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LONG-TERM MONITORING AND EVALUATION OF STRAIN HISTORY

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Abstract: The introduction of fully probabilistic structural reliability assessment concepts in codes requires more attention to be given to the analysis of the structural response to the loading. Monitoring device DATREQ allows for long-term recording and evaluation of the actual response of a structure exposed to wind, vehicles, etc.

Keywords: monitoring, rain-flow, recording, reliability, response, structures.

Introduction

The structural response to the loading is one of the main inputs into the reliability assessment procedure. In many cases only limited data representing the loading history are available, the response history is based upon estimation and therefore it is very difficult to perform, for example, a consistent remaining fatigue life reliability assessment. In special cases when there are substantial uncertainties in the transformation model and/or loading that is used to establish the response history, a “feedback-loop” approach may be applied as explained in [3]. In this case the structure is built based upon the estimated response history, and assessed subsequently using data on actual response recorded in service. The recorded response is evaluated and used as feedback in the reliability analysis.

The results obtained from feedback-loop approach reliability assessment may lead to modification or strengthening of existing structures, to improvement of codes, or to other modifications of design, fabrication, construction and structural maintenance practice. Such approach is especially very useful in case of safety assessment of structures exposed to fatigue.

To obtain reliable long-term records, the response history may be recorded in situ on existing masts, towers, bridges and other structures. In the end of eighties, special low-cost device has been developed in Czech Republic to monitor the strain history [1]. This commercial electronic device was evaluated through laboratory and field measurements of stresses in the USA [2]. The accuracy of the random stress processing was examined by application of controlled cyclic loads on a small beam, by testing full-scale girders under spectrum of loads, and by measuring stresses in bridge members (Tie Arch Bridge and Deck Truss Bridge). The device had been applied for monitoring the dynamic response of a steel box-girder bridge on a freeway in Sacramento, California [4], and the response to wind load of a TV tower and of some other structures in the Czech Republic [5] to [8].

The development of the electronics and computer technology allows for qualitative

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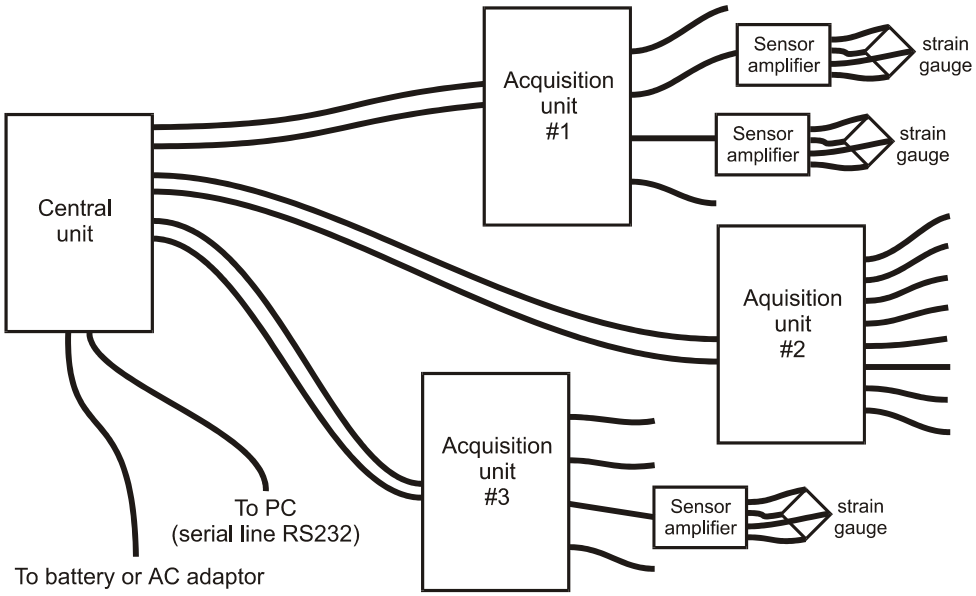
improvement of the device. The subject of this paper is an introduction of a new device DATREQ developed recently in Czech Republic [9]. The system design benefits from the dramatic improvements of modern electronic components. Many available microcontrollers with sufficient computational power are optimised for low power operation and contain many integrated peripherals, which simplifies system design. Modern high-capacity memories have low power consumption and high speed. Many non-volatile memory types, like Flash or static RAMs with built-in battery, are available. Other components, like A/D converters, analogue multiplexers, communication interface devices, precision voltage references, power supply devices or precision and fast operational amplifiers are available in low-power versions.

