FATIGUE AND CORROSION MONITORING BY MEANS OF ACOUSTIC EMISSION (AE) ON TRANSPORT PRODUCTS

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BASIC

Fatigue cracks and corrosion damages are beside human errors the main causes for structural failures of all surface transport products like ships, road tankers and railway tank cars. In order to prevent those structural failures, maintenance and inspection has to be carried out. These activities require high efforts and are usually performed while the transport product is out of service. Such kind of maintenance is often referred to as “Preventive maintenance”. It is performed on a time driven or routine basis. Despite these high efforts the risk of not detecting the onset of a defect is still implied in this maintenance process and thus failure within the next service period may occur.

There exist many examples, where weakened structures have failed to withstand severe operating conditions. Accidents of oil tankers have led to tremendous pollution of the environment and subsequent to economical loss in large costal areas. The most well known in Europe have been those of the oil tankers “Erika” in front of the Bretagne and “Prestige” near to Galician coast. But also bulk carrier and container ships have been involved in ship accidents, like the “Server” and Napoli.

Accidents related to road and railroad tank cars have much less impact to the environment compared to ships due to their smaller capacities. But since they may be operated within densely populated or industrial areas, the consequences on human life may be much higher. Transportation of dangerous goods within atmospheric or within pressurised tank cars on road or railroad puts human life to risk in case of structural failure. There have been explosions of railroad tank cars, which had lethal consequences for the operating personnel.

Not in contrary to the today preventive maintenance but in parallel to it, another maintenance approach called “predictive maintenance” has been developed, where periodic or continuous measurements on the structure are performed during operation. Predictive maintenance aims on obtaining the optimum duration of the current period of safe operation. Evaluation of monitoring data reveals the condition against defined criteria (condition assessment) and enables to schedule maintenance activities as required.

Applied on transport products, the concept of predictive maintenance offers many advantages, with the most significant as follows:

1. Provided that the transport product is in good condition, this kind of maintenance process offers enormous savings due to well justified longer periods of safe operation compared to preventive maintenance.
2. If unexpected structural degradation takes place, it can be detected already in an early stage so that the appropriate repair can be performed in time and clearly before a critical situation appears. The savings in such case may be high, because of the consequences of an accident with severe damage of environment, structure or even fatal consequences for human life.

EC–FUNDED PROJECT

For these reason an European consortium from 11 companies coming from 8 EU-member states developed a project, where the predictive maintenance shall be applied for all transport products (ships, trucks and railroad cars). The key technology, which shall be applied as a monitoring technique to detect any kind of fatigue and corrosion within the structure, is Acoustic Emission. The consortium is described in table 1.

Table 1: consortium for the EC-funded project

#	Name of the company	country	Company profile
1	TÜV AUSTRIA SERVICES	Austria	Project-Coordinator, Testing and Inspection Institute
2	Vallen Systeme	Germany	AE-equipment producer
3	ABS (American Bureau of Shipping)	United Kingdom	Ship-classifier
4	BAM (State-Organisation for material testing)	Germany	Research and Testing Institute
5	AUTH (University of Thessaloniki)	Greece	University ,truck experts
6	GUT (University of Gdansk)	Poland	University, maritime experts
7	ISQ (Welding Institute)	Portugal	Testing and Inspection Institute
8	LAR (University of Krakow)	Poland	University, Fatigue and AE experts
9	NNDT (NDT company)	Romania	NDT testing company
10	Reneko	Latvia	Service company
11	NSG (Naval Ship Yard)	Poland	Ship repair yard

The aim of the project, which was accepted from the European Commission and started November 1st, 2008, was to develop an overall strategy for maintenance and inspection of all different transport products. The development includes the necessary AE-equipment and -technology, definition of hot-spots of the structures and evaluation and criteria of the monitoring data.

The overall strategy shall demonstrate the application of the predictive maintenance on the different transport products and will point out the advantages of this methodology.

PERFORMED TEST

Beside the establishment of a common understanding for all different partners and elaboration of the differences between the transport products, the consortium started to develop and /or adapt the different available technologies.

The key technology for the monitoring of the structures is Acoustic Emission and it should be proven, that the different degradation processes could be detected, located and evaluated by AE.

