Engineering integrity: a controversial issue in Germany

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Abstract

Public acceptance has become a decisive factor for promoting technical progress. This is especially true in Germany, due primarily to political pressure to ensure checks on ecological consequences and on the integrity of technical products and processes. As a consequence, sophisticated testing procedures have been developed to prove engineering integrity. Stress analysis and materials testing procedures are typical examples of such developments. However, modern testing procedures require the employment of the computer, not only for the control of the testing process, but also for data acquisition and analysis. These will be outlined for the modern versions of well known classical materials testing procedures such as the tensile test and the impact bending test. The difficulties of obtaining results acceptable by German authorities for approval to build and employ new technical apparatus and materials are discussed. The concept of developing simple test procedures which are transparent and easy to check is emphasised.

Introduction

In the past, it was almost unanimously accepted, that technical progress would improve the welfare of mankind, hence representing an effective instrument to advance civilisation. In the meantime the attitude towards technique has changed, primarily in the industrialised countries. The hazards of the technical progress to the ecology and to survival of mankind are well understood. Therefore any technical invention, which might represent a risk to the public will be seriously considered in regard to its consequences to public concern, before its production will be decided. This issue has obtained an important attention of the industrial management especially in Germany, where the Green-movement
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has an important influence on the media. Any new technical construction or process must be thoroughly assessed and checked, whether any harmful consequences are possible and what measures have to be taken, to secure a safe service. Likewise great effort is required to prove it, before a licence for service is given by the authorities. Special technical institutions are installed, with the mere objective to survey and check the technical devices and appliances in regard to the design, to its intended function and performance in service. The TÜV is in Germany the best known institution of this kind.

Modern testing procedures

In order to test the integrity of a technical device or appliance more and more sophisticated procedures have been invented in the different fields of engineering applications. A few will be mentioned here.

Stress analysis

One calls a procedure to verify in mechanical loaded structures, that the local stresses in the whole construction will not exceed the limits of the materials selected for this construction during service as stress analysis. Today this procedure requires the employment of very complicated computer-programs for finite element calculations. In order to compare the results of the theoretical calculation of stresses with the reality, a very subtle experimental method of stress analysis by applying strain gauges to the structure has been developed. In order to convert the measured data from strain gages into data of local stress values, again a very complicated computer program is required.

Materials testing

In order to define the limits of mechanical properties under various loading conditions, mechanical testing had been developed into more and more sophisticated procedures. Even the simple tensile test requires today a computer, for data logging during the test, for converting it into the required test data of materials properties and for documenting it [1]. Figure 1 shows an example of a document of a tensile test, recorded by employment of a computer. In many cases the computer is today also used to control the prescribed testing program performed by the testing machine. Materials testing according to the methods of fracture mechanics requires the
employment of a computer for data-logging as well as for the control of the testing machine, as demonstrated in other papers given in this conference [2]. Analysing the test data and calculating the materials behaviour from the test data is another task performed by a computer program.

- Another example, where computer are necessary for the testing procedure, are the different methods of fatigue tests. Fatigue is even still today the most common origin of failure of industrial components of machinery. Complicated test procedures are invented, which require the employment of a computer for control, analysing and calculating the test results [3].

- A further example of development of a well known classical test into a very sophisticated testing procedure by the employment of a computer represents the so-called Instrumented Charpy-V Impact Bending test [4]. In the past it was sufficient to register the value of absorbed energy during the impact, which eventually led to fracture of the test piece. Today data logging during the impact is preferred by applying a special strain gauge to the fin of the hammer. So one can record the actual load applied to the specimen during the very short time of the impact. From this record one can calculate a stress-strain diagram during the impact of the hammer [5]. Integrating of this diagram should result in the total energy consumed by the test. [As demonstrated in the figure 2].

