PROJECT NO: FP6-508298

SMARTSTRAND

A Novel Built-in Remote Stress Sensing Element for Increased Safety and Efficiency in Manufacturing, Mooring and Craneage Applications

Co-operative Research (Craft)

Horizontal Research Activities Involving SMEs

Final Activity Report
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PROJECT INFORMATION

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TITLE OF PROJECT*:* SMARTSTRAND – *A Novel Built-in Remote Stress Sensing Element for Increased Safety and Efficiency in Manufacturing, Mooring and Craneage Applications*

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1 Wirebelt
2 Astech Electronic
3 Nuova Faudi
4 ~~A & R Electronic~~
5 Webster and Horsfall
6 SIA

***OTHER ENTERPRISE / END USER CONTRACTORS*:**

7 Timm

RTD PERFORMER CONTRACTORS:

8 Pera Innovation Ltd
9 D'Appolonia

Abstract

A consortium of European SMEs with a rare combination of skills have successfully completed a project to develop a sensor wire material and non contact signal system for the manufacturing, construction, stone cutting and shipping industries. The project has solved problems associated with cable breakage by inventing a quantifiable sensor wire material and robust non contact signal system.

In a two year EC Craft project called SMARTSTRAND, the SMEs and researchers have invented a non contact system that continuously monitors the stress in a cable, stationary or in motion, for increased safety and efficiency in EU industry.

Overview

Many industries, as diverse as food manufacture, construction, stone cutting, shipping and mining, use cables that contain structural or strengthening wire elements under tension. The tension, stress and strain of operation in these installations leads to frequent failures, particularly when they are not set up perfectly to the optimum level of load, tension or straightness, or when they wear or go out of adjustment during use. The current methods used for inspection are subjective and as such lead to inefficiency and safety hazards.

The EC Craft project, SMARTSTRAND was set-up to develop a rigorous quantifiable assessment method to measure the real time stress in a cable. The consortium being transnational in nature comprises of skilled SMEs and a partnership representing end users manufacturing food, cutting wire, mooring ropes for shipping and wire ropes for construction.

Project Objectives

The objective of the SMARTSTRAND project was to develop and validate an innovative stress measurement process that generates signals from a sensor wire material in response to an applied external signal. As the system has to withstand harsh environments, to magnify the effect for industrial use a new wire element had to be developed based on nitinol, an alloy that has a super-elastic deformation mode exhibiting very high reversible electrical property changes.

Current methods of measuring stress on a cable are limited to the finite stiffness of the strain gauge used, which needs to be in contact with the cable to deform in order to measure loads. This leads to inaccurate measurement as a result of the strain gauge oscillating about its natural frequency. Hence the industrial objective of the SMARTSTRAND system was to develop an accurate non contact signal system for measuring stress based on the super-elastic and electrical characteristics of Nitinol.

The technological objectives of the project were to develop:

- A wire element to be incorporated into a normal cable manufacturing process, capable of sustaining a sufficiently detailed signal to give stress readings
- A forming process to turn the individual wires into rope element.
- A signal inducer and reader system capable of precisely reading to within 5mm to give new information about localised strain peaks and tight bends

- Integrated case study prototypes of a wire rope, mooring rope and a high speed cutting wire

Project Results and Approach

The project aimed to reduce the waste and Safety hazards associated with rope breakage in the EU industry through the non contact real time measurement of stress in an embedded sensor wire. To achieve the objectives of SMARTSTRAND, a two year research and development campaign was undertaken under FP6 Craft scheme to advance existing knowledge and overcome project goals.

The key scientific and economic achievements of the SMARTSTRAND project are:-

- Nitinol sensor wire: A nitinol wire that acts as a "sensor". The properties of the nitinol wire which are derived after heat treatment is a large change (28%) in electrical resistance for applied strain (6%)
- Nitinol sensor wire formed into three practical solutions: cutting wire, mooring rope and wire rope
- A non contact retro-fittable signal inducer and detector to provide continuous monitoring of the state of the rope/wire
- Feedback control loop to give information on the percentage strain and life of the rope/wire for **maintenance** and **safety**

A failure mode analysis was carried out to determine the practical failures of ropes and a set of experiments were defined to predict and prevent an occurrence.

