# **SAIW hosts** fracture and fatigue seminar

**Professor Adolf Hobbacher from the University of Applied Sciences in Wilhelmshaven, Germany presented a series of SAIW-hosted fracture and fatigue seminars during February 2019. *African Fusion* presents some of his comments from the opening session.**

Adolf Hobbacher is a one of the world's leading experts in fracture mechanics and fatigue failure. He was instrumental in identifying how cracks propagate and developing the formulae for predicating the critical crack length leading to brittle fracture in welds (Hobbacher: Engineering Fracture Mechanics, 1993).

"For those of you needing a reference to ensure your welds joint designs are resistant to fatigue, I highly recommend Professor Hobbacher's booklet: *Recommendations for Fatigue Design of Welded Joints and Components*, which is IIW endorsed and published by Springer," says SAIW executive director Sean Blake in introducing Professor Hobbacher.

Hobbacher opens his seminar with a summary of what engineering is about. "The professional work of an engineer must meet the following requirements: It has to represent the state-of-the art and to be technically sound; it must be economical, since money is not infinitely available; and, third, it is very important that the design is defendable before a court of law in the case of any litigation that arises after an accident or incident," he notes.

Immediately relating this to welding technology, he says that welding is very complex, involving getting everything right in three competing areas: materials and welding metallurgy; manufacture and the welding procedures; and the structural design of the welded components. "From a structural design perspective, engineers try to specify joint detail using simple formulae derived from the mechanics of rigid bodies. But welding completely changes the conditions of the materials and the design assumptions.

"When welding, the materials used must be suitable for welding. Cast iron, for example, is not. Then in the design, we need to make sure that it is possible to manufacture the structure using available welding processes and equipment. We cannot have submerged arc welding in position, for example.

"And we have to make sure that the structure we design will be safe after manufacture. Therefore there are many additional aspects that must be considered if the structure is to be welded," he points out.

He says that all aspects need to be considered at the same time in order to ensure safe in-service use, which makes for a bigger design task. "This leads to the slogan for welding technology as a general denominator for engineering – all engineering aspects must be included. The other comparable field is medicine, which also involves every aspect of science, chemistry, biology, mechanics, psychology and a host of other knowledge disciplines," Hobbacher says.

"Some might look at this in fear, but we shouldn't. It is like a medical student who learns early on that a person can die of some 700 different diseases and finds it difficult to believe how anyone is still alive. But people carry on living and, while structures can fail for numerous different reasons, it is possible to design and build ones that don't," he assures.

Showing a slide of a heavy gun dating back to 1342, he says that humankind has been joining metals such a copper, tin and iron for centuries; by forging, soldering or welding, "and it is fascinating to see how this was done".

The development of steel, however, significantly enhanced weldability, which enabled the design and use of heavier and bigger structures. Hobbacher displays a slide of the minimum yield strength of structural steels starting back in the late 19th century with S235, one of the early low-carbon steels. "In the 1950s, carbon manganese steels arrived and steel strength increased steadily to over 500 MPa. Then quenched and quench and tempered (QT) varieties were developed and, in the early 2000s, thermo-mechanically treated steels arrived," he says, adding that today there are QT steels with tensile strengths of 1 200 MPa that are widely used for railways, for example.

*SAIW hosted a series of fracture and fatigue seminars by world-leading specialist Professor Adolf Hobbacher in Johannesburg, Cape Town and Durban during February 2019.*

*A 1934 image of a bridge collapse in Belgium that occurred while unloaded in the middle of a very cold night. "... if toughness is not present or has been degraded in service or the service temperature becomes lower than the values used in the design, then brittle fracture becomes a very real risk," Hobbacher advises.*