**Computers are essential in testing for the integrity of structures.**

All those examples mentioned, demonstrate, how much the methods of calculation in design and the testing procedures of the material employed have been developed, in order to secure safe performance of technical structures. Furthermore those examples demonstrate likewise, that employment of a computer is inevitable for modern testing procedures. Of course one could demonstrate other technical fields as well, which can prove in the same manner, that employment of a computer plays a vital role for calculating and testing. Special methods to assess the safe performance of machinery had only become possible by the utilisation of a computer as e.g. the recently developed methods of simulation of the mechanical behaviour of a real structure in service on a computer-screen by an animation program.

Since the introduction of the New Natural Science by Galilei and Sir Francis Bacon [6], it was realised that mathematical description is the most appropriate
procedure to understand and to exploit the processes known in nature and technology. Therefore the invention of the electronic calculator and the methods of programming the calculation procedure in the middle of this century have become a strong impact to the technical progress. Several new technologies like space- and nuclear energy-technology had depended on the progress of computer technology for the necessary calculations. One can predict, that other new technologies are still to come with the employment of computer technology. On the other hand, Galilei already knew that theoretical calculations in mechanics require the verification by experimental techniques, since reality deviates from theoretical predictions [7]. Hence, experimental engineering attracted much attention since the last century. Technical progress is therefore accompanied by developing testing procedures, which again require a mathematical description of the testing process. As a consequence the application of computer technology had been introduced into the testing procedures of the integrity of man-made structures. The following reasons made the employment of computers inevitable for testing procedures of today:

- The employment of a computer is required for complex modern testing procedures in engineering.
- Only the application of a computer with its appropriate software program has made complicated testing methods economically feasible.
- Furthermore the application of modern computer techniques reduces the sensitivity to human errors, one had to face, when all the testing had been conducted by hand.
- In many cases the application of a computerised program reduces the limits of scatter and errors due to individual bias introduced by man handled procedures.

The employment of a computer for testing has also disadvantages.

- Computer-programs become more and more sophisticated and loose transparency. The whole procedure of data logging, transforming test data into the required results by calculation may loose trustworthiness to non-experts, who do not understand the program.
- From the experience in the commercial section of the banking system, where computer are in service for some time, one has realised the
sensitivity of results, obtained by the use of a computer to all sorts of criminal assaults to falsify data.

- The legal issue has not yet been resolved, who can be made liable for damage caused by malfunction of a computer-program utilised for a technical procedure [8].

As a consequence of those disadvantages one will run into difficulties, when testing results obtained by employment of a computer are required to be approved as demonstration of a safe performance of the technical item at stake.

1: It is difficult to prove that the mathematical description of the testing procedure is in agreement with the reality.

2: It is likewise difficult to prove, that the hardware and the software operate without error.

3: Furthermore one runs into the difficulty to assure, that the measures are sufficient to protect the operation of a computer against criminal assaults to falsify its operation.

As a consequence of those disadvantages it has been almost impossible to obtain approval of German authorities responsible of surveillance, when the results of proving integrity are obtained by assistance of a computer. One of the reasons is the present lack of acquaintance with computer technology of the people involved in the surveillance business of testing integrity. Another reason are the legal regulations of testing integrity, which hardly take notice of the progress of information technology. As an example, the experience should be mentioned, when it was required to perform certified tensile tests in our university-laboratory. There had been no difficulties, to get approval to make those tests with the old mechanically driven testing machines after the surveillance-institution had verified on their own tensile specimens, that the recorded values had been correct. After the replacement of the mechanically driven tensile test facilities by electronic control, no approval was firstly obtained to use any of these machines. Finally the people from the surveillance-institution put a seal to all the amplifiers of the measuring gages in the electronic control, then we could use those machines for certified tests. However, even up to now a tensile test performed by a machine, which is controlled together with the calculation of test results by a computer program is not accepted as certified test.
Therefore it is still not resolved, how one can get approval for service, when testing the integrity of a structure or the safe operation of a technical unit requires the employment of a computer with a sophisticated program. The solution to this problem as mostly verified today in Germany is the appointing of a well known and highly estimated special institution for the surveillance, which may attain the authorisation by the government, to perform those tests on their own machines with their own computer and software programs in their own responsibility. This solution however transfers only the problem of trustworthiness to another institution, it will add extra costs to the testing procedure but by no means increase the integrity of the structure.

