In-service inspections of deep water structures

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In-Service Inspections of Deep Water Structures

Inspection en service des structures en eau profonde

Inbetriebinspektionen von Hochseebauwerke

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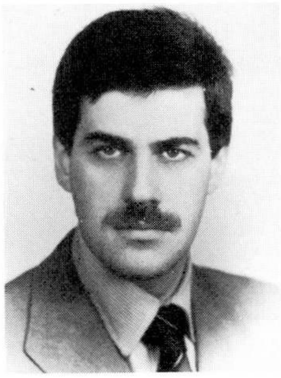

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SUMMARY
This paper deals with the analysis of the main problems which arise in the definition and management of the in-service inspection program for deep water structures. Present underwater inspection tools and techniques are briefly discussed and some applications to existing structures are reported.

RESUME
Ce mémoire traite les principaux problèms qui apparaissent lors de la définition du plan d'inspection pendant la vie des structures en eau profonde. On débat les techniques et les appareils d'inspection en eau profonde et on présente aussi des applications à des structures existantes.

ZUSAMMENFASSUNG
Dieser Vortrag behandelt die Analyse der Hauptprobleme, die bei der Definition und der Handhabung der Inbetriebinspektionspläne von Hochseebauwerken entstehen. Dazu werden heutige Unterwasserinspektionsgeräte und -techniken kurz erörtert und einige Anwendungen bei bestehenden Bauwerken beschrieben.

1. FOREWORD

The definition of an accurate and efficient in-service inspection program is an essential tool for the assessment of the structural integrity of an offshore installation and for assuring its reliable and cost effective operation at the highest possible level of safety to personnel and environment.

Since fixed offshore structures are designed for specific environmental and operational parameters, the inspection program is normally defined on a case by case basis, in order to comply with the specific requirements of governmental regulations and Classification Society guidelines.

The main philosophical aspects of these requirements are thoroughly discussed and reported in technical literature (/1/ ÷ /7/), but the actual trend to design structures for more severe environmental conditions and the recent development of inspection techniques require high priority, beginning with the description of the inspection program so as to include, in addition to sound engineering practise and judgement, all information derived from the design, fabrication and installation phases.

The need to incorporate these findings has necessitated the implementation and, if necessary, revision of the formulation of the R.I.NA. approach to in-service inspection in order to develop a more suitable and comprehensive program. The main philosophy of this new methodology can be summarised as follows:

1) the definition of the inspection plan should start at an early design stage. This leads to incorporation of the design parameters (stress level, fatigue life, stress concentrations, etc.) and selection of the critical items (most stressed areas, essential details, main mechanical components, if any) for inclusion in the inspection plan;

2) all "as built" drawings, survey reports, quality control documentation should be reviewed in order to define key items to be included in the inspection plan;

3) the scope of work of the inspection plan, its limits and applications should be highlighted before starting;

4) all NDT procedures and operators which are deemed suitable for the captioned structure should be previously defined; they should be qualified and certified for the specific tasks;

5) updating and re-evaluation of the inspection plan should be periodically carried out on the basis of the results of the previous inspections.

The main considerations and criteria from the design, fabrication, installation and in-service inspection phases, which affect the definition of a suitable and reliable in-service inspection program as well as the criteria for recording and evaluating the actual conditions of the structure at each stage of its life are discussed in this paper.

Present underwater inspection tools and techniques are also briefly discussed and some applications to existing structures are mentioned.

2. IN-SERVICE INSPECTION PROGRAM CONSIDERATIONS AND CRITERIA

In addition to the usual quality control and cost-effectiveness factors, the definition of a suitable in-service inspection program necessitates carefully taking into account at a conceptual design phase all the design, fabrication and installation considerations as well as findings from in-service inspections.

During the design activities, it is essential to thoroughly analyse all the design parameters, i.e. design load definition, material characteristic assessment, behaviour of the soil/structure interaction, efficiency of the cathodic protection system in order to identify the most significant areas and matters of the structure. This analysis results in:

a) the definition of the most critical nodes of the jacket and deck structure with respect to yielding, stability, punching and fatigue life;

b) the identification of zones affected by welding of padeyes, piping supports, seafastening, anodes and all other items which could reduce the fatigue life of the structure;

c) the identification of elements representing the foundations of cranes, drilling or production packages, bearings and hinges, if any.

In addition to the previous activities, during the design phase it is also advisable to establish a firm interaction between designers and operational personnel in order to develop the design, taking into careful consideration all the problems relevant to the inspectability of the structure.