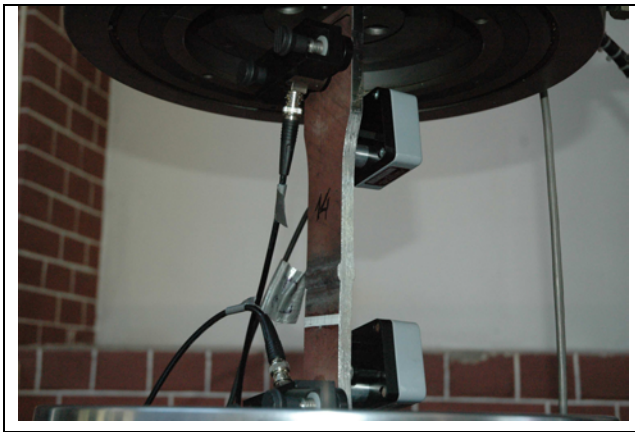
From a former performed EC-funded project “Corrosion detection of ships” the TÜV has the expertise to detect, locate and discriminate corrosion within ship hulls with AE”. Because this project was only based on the acquisition of acoustic waves, which were travelling through liquid, the new project has to prove, that this can be also performed for corrosion in the deck-plates, where the travelling path and acquisition is within the metallic plate itself. For this reason different plates, - plan, with welding and – with stiffeners were tested at the lab. A test sump were built, were we have been able to create a similar atmosphere, how we can expect on a ship between the cargo

liquid and the deck plates. The atmosphere corrodes the test-plates and the acoustic signals were acquired and stored in the AE-equipment.

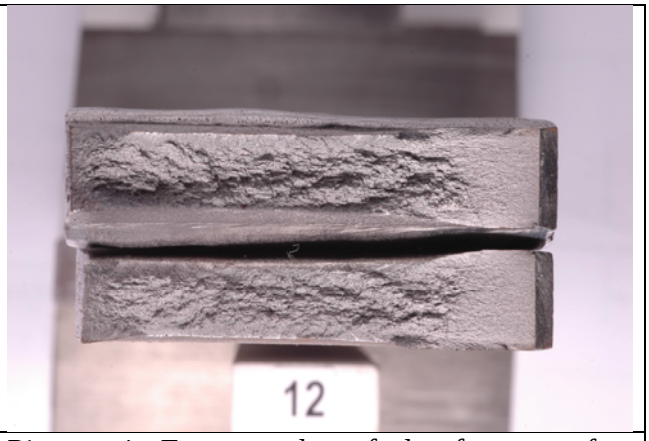
Picture 1: test set-up for corrosion tests under corrosive atmosphere without contact with liquid

Picture 2: corroded test plate after first part of corrosion test

For the fatigue cracks tests were performed at three partners (BAM, LAR and GUT). These partners should cover the complete range of fatigue, which can happen on ships, truck and railway cars. For this reason the fatigue-tests have to be performed on different materials, crack modes I, II and mixed mode, different loading cycles at the different labs according their available test rigs. The loading frequencies, which were based upon the normal service conditions, were varied between tenths till ten Hertz.



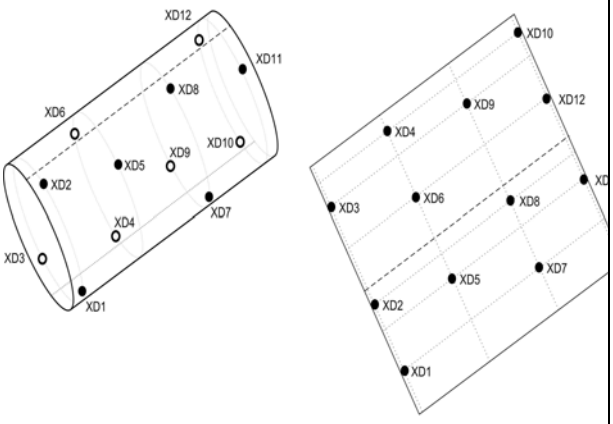
Picture 3: test set up for the fatigue on butt welded samples



Picture 4: Fractography of the fracture after fatigue

For the monitoring it is very important task, that the AE-signal can be distinguished from the background. The background for ships (single – and double hull) comes from the former project. The background noise from trucks and railway cars, during the different operations, were acquired and stored in the data base.