Figure 1a – Stone cutting wire machine

Figure 1b – Mooring rope

The capabilities of several commercially available Nitinol shape memory alloy had to be investigated to map its electrical and mechanical behaviour. As such an extensive experimental campaign was set-up to determine the optimum processing conditions for Nitinol to achieve an effective electrical versus strain measurement. Although, the thermomechanical behaviour of Nitinol alloys, is not only strongly affected by the variation of processing parameters but also by even slight variations in chemical composition, a qualitative specification of heat treatment and cyclic training was defined.

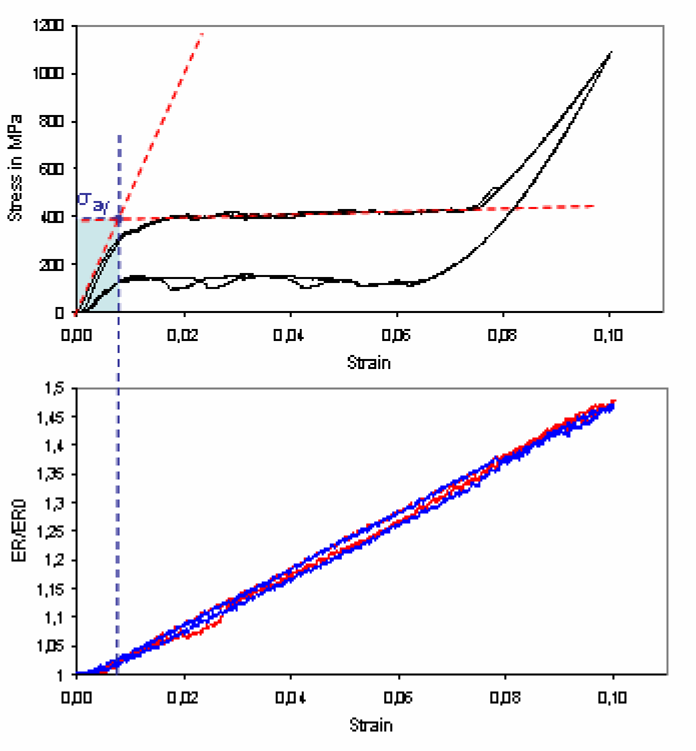

Figure 2 - Optimized curves of relative electrical resistance and stress versus strain

The signal spectrum and sensitivity of Nitinol has been investigated using several techniques. A contact technique has been used to determine the electrical resistance versus strain relationship at varying load. Initial tests carried out on commercial Nitinol showed that target processing was required to suppress the Nitinol phase transformation causing 'hysteresis' of electrical resistance measurements.

An optimized specification of the Nitinol sensor wire as shown on fig 2 was derived and the electrical resistance versus strain achieved is a 28% change in electrical resistance for a strain of 6% without hysteresis. Using this Nitinol processing specification, Nitinol has been embedded into three different prototypes.

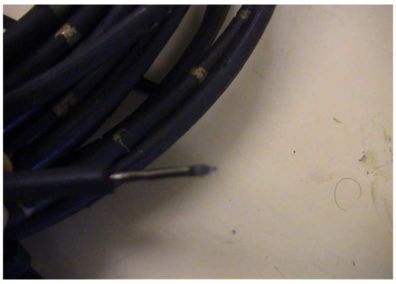

Figure 3 – Nouva Faudi diamond cutting wire with 2mm Nitinol (sticking out) wire as core.

Nouva Faudi Diamond Nitinol Cutting Wire has been constructed and tested. The core nitinol wire has been used for multiple purposes as a cutting wire due to its mechanical strength and as a sensor to detect the strain in the cutting wire.

Figure 4 – Timm Nylon mooring rope; Nitinol wire has a darker colour than the two stainless steel wires.

Timm Nylon Nitinol Mooring Rope has been constructed and tested. Nitinol has been used as one of the core wires instead of stainless steel to detect the strain in the mooring rope.