This interaction is very important to enhance the reliability of both the structure and the inspection results and leads to a significant reduction of cost, since further costly procedures to correct abnormalities can be avoided.

The assessment of all fabrication procedures is another main influential factor in developing the in-service inspection plan. Since an early detection of significant defects is imperative to fabricate an adequate structure and considerably reduces the probability of failures during the life of the structure, quality control procedures are to be complied with in order to check material quality, weldings, tolerances and alignment of members.

During this "as built" phases, scantlings and dimensions, misalignment, welding discontinuities and any other deviation from specification are to be recorded in the inspection records. These records should be compared with the ones derived from the design phase in order to check possible overlaps of critical items in design and fabrication of the structure. This comparison is essential to enhance the selection process and to easure that all critical areas and items are included in the inspection program.

With regard to the installation phases, all the operations, such as load out, seafastening, towing, launching and final hook up operations are to be reviewed in order to ascertain that allowable limits are not exceeded.

During these phases suspected overstressing of members and possible damage which may influence the structural capability of the structure are to be noted in order to modify the frequency of inspections or to include, if necessary, other items in the inspection program.

3. SCOPE OF WORK OF THE INSPECTION PROGRAM

As already mentioned, the inspection program is based on information developed from the design, fabrication and installation phases and may vary from case to case, depending on many factors, such as type of structure, criteria and frequency of inspections, continuous monitoring, maintenance activities and so on. In general, the inspection program consists of the following main points:

a) specification of inspection items and extent;

b) definition of inspection types for each inspection item;

c) means, methods and equipment for each inspection item;

d) frequency and time schedule of inspection;

e) definition of actions to be taken in the case of significant findings or deviations from the inspection program;

f) procedures for reporting, filing and updating.

The definition of items and the relevant type, extent and programs of inspections is derived from the considerations discussed in the previous chapter. In particular, on the basis of different criteria (yield, fatigue, corrosion, consequences of failure), the structural elements (joints, members, components) are to be divided into different classes. For each class, the frequency, extent and inspection procedure and methods are defined in a rational way. This criteria leads to frequent and close inspection by means of one NDT examination after cleaning highly stressed members or members whose failure directly leads to loss of life and/or structure. For less stressed members, whose failure leads to slight local or secondary damage, only a visual inspection is foreseen.

In any case, the task of these structural surveys is to check for possible major damage (bent, severed or missing members) as well as to detect fatigue cracks at member-ends by a close inspection of weld and parent metal areas.

In addition, thickness measurements should also be carried out at selected points in order to check for any corrosion and pitting.

Reports of this inspection should define the location of any damage and the relevant extent, deflection and out-of-roundness of tubular member and any other significant concern. Photography video documentation is advisable for analysis and further review.

With regards to means, methods and equipment, it is to be noted that inspection of underwater structures is to be carried out by qualified personnel in order to comply with a standard similar to that required for above water inspections. The use of telecameras, photocameras and remotely operated vehicles is normally accepted on a case by case basis according to procedures previously agreed upon. The following fire underwater inspection techniques are generally used:

1) visual inspection (obvious damage detection)

2) magnetic particle inspection (surface crack and pit detection)

3) ultrasonic inspection (thickness and flaw detection)

4) radiography (internal defect detection)

5) corrosion-potential measurements.

Variations of these techniques include a magnetographic method of crack measurement and an açoustic holographic technique for internal flaw detection.

The application range of these methods and the relevant advantages and limitations are discussed below. It is only to be noted that, combining the quality assurance procedures for personnel and equipment, the validity and reliability of the results of the inspections are well within the acceptable range.

4. VALIDITY OF UNDERWATER INSPECTION TOOLS

As previously outlined, testing of offshore structures is carried out by means of NDT methods which are normally used to test land structures (/8/÷/10).

As in only a few cases could the particular working conditions be taken into account by making minor modifications or adjustments, completely new equipment was developed and manufactured for underwater applications. The aim was to allow testing to be performed without the need of skilled diver, as the satisfactory completion of the inspection was dependent on his ability.

One of the main aspects of in-service NDT is to compare results from previous inspections or from construction, therefore all NDT are to be performed in accordance with a detailed procedure which defines the requirements to be met with regard to:

a) degree of surface cleaning before NDT;

b) type and characteristics of equipment to be used;

c) diver NDT qualification for the specific task;

d) sequence of all operations;

e) acceptance criteria of findings;

f) report form to be filled in.

An outline of various NDT methods and their relevant advantages and limitations is presented below.