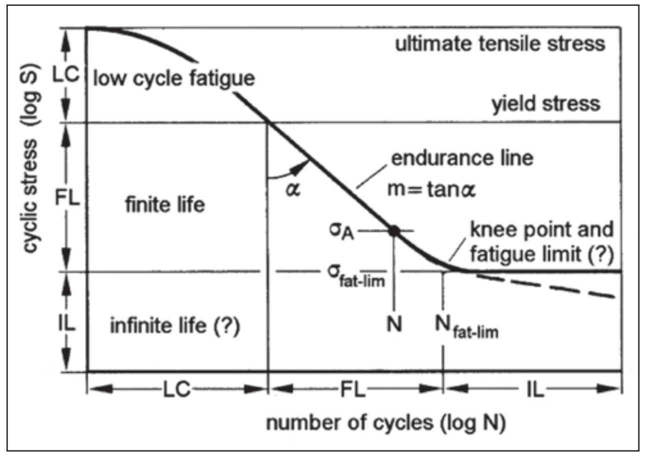
Introducing the possible failure models for welded structures, he says that the first cause of structural failure is static overload, and codes such as Eurocode, DNV-GL, AASHTO and BS standards are in place to help designers prevent this from happening. "The problem is that while these codes deal well with the resistance side of the structures, designs depend on load assumptions and if these are wrong or change due to circumstances, failures will occur. Eurocode, therefore, embeds a margin of safety into its requirements to ensure that the structural resistance is always higher than the predicted maximum loads, but this may be set to only 10%, which is acceptable if we are able to predict the loads accurately. But uncertainty always exists!" he warns.

With respect to fatigue, Hobbacher says that codes exist here too, but warns: "You cannot learn about technology by reading codes. They only tell you what to do but not why," before citing Eurocode, DNV-GL, IIW Pressure vessel codes along with API for pipelines and ASME codes, which all present requirements for preventing fatigue failures.

Fatigue failure risks may arise from the structural design detail, which can embed unintended shapes that impair the fatigue resistance, while manufacturing imperfections such as undercut in a weld will also have a negative effect. "Generally speaking, the metallurgy is secondary. One cannot prevent fatigue by selecting a stronger material," says Hobbacher.

Another common failure mode for structures is brittle fracture and codes such as Eurocode 1-10 specify minimum fracture toughness or Charpy-V-notch values in mitigation. "But if toughness is not present or has been degraded in service or the service temperature becomes lower than the values used in the design, then brittle fracture becomes a very real risk," he advises.

Describing a recent bridge collapse in Genoa, Italy, he suggests the cause was a question of design. "There was a single steel rope hanger with no redundancy and this was embedded in concrete, so it could not be inspected. This should not be done. Ropes such as these must be able to be inspected, because, like an Irish harp, if one breaks, then load transfers to the others. This brings into sharp focus the need for redundancy in support structures.



*The Wöhler S-N curve was developed in 1860 following an investigation into the failure of railcar axles. The curve describes three distinct fatigue regimes: low cycle (LC) fatigue at high plastic strain; finite life (FL) fatigue where the number of lifecycles (N) is inversely related to the stress range ($N=C/\Delta\sigma^m$); and an infinite life (IL) regime at stress range levels below the fatigue limit.*

"As an engineer, I cannot understand how any engineer would have taken this risk. In Germany some 200 bridges will have to be replaced for fatigue reasons.

"Civil engineers in Germany are required to comply with huge numbers of codes, so they sometimes see only the legal implications and follow what is allowed instead of what is reasonable. But this is not what engineering is about. Safety is an engineering responsibility not just a legal one," he says.

Citing some relatively recent failure statistics for buildings, bridges and conveyors, Hobbacher says that overloading failures are the cause of about 29% of the failures, but this mostly applies to buildings and conveyors. "With respect to bridges, static overload is seldom the cause. Fatigue accounts for nearly 40% of recorded bridge failures, with corrosion accounting for another 32%. For conveyors, fatigue is also a big issue (31.5%), along with static strength (36%) because conveyors are also often overloaded.

Hobbacher's seminar went on to detail failure mechanisms for brittle fracture, crack propagation and fatigue as well as to highlight the code requirements and his own engineering insight into how such failures can be best prevented.

Especially relevant to professionals in steel construction, design, fabrication and maintenance, Professor Hobbacher's seminar was presented in Johannesburg, Cape Town and Durban. ■

## Prof Adolf Hobbacher

Prof Hobbacher, one of the world's leading fatigue experts, has an extensive background in engineering as a designer, researcher and educator. His experience includes chemical plant equipment, heavy machinery, pressure vessels/pipes and structural steelwork.

Hobbacher's research activities are mainly on the fatigue of welded structures and he was instrumental in establishing the new fatigue design recommendations of the International Institute of Welding (IIW) through Commission XIII: Fatigue of welded components and structures; and Commission XV: Design, analysis and fabrication of welded structures.