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Nippon Telegraph and Telephone Corp.
The University of Tokyo
GH Craft Ltd.

Joint Construction of a Fiberoptic Hull Damage Detection System Supporting Nippon Challenge in the America's Cup

NTT, The University of Tokyo and GH Craft Ltd. have worked together to construct the Fiberoptic Sensor Hull Damage Detection System (Figure 1) to detect deformation in and damage to the hull of Nippon Challenge, Japan's entry in the America's Cup 2000[1], the king of yacht races.

Yachts entered in the America's Cup have hulls shaped to provide minimum resistance and formed of light and very strong sandwich compound materials. Because they are designed at close to the limits of the strength of the materials used, technology was needed which allowed early detection of the location of deformation and damage (cracks or debonding) leading to hull break-down.

The Fiberoptic Sensor Hull Damage Detection System jointly designed by the above parties combines NTT's BOTDR[2] technology, the structural analysis technology of the Department of Environmental & Ocean Engineering at The University of Tokyo, and GH Craft Ltd.'s composite design and manufacturing technology. This is a radical new detection system which can measure the location of deformation in and damage to the hull automatically or by remote control by analyzing the continuous strain data which is obtained by the fiberoptic sensor attached to the hull.

Main Features

This system allows (1) structural design verification, (2) detection of the location of deformation and damage and (3) diagnosis through automatic measurement and remote control.

Technology Points

1)Feedback on hull structural design

This system produces three-dimensional strain data on the entire hull on the basis of the continuous strain measurement results by the fiberoptic sensors attached to the yacht rather than the point data by conventional sensors such as strain gauges[3]. Moreover, the system not only detects damage but allows checks on hull deformation.

Nippon Challenge and the other yachts are designed so that the rigidity in the longitudinal direction line is high to resist deformation, because the great force acts in the line direction. We practically measured strain produced in the both on the water and land, and analysed the change in their strain using the Detection System (Figure2). These results indicate that the hull has an ideal structure, and they were consistent with the structural analysis produced through simulations, proving that the hull has an ideal structure. This bears out the value of the Detection System in structural design verification.

2)Establishment of damage (cracks or debonding) detection methods

The point where cracks or debonding have actually occurred can be detected from the continuous strain distribution measured by the fiberoptic sensors (Figure 3).

By comparing the strains shown by two fiberoptic sensors attached along the bonded joints between hull and bulkhead, it is possible to detect failure of the structure by comparing the stress distribution whether the cause of strains appearing between material layers are the result of deformation or material cracks or debonding.

Further, by altering the type of optical fibers used in the sensors and elsewhere, their boundary can be used as a mark to correspond position between the fiberoptic sensor and the hull.

3)Diagnosis through automatic measurement and remote control

Automatic operation of the system makes it easier to detect damage which occurred in the yacht in New Zealand base camp. The system can also be operated by remote control using telecommunication lines, etc. During the America's Cup 2000, remote diagnoses will be carried out from Japan while Nippon Challenge is in its base camp in New Zealand.

Next Steps

The next steps planned by the three parties which worked on the Detection System are as follows.

To clarify the relationship between strain and damage (cracks or debonding), we perform simulation employing the finite element method which can calculate approximately deformation, abd an experiment using a model. In addition, we plan to collect fundamental strain data of the yacht while applying this system practically.

Glossary

[1] America's Cup 2000
The world's top yacht race, fought out with national backing to capture the sterling silver cup called the America's Cup, presented by the United Kingdom's Queen Victoria in 1851.

Subject to given rules and conditions, participating nations compete on the basis of their handling and construction technology.

*** Overview of the 30th America's Cup (America's Cup 2000)**

- Race area: Off Auckland, New Zealand

- Race schedule: Louis Vuitton Cup (preliminaries) October 1999-February 2000
America's Cup (final) February-March 2000

- Participating teams (as of June 1, 1999):
Defending yacht club: Royal New Zealand Yacht Squadron
Challenging yacht clubs: 15 syndicates from 10 countries (including Nippon Challenge)

The official Nippon Challenge Home Page can be found at:
http://www.nc2000.co.jp/

[2] BOTDR (Brillouin Optical Time Domain Reflectometer)

When an optic pulse is launched into an optic fiber from one end, some scattered lights is produced at many points along the fiber. The frequency of the light which comes back to the some end (Brillouin backscattered light) is proportional to the strain producing in the optical fiber. Strain is calculated from the frequency change of the backscattered light, while the measurement position is determined by the elapsed of time between launching and receiving the light. BOTOR enables us to perform long distance and continuous measurement without being influenced by electromagnetic noise, because the optical fiber is used as the sensor.

[3] Strain gauges

Sensors measuring strain using the change in the value of electrical resistance created when a metal thread shrinks or lengthens. These sensors are glued to the surface of the object for which strain is to be measured, and used by attaching them to a strain measurement device with copper cables.

Attachment

- Figure 1: Image of the Fiberoptic Sensor Damage Detection System
- Figure 2: Structural Design Feedback through Hull Deformation Measurement
- Figure 3: Establishment of separation detection methods

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