4.1 Visual inspection

The visual inspection is the most popular NDT method and is generally performed by divers using TV cameras or, where possible, Remote Operated Vehicle (ROVs).

The choice between divers and automated vehicles is mainly economical and also depends on the water depth and the extent of the survey. Photographic surveys, using 70 mm film, are required when a high resolution degree is required. When good lighting conditions can be expected, colour films are preferred, otherwise b/w films are used.

For detailed dimensional measurements, photogrammetry is used.

4.2 Magnetic particle inspection

Magnetic particle inspection is frequently used for the detection of major external defects, such as fatigue or stress corrosion cracks /11/.

Various methods of magnetization may be used, generally fluorescent powder on liquid suspension and wood lamp. Particular attention is to be paid to the choice of TV cameras and to the suitable filters to be used for recording purposes.

Recently, a lot of semi-automatic equipment has been made available. Much of it was tested by the authors and the results were particurlaly satisfactory when the true dimensions of the detected defects were recorded on magnetic tapes.

4.3 Ultrasonic testing

Ultrasonic testing is mainly used for thickness measurements and corrosion detection. Ultrasoning testing is widely employed for the detection of internal defects, particularly the ones initiating inside the structure.

For thickness measurements, both manual and automatic equipment is used.

Manual equipment, generally of the digital reading type, is available with built-in memories up to 1000 readings.

A probe in contact with the structure, can be kept on board the supply vessel. It is mounted on a track and moves according to prefixed positions. Its readings are sent to a computer which plots, in real time, the measured thickness.

Detection of internal defects, particularly for structural nodes, is mainly carried out by manual equipment.

Many solutions were studied allow the survey to be carried out from a supply vessel, giving the experts on board the chance to verify the actual results.

Generally, this equipment relies on the principle that the information on the diver's screen is exactly the same as that on the supply vessel.

Ultrasonic testing is appropriate for the detection of water level inside a structure suspected of through cracks.

4.4 X and γ Rays

This type of testing is not commonly used, being generally performed on double wall technique. When possible, X Ray Ir 192 is preferred for safety reasons.

The source is put in watertight envelopes and is kept at any suitable distance from the structure to be inspected, avoiding any contact with water by using gas or air chambers.

4.5 Acoustic emission testing

This type of testing is very promising as it enables the propagation of possible existing defects to be detected. Its main limitation is the high number of probes needed to keep a complete structure under survey.

4.6 Impressed vibrations

This type of testing is only applicable when cracks in some components of the structure are so important as to give rise to characteristic vibrations, easily detectable by a number of accelerometers suitably placed in the structure.

5. APPLICATION TO EXISTING STRUCTURES

As previously mentioned, R.I.NA. has tested many types of NDT methods for underwater applications.

In many cases, NDT techniques were developed together with the manufacturers of the NDT equipment and the results satisfy the technical need.

It is interesting to note that several of the NDT methods already discussed are generally applied to in-service inspection of offshore structures.

Structures in water depths ranging from a few meters to 100 meters were inspected and from the experience gained, no difficulties are expected in the case of deeper water.

Moreover, taking into account that the reliability of divers decreases when NDT is carried out in increasing water depth under saturated conditions, the tendency for future developments can be summarized as follows:

- visual examination: manual submersibles are to be used as far as possible, with the assistance of divers for specific surveys limited in time and extent;
- magnetic particle inspection: is preferable as it gives the chance to use divers who are not necessarily MPI experts as well as evaluation and referring equipment placed on the surface;
- ultrasonic inspection: computer assisted automated equipment of the C or P scan type, is to be used as far as possible, as this solution does not require particularly expert NDT divers;
- Eddy current testing: at the moment, multifrequency equipment which has particular probes is being studied.

6. CONCLUDING REMARKS

The development of an inspection program that yields a reliable assessment of the integrity of an offshore structure requires that:

a) the development should start at the design stage;

b) all the survey report of each phase should be reviewed for inclusion in the inspection plan;

c) the scope of work of the inspection plan should be carefully defined at an early stage;

d) all NDT procedures and operators should be qualified for the designated tasks;

e) re-evaluation of the inspection plan should be periodically carried out on the basis of previous inspection findings.

The initiation of these items should satisfactorily achieve the required structural integrity and assure a reliable and cost effective operation of the structure.

The used underwater NDT methods do not greatly differ from the ones applied to land installations.

The reliability of NDT methods depends on the degree of clearness of surfaces to be inspected and on human performance, which turns out to be strictly depending on environmental conditions. This results in a tendency to study and develop automatic equipment, which allows results to be more reliable and repeatable, and at the end, less expensive.

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