DATREQ system

DATREQ is a complete system for long-term monitoring, recording and evaluating of data from various kinds of sensors and transducers. The heart of the system is an **Acquisition unit** that serves for converting input analogue signals from **Sensor amplifiers** to digital form suited for further processing, evaluation and storing. Acquisition unit contains high-precision A/D converter for accurate measurement and high-capacity non-volatile data memory for storing collected data even in the case of power loss.



DATREQ system

Multiple Acquisition units can be connected using a **Central unit** that allows the synchronisation between units and centralised data collection.

Both Acquisition unit and Central unit are fully software-controlled. They contain no mechanical controls, knobs or buttons. All types of units are housed in water-resistant metal cases and are equipped with water-proof connectors.

Units can be connected to PC computer by standard serial communication port (RS-232). High communication speed 115200Bd allows fast retrieving of data from the unit into the computer. The default communication speed can be reduced if the low quality line is used or if the environment noise does not allow reliable high-speed communication. The distance between PC and connected unit is limited according to RS-232 specification to few meters. Longer distance can be achieved using differential communication interface RS-485 and **Communication unit**. In this case the distance between PC and connected unit can be more

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than 1000m.

All units are powered from single DC power supply (9-15V). Special design techniques such as dynamic bridge excitation and the use of carefully selected micropower components result in very low power consumption (tens of miliamperes) of the whole system what enables long term battery operation. Collected data are preserved in the non-volatile memory for more than 10 years in the absence of power supply.

Control and data collection software **DATREQ Control** serves for setting and monitoring all Acquisition and Central units as well as for data transfer, collection, saving and presentation. Control program allows instant printing of measurement protocol. Collected data and unit parameters can be saved for further processing and presentation in the format directly accepted by spreadsheet programs

Acquisition unit

Acquisition unit **RR8Ti-1** serves for data processing and recording. It allows connection of up to eight Sensor amplifiers. Data collected from the Sensor amplifiers are evaluated using Rain-flow method and the individual numbers of stress cycles with corresponding mean values of strain range are sorted into 31×31 classes and stored. Up to 2^{32} (more than 4×10^{9}) cycles can be recorded in each class. It allows extremely long monitoring time without need to collect data and clear the memory. Acquisition unit contains high-precision A/D converter and high-capacity non-volatile data memory for storing collected data even in the case of power loss. Adjustable sampling rate in the range 0.8 - 200 samples per second allows evaluation of fast strain changes. Continuous temperature recording is possible using built-in temperature sensor with the precision ± 1°C. Temperature sampling interval is adjustable in the range 1 - 250 s. Acquisition units with different number of channels, external temperature sensor, etc. are available.

Acquisition unit RR8Ti-1

Sensor amplifier

Sensor amplifiers allow connection of various types of sensors. Strain gauge amplifiers **SG120F56** and **SG120H56** are designed to work with 120 Ohm strain gauge sensors in full-bridge or half-bridge configuration. The fixed gain A=56.6 is suited for steel strain measurement. Universal amplifier **UA10V3** is a general purpose Sensor amplifier for voltage measurement. Input gain is selected by connection to one of three inputs with gains A=0.1, 1.0 or 10.0 respectively. Any sensor with voltage output can be connected. Other types of Sensor amplifiers are available or can be designed on request.

Summary and Conclusions

To improve the structural reliability assessment using fully probabilistic concepts, such as SBRA [3] and [10], more information and data on the actual structural response to loading would be required. A monitoring device DATREQ developed recently [9] corresponds to the improvements of the computer technology and electronic components. It allows for long-term recording and evaluation of the response history leading to data applicable in probabilistic reliability assessment concepts. The device can serve as an important tool in the analysis of the accumulation of damage, especially considering the remaining fatigue life, and can contribute to the improvement of the evaluation of the load and structural response history in the framework of the probabilistic structural reliability assessment.

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