Picture 5: railway car with applies sensors for the background measurements

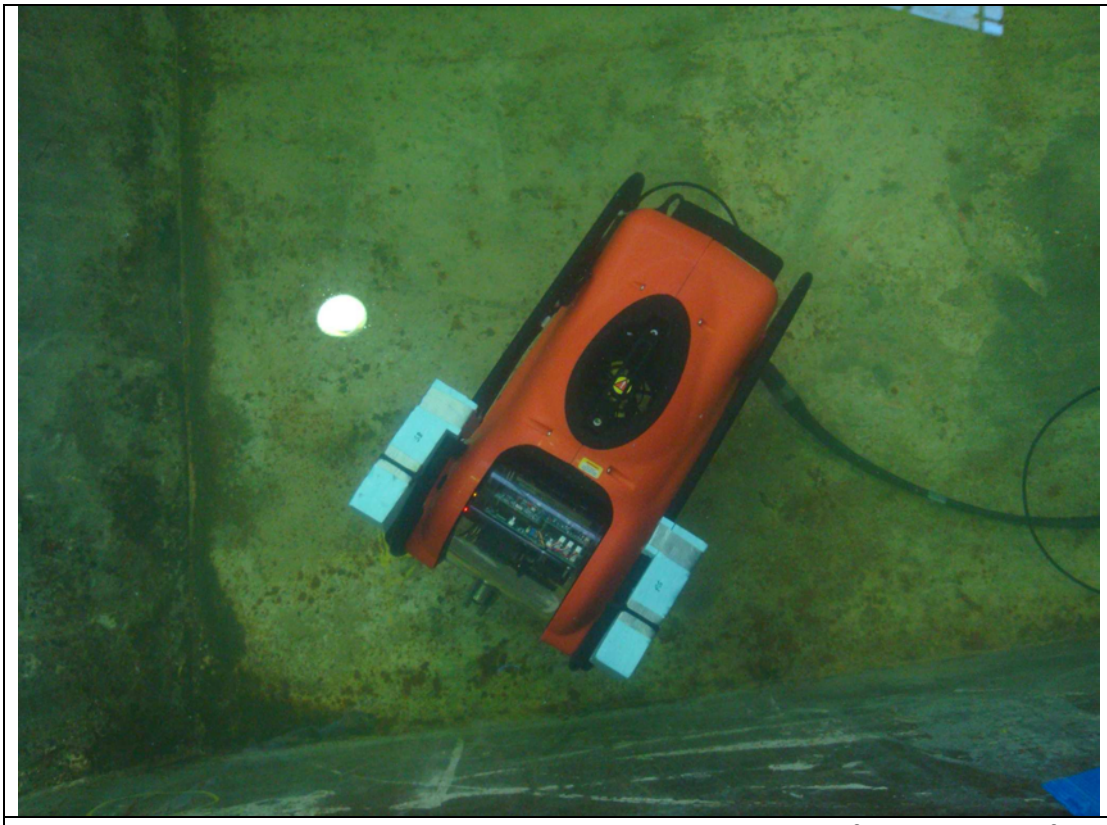


Picture 6: sensor lay out on railway cars for background measurements

Parallel partner Vallen adapt the AE equipment (sensors and acquisition unit) for the use at the different transport products, where all requirements according the intrinsically safety (EX) have to be satisfied.

A further important part of the project is devoted the follow-up tests. The availability of the different testing methods for their application as follow up tests with minimum interference of the service was checked.

One opportunity for the follow up tests for ships, especially double hull tankers, should be provided from a remote operated vehicle (ROV), which provide VT from suspicious areas but also could be used as an acoustic sensor carrier. For this reason it also became necessary to check the operational noise of this ROV.



Picture 7: Remote operated vehicles (ROV) with AE sensors for detection of the service noise

RESULTS OF THE INVESTIGATIONS

According to the data, which were acquired during the different lab tests together with the available data, we were able to acquire AE with directly applied and liquid contact to the degradation process sensors. The comparison between useful AE-signals and background were investigated and a path for the discrimination was found. Because the expected and/or measured background during the service operation is very high the discrimination has to be performed on a frequency domain pattern recognition system. Of course the background noise for the different transport products (ships, trucks and railroad cars) are completely different and has to be validated for every type of transport product itself.

For the AE signals also more advanced methods have to be applied, especially for the comparison of data, which were acquired on plates in different distances. We found meaningful differences of the AE signals between corrosion and fatigue cracks and here also between the different mechanisms. For the real tests themselves we have to establish much rougher classifications because of the influences of the environment and the noise coming from the different service conditions. The more quantitative determination of all influences have to be checked on tests on real structures, where we have real AE signals and the background noise available at the same time.

DISCUSSIONS

The first results coming from laboratory tests showed from the technical side, that it would be possible to monitor the structural integrity in term of developing fatigue cracks and wall thickness diminution due to corrosion. This will enable preventive maintenance on a condition driven basis. This proposal addresses ships, railroad cars and road tankers. The experienced structural failures for these products are similar and thus the same process applies.

Cost effectiveness is clearly given by reasonable installation and service costs of the monitoring system in relation to increased availability and safety, which even will be developed within the upper mentioned EC-funded project. Preventing failure of transport products is a major contribution to environmental protection. Minimising personnel entry into tanks improves working conditions

SUMMARY

The paper shall point out the today’s problems with the time driven maintenance and inspection of all ground transportation products. It shows that the conventional methodology is time-consuming, expensive and sometimes improper. By the application of a monitoring technique, which can detect the different damage mechanism during their origin, we would be able to replace the maintenance intervals by information, which is coming in-service and on-line from the monitoring technique. Acoustic Emission provides an integral statement about the structure and is therefore the only possible solutions for a complete monitoring.

During the pre-tests the application of AE was proven even the support of other techniques (e.g. preceding calculations and definition of hotspots, further in-service measurements) become necessary for a complete health monitoring of the transport products.