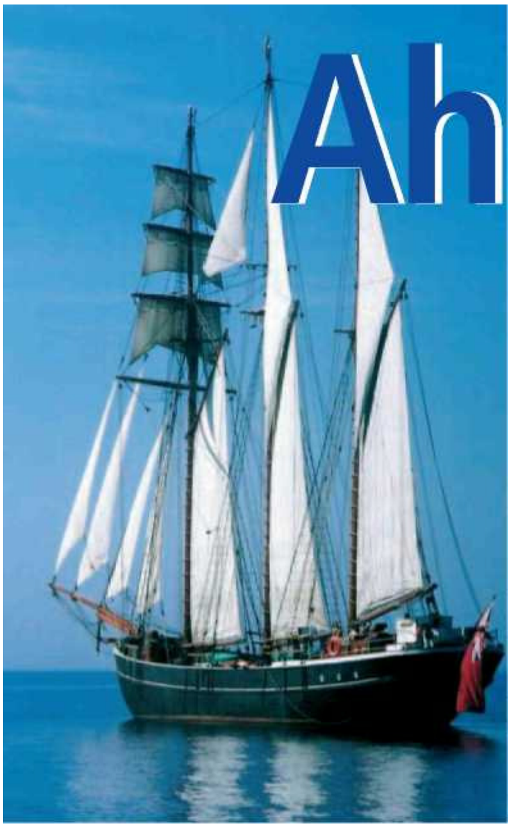


Ahoi!

Stress Analysis During Manufacture and Operation of Shipbuilding and Structural Steelwork

Large steel structures in the shipbuilding and steel building industry are usually joined by welding techniques. Welding involves local heating of the steel which leads to basic changes in the microstructure of the material and results in significant shrinking forces. The free shrinkage is constrained near the weld seam during cooling down which leads to welding deformations and residual stresses. This increases the risk of failure under operational load. Detailed knowledge is required on the distribution of the deformations and stresses to optimise the welding technique and the failure risk. In view of increasingly strict safety regulations, the monitoring of existing steel structures becomes more important, too.

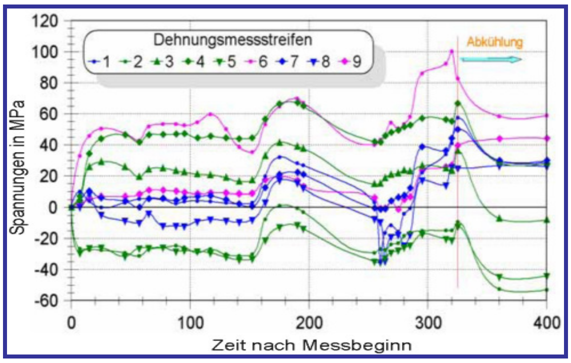
The approach to the study of complex stress scenarios is based both on theoretical calculations and on experimental testing. Modern calculation methods based on the finite elements or contour integral methods enable realistic models of steel structure geometry, parameters and loading conditions. The modern measurement technique related hardware and software have considerably increased the limits in terms of disk capacity, processing speed and display of results. Nevertheless, there are still limits in the modelling of technological processes and the performance of steel structures. The time-dependent load and the response of the steel structures to these loads is important to know for the verification of the theoretical models and calculation methods, the constructive optimisation of the structures and the technological optimisation of the production process and last, but not least, for the timely advance notice or the prevention of local or global failure phenomena.

Requirements for a versatile measurement data acquisition system

Measurement equipment – sensors and recorders – must be compatible to the rough ambient conditions prevailing in the production process of large shipbuilding structures. This calls for robust, self-sustaining and reliable measurement equipment. This is also true for long term measurements at ships or other structural steelwork, the measurement equipment being also subject to rough handling by the operating personnel. Easy operability of the equipment is important, if it is to be set-up and operated by external staff.

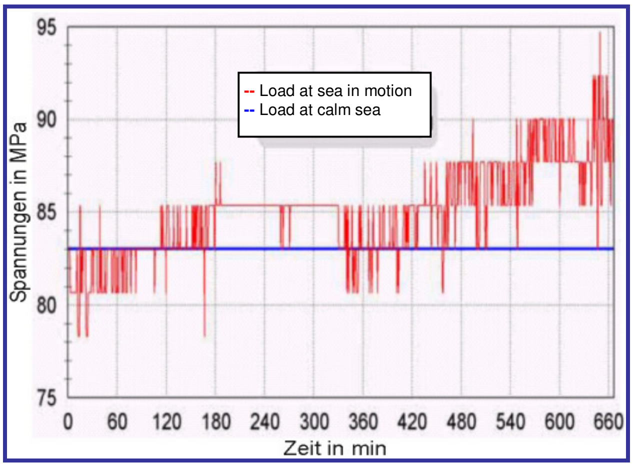
The measurement engineer prefers recorders that are easy to use and adaptable to various measuring tasks. This concerns both the sampling rate that is to be adjustable in a wide range and the available options for recording and storing the long term data while they are accessible for visual verification at any time. The data volume with long term measurements shall be kept within

