAZ
Austenitic stainless steel weld materials
Austenitic stainless steel overlay coatings
Ferritic base materials
Martensitic stainless steels
Inconel 600
Inconel 690 (SG-tubes)
Inconel 182
Titanium
Udimet 720
Nimonic 80A

Table 3
Trueflaw current list of different materials where the technique has been successfully used.

7 STATISTICS BEHIND THE TOLERANCES

Figure 1 shows all the data that has been revealed by destructive testing of different validation cracks (more than 300 cracks). Furthermore, the figure shows the limit values for the ± 1 mm tolerances applied.

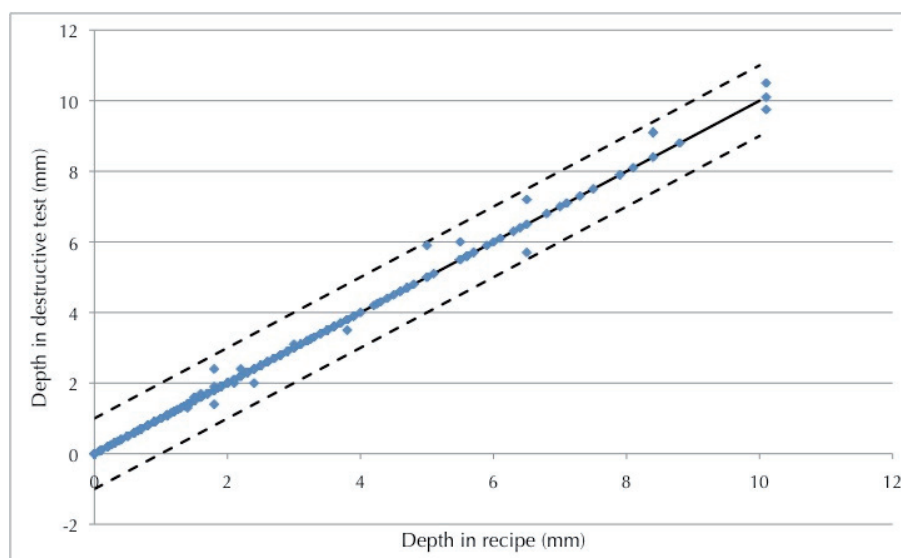


Figure 1
Validated crack depths together with the ± 1 mm tolerance limits.

8 REFERENCES/FURTHER READING

- 1 Kemppainen, M., Realistic artificial flaws for NDE qualification – novel manufacturing method based on thermal fatigue, Dissertation for the degree of Doctor of Science in Technology, Espoo, Finland, 2006. (Available online from: <http://lib.tkk.fi/Diss/2006/isbn9512282631/>)
- 2 Paussu, R., Virkkunen, I., Kemppainen, M., “Utility aspect of applicability of different flaw types for qualification test pieces”, Proceedings of the 6th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurised Components, Oct 8 th–Oct 10th. Budapest, Hungary. 2007. p. 85–91.
- 3 Packalén, T., Sillanpää, J., Kemppainen, M., Virkkunen, I. and Paussu, R., “The influence of the crack opening in the UT inspection qualification”, Proceedings of the 6th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurised Components, Oct 8th–Oct 10th. Budapest, Hungary. 2007. p. 463–470.
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- 5 Virkkunen, I., Kemppainen, M., Ostermeyer, H., Paussu, R., Dunhill, T., “Grown cracks for NDT development and qualification”, InSight, 5, 2009.