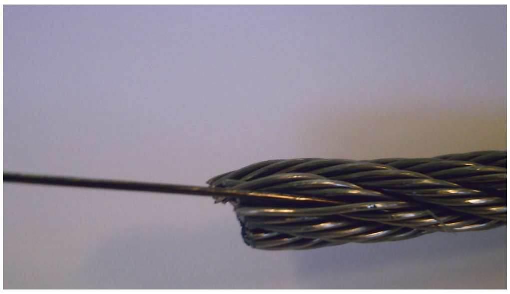

Figure 5 – W&H stainless steel wire rope; Nitinol wire protruding in picture.

Webster and Horsfall Stainless Steel Nitinol Wire Rope has been constructed and tested. Nitinol has been used as one of the core wires instead of stainless steel to detect the strain in the mooring rope.

The signal capability of two non contact methods was tested. An eddy current sensor was constructed to detect the change in resistance of the Nitinol due to strain. The maximum sensing range of the eddy current coil is approximately equal to the radius of the sensor coil. For highest accuracy and stability the radius has to be 3 x the range; a small sensor has a small range, too large a sensor has reduced sensitivity and the larger the sensor the larger the required wire dimensions.

The second method, a novel technique for sensing strain in non contact manner based on electromagnetic induction has been developed using two separate instruments. The first instrument is designed to induce a low frequency milliAmpere current into a looped Nitinol wire and the second instrument senses the current. The ability of the signal sensor to filter noise while maintaining signal integrity in the Nitinol loop is an essential characteristic when applied to the W&H stainless steel wire rope. A high performance control system, with high frequency sampling rate has been designed to complement the developed Nitinol sensor wire properties to produce a large change in resistance for strain. With this technique, change in signal current due to the stress on the wire can continuously be detected even while the cable is moving.

The development of the SMARTSTRAND technology has now been completed. This was achieved through the CRAFT scheme which offered the SME partners access to two European Research teams based in Genoa, Italy and Leicestershire, United Kingdom. The partnership between industrial partners and research teams provided the industrial and economic drive while achieving the technical project goals.

Marketing Plan

The success of the project objectives has been reflected on the interest from end user groups in various industries. In particular, the SME partners are committed to a robust plan to commercialize the SMARTSTRAND technology first in the fishing and shipping industry. They plan to achieve this through seeking additional funding from the European Community in FP7 to demonstrate SMARTSTRAND in this market sector.

The potential market for the product in the fishing and shipping industry is large. Eurostat estimates that the number of fishing vessels in the EU15 countries to be 90,000 and that may increase by 10% when the full EU25 nations are included. The worldwide potential is 1.4 million vessels (Fisheries and Aquaculture Department of the UN).

There is a growing need for a technology that will enable fishermen to preserve the quality and freshness of fish, reduce trawling times and avoid problems caused by overfull trawls. A fishing net snagging could result in loss of catch and the need to re-trawl wasting additional fuel. In shipping, a mooring rope snagging while under stress produces a dangerous backlash which could potentially damage contents of the vessel, cause injury or even death. As such achieving maximum efficiency from fishing gear and mooring ropes is essential to the sustainability of the industry.

The SMARTSTRAND product is the only technology that can continuously monitor the load on fishing nets and mooring ropes in a non contact manner. We expect SMARTSTRAND to positively contribute by assisting in compliance with the Common Fisheries Policy (CFP) by making the most of limited fish resources, given that a significant increase in fish landings is highly unlikely, by aiming at higher added value (reduced costs) for catches.

Conclusions

The SMEs and researchers have invented a non contact system that continuously monitors the stress in a cable, stationary or in motion, for increased safety and efficiency in EU industry. This has been recognized by senior experts in a consortium of fish associations lead by the SWFPA (Scottish White Fish Production Association) in a bid to bring SMARTSTRAND to their industry.

The SMEs have cooperated successfully on a TransEuropean level and are committed to exploit SMARTSTRAND by commercializing the technology in the fishing and shipping industry.

Acknowledgements

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PROJECT DETAILS

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SI Automation	SIA	Norway
Pera	Pera	UK
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