Picture 1: Recorder Micro-II

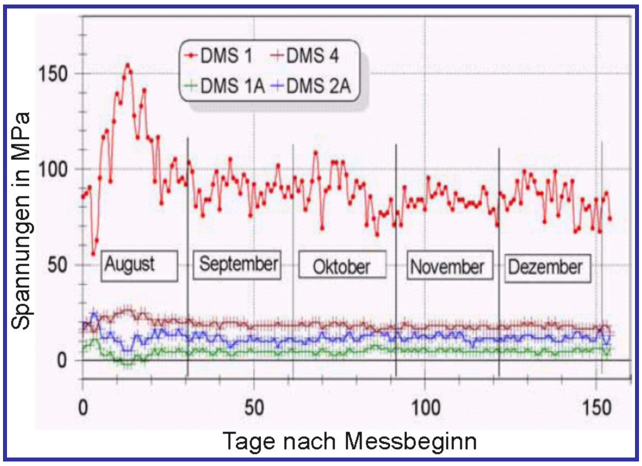


Picture 2: Welding tensions in an orthotropically stiffened flat section

MessTec & Automation 05/2005, S. 36–37, GIT VERLAG GmbH & Co. KG, Darmstadt, www.messtec.de



Picture 3: Sea state induced tensions in a ship's structure



Picture 4: Long-term monitoring of tensions in a ship's structure

reasonable limits by suitable reduction methods. Automatic self-testing is desirable to ensure the data security. In addition the measurement equipment should be small- sized and cost-efficient in terms of investment and operation.

The selected examples presented below were recorded with the data recording system Micro-II of Swift GmbH, Reinheim, Germany. The main unit is the modular designed recorder in CMOS technology (Picture 1). It can be equipped with up to 20 analogue and 16 digital channels, measurement range from 1µV to 10V, sampling rate up to 2kHz. The recorder is operated – measurement parameters, start / stop, display, data transmission – by a laptop PC. Standard features include a variety of evaluation algorithms that suit all typical measurement tasks.

Measurements for optimising technological processes

When joining steel slabs to larger panels the heat source for the welding process is directed along the welding split that is pre-set within narrow limits. The welding split depends on the thickness of the slab, the material to be welded and the welding technique. The zone near the welding seam develops a time dependent temperature field that constantly changes the set welding split causing larger (spread) or smaller (constriction) split. This phenomenon is called "welding split breathing". Both phenomena are undesirable and can have negative consequences.

Based on strain gauge measurements, Picture 2 depicts the progression of welding tensions at selected spots of an orthotropically stiffened, two-dimensional flat steel section sized 8 m x 4 m. The section is slab-built with double T-girders arranged in longitudinal and transverse direction being joined at either side by fillet welding. The measurement started simultaneously with the welding.

The curves pertaining to strain gauges nos. 1 and 7, that were placed rather distant from the location where the welding started, indicate only minor welding deformation, whereas the other measurement locations register the deformations from the beginning. An appreciable variation of the strain gauge indication is noticeable at the spots no. 1, 7 and 8 after approx. 150 min., because at that time the welding process had reached the area of these gauges. After completion of the welding works, the whole structure begins to cool down, and after approx. 360 min., a state of residual stress with tensile and compression stresses can be observed.

Experimental determination of sea state induced tensions in a ship's structure

Sea state induced tensions in the structure of a ship fluctuate at random and, depending on the sea state, can significantly exceed the tensions resulting from the ship's loading state at calm sea. Picture 3 depicts the tension distribution towards the ship's longitudinal axis, as measured at a typical structure of a ship. Sea state induced tensions are decisive for the fatigue performance of the structure. In principle, fatigue phenomena are predictable and thus controllable, however, they are subject to sizeable variability. Material fatigue is difficult to detect by visual check due to the limited access to the structure, and fatigue cracks may not be discovered under the conservation or corrosion layer. Monitoring the tension at crack-vulnerable spots of structures can contribute to early detection of damages and hence allow appropriate action to be taken in time. Since the endangered areas of the structures are known from calculations carried out for verifying the static and oscillation strength of the ship's body, the placement of a limited number of sensors is normally sufficient to cope with the potential danger effectively.

The long term run of the tension distribution near an affected structure normally shows a systematic change as recorded by strain gauge no.1 of Picture 4. Unless this strain gauge has a drift and or other measurement errors have occurred, the constantly decreasing tension to the months after August points to a possible deterioration in the vicinity of the measurement location, since the loading state of the ship remained unchanged. The curves pertaining to the other three strain gauges did not show such distinctive features.

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