Conclusion

Proving the integrity of the structure is likewise important as all the effort to provide integrity. For providing the integrity of structures or of the performance of devices and appliances the utilisation of modern information technology has become inevitable. The same goes for complicated testing procedures. The difficulties however arise, when the results of computerised testing must be approved by surveillance-institutions. One must admit that none of the computerised procedures are sufficiently protected against different methods of falsification. Sophisticated computer-programs are characterised by a lack of transparency. It is therefore very difficult to discover falsification of the results obtained by such a program. It is therefore highly recommended to put much effort in developing simplified testing procedures, when approval of the results of testing is required. Such simplified testing procedures should demonstrate transparency to such an extent, that even non-experts can easily discover sources of falsification of results, to avoid uncertainties of the trustworthiness of the results obtained by such testing procedures. The above mentioned Charpy-V Impact Bending test, to prove ductility of steels or other materials, is such a simple and transparent test, when the absorbed energy is measured by the classical procedure [9]. The instrumented Charpy-V Impact Bending test requires the employment of complicated data-logging and calculation, so that transparency is missing. It will not be appropriate for getting approved results. It offers however a very useful information, which supports the reliability of the result in measuring the absorbed energy as indication of ductility of the material.
Public acceptance of a new technical solution of a certain process or a specific appliance or construction represents today an important issue to put those new items into realisation. Today one can not count anymore on the former general confidence of the industrialised society, that technical progress will bring a better welfare to the people, so that a certain risk is justified for its realisation. At present a pronounced distrust prevails, that technical progress may lead to more harm than benefit to the welfare of environment and nature and eventually to the survival of the human society. Each step of technical progress requires therefore today a simple and transparent test of integrity in order to overcome the distrust of the public against the technical progress.

List of References

[5] DVM Merkblatt 001 09.86 Berlin

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Fig. 1 Record of a computerised tensile test
Fig. 2 Record of an instrumented Charpy-V Impact Bending Test
Fig. 1 Record of a computerised tensile test

![Graph showing tensile test results](image)

**Adolfs Baustahl St37**

- **Prüfer:**
- **Werkstoff:** Baustahl St37
- **Probennummer:** 1
- **Bemerkung:** 120 HV30
- **Probeneigenschaften:**
  - **Probenform:** Rundprobe
  - **Probenquerschnitt:** 78.54 mm²
  - **Dehngeschwindigkeit:** 13.5 %/min
  - **Prüftemperatur:** 20°C
- **Eigenschaften:**
  - **Elastizitätsmodul:** 205623 MPa
  - **Obere Streckgrenze:** 306 MPa
  - **Untere Streckgrenze:** 278 MPa
  - **Zugfestigkeit:** 406 MPa
  - **Bruchdehnung:** 43.0 \%
  - **Bruchzähigkeit:** 32.0 \%

Fig. 2 Record of an instrumented Charpy-V Impact Bending Test

![Graph showing Charpy-V impact test results](image)

**Name der Datei:** c:\program\kerb\gw5fl.asc
**Name des Prüfers:** Matheis
**Kerbschlaghammer:** 300 J
**Werkstoff:** 20 MnMoNi 5 5
**Prüftemperatur [°C]:** RT
**Probenentnahme:** quer
**Probenbezeichnung:** GW5FL
**Typ des Diagramms:** E

*Kennzeichnende Werte der Kraft*
- Fgy [kN] = 13.08476
- Fa [kN] = 16.28255
- Fu [kN] = 15.604
- Fa [kN] = 4.704

*Kennzeichnende Werte der Arbeit*
- Wm [J] = 35.96032
- Wu [J] = 57.75718
- Wa [J] = 57.75718
- Wt [J] = 78.24133

*Kennzeichnende Werte des Weges*
- sb [mm] = 3.166613
- ss [mm] = 4.525391
- sa [mm] = 4.525391
- st [mm] = 26.16262

*Anteil des Verformungsbruches (%)* 33.05747