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2- "A General Outlook to Offshore Technology", Egyptian Society of Marine Engineers and Shipbuilders, Forth seminar, Alexandria, April, (Egypt-1983), Shama, M. A., (100%)

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A PROJECTION ON THE FUTURE DEMANDS AND CAPABILITIES OF OFFSHORE TECHNOLOGY

By

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1 — Introduction :

Offshore technology comprises the enginnering efforts required to support the exploration, utilization and transportation of offshore resources, the development of engineering products for the execution of these efforts and the study of the relevant environmental effects.

The broad demands for offshore technology comes from the exploration, exploitation and transportation of gas and oil, the increasing need for protein, minerals, ... etc. and the need for advanced oceanology and oceanography.

This article highlights the need for offshore technology and gives a brief outline of the main environmental effects associated with offshore industry. The major types of offshore structures are mentioned and the factors affecting their design are indicated.

2 — Need for offshore technology :

The need for offshore [redacted] technology comes from the demands of the following fields :

a) Exploration of offshore resources.

The continental shelves are simlar in geography and geology to the adjacent land. Thus, they contain many of the raw materials currently exploited on land and may therefore provide useful alternative sources when land resources become uneconomic or exhausted.

In this connection, underwater farming (vegetation and fish) has great possibilities in the Red and Mediterranean Seas as well as the Arabian Gulf.

b) Coastal protection.

Coastal protection could be achieved by controlling coastal waters, particularly near harbours and ports, and is very much needed after the building of the High Dam in upper Egypt.

c) Sea Transportation.

Environmental data on winds and waves are needed so as to improve the economy of transportation through synoptic forecasting, reduce the hazards to passangers, ships and cargo, develop high speed sea transportation systems and also to improve the design of ships and off-shore structures.

d) Oil pollution.

Study of offshore environment will help in the control and prevention of oil pollution in the Red and Mediterranean seas as well as in the Arabian Gulf, as these areas represent major routes for oil tankers. The beaches of these seas represent the future resorts for holiday makers. Therefore, their protection should receive the utmost care and attention as they will represent a major sector of the national economy.

e) Energy.

Wave and tidal energies may represent alternative energy sourcses after oil and gas fields are exhausted.

f) Ports and harbours.

Improving the design of new harbours, or ports, requires geolgical surveys and mapping of underwater sea bed. Dredging operations are needed to meet the increase in ship sizes. The size and type of dredging facilities depend entirely on the depth of water and the nature of sea bed.

g) Underwater technology.

Research in underwater technology will provide the means and tools for the execution of many of the offshore projects. Diving, manned or unmanned, represent an essential operation in all offshore projects.

h) Recreation facilities.

The beaches of Mediterranean and Red Seas as well as the Arabian Gulf require a lot of developments to attract tourists from Europe and other places. Special types of boats (such as hovercrafts, hydrofil boats .. etc.), recreation focilities, diving facilities ... etc. are required.

i) Navigational aids.

Buoys and other floating structures used to aid navigation require either fixation to sea bed or anchorage. The depth of water, currents and waves are important factors in the design of these structures. The nature of sea bed determines the methods required for their positioning. The achievement of these objectives can be realized only by designing suitable structures and facilities to operate satisfactorily and safely in the offshore environment. It is necessary, therefore, to study the main environmental effects relevant to offshore structures and operations.

3 — **The offshore environment :**

The offshore environment relevant to the design and operation of ships and offshore structures is divided into :

i — waves and winds.

ii — tides and surges.

iii — currents.

iv — temperature, salinity and density.

v — propagation of light and sound.

vi — properties of the sea bed.

A brief note on each item is given below :

i) **Waves :**

Waves represent the major factor affecting the motions of and the forces acting on ships and other offshore structures. Because of the stochastic nature of sea waves, they can only be described statistically. However, they could be related to the wind velocity, duration and the length of fetch.

For the prediction of motions of ships, or any floating structure, the wave system is described by a wave spectrum, which could be derived from data obtained from measurements in particular areas and over a limited period of time.

The orbital motion of waves affects a ship attempting to moor alongside an offshore platform. In shallow water, the orbital velocities of the bottom affect the movements of the bed material, thus producing scour around structures and bringing fine material into suspension.

Wave characteristics are measured by wave recorders. These recorders could be used for measuring :

a) vertical movements of the sea surface.

b) pressure fluctuations, using pressure gauges at the sea bed.

c) vertical acceleration, from which, by double integration, the vertical movements could be deduced, using shipborne or buoyborne recorders.

These types of wave recorders neglect the effect of wave propagation. Directional wave recorders may employ one of the following methods :

a) stereo-photographs, from aircraft.
b) array of recorders of the pressure gauge type.
c) measuring the orbital velocity components in two perpendicular directions.

The collection of detailed information on wave forecasts is necessary for :

a) The calculation of ship responses to a random sea. This will bring a better understanding of the behaviour of ships among waves and therefore will result in improved design and safety of ships and other floating structures.

b) The estimation of wave forces on piles. This will improve design methods of piled offshore structures.

c) Synoptic forcasting. This will improve the economy of transportation by improving ship routing.

ii) **Tides and sea level :**

The periodic rise and fall of the sea due to tides is of primary importance in deternining the depth of water available when approaching harbours and ports, particularly when large ships are considered.

Tidal levels may be seriously affected by storm surges produced by meteorological effects. Storm surges are more significant in shallow water than in deep water. A high surge may be dangerous for flooding and coastal protection. Low surges are hazardous to navigation and could lead to stranding of ships.

Strong winds create highwaves, surges and wave set-up, which is the rise of sea level near the coast. These three effects, when occuring at the same time, may represent a serious hazard.

iii) Currents :

Currents are generally divided into :

a) tidal currents.

b) wind-driven currents.

c) major currents.

The importance of studying currents stems from their effects on ships and offshore structures. These effects could be summarised as follows :

a) They impart their own motion to a vessel floating in the water, and thus will affect its course.

b) They exert forces on structures erected on sea-bed.

c) They cause movements of the bed material and bring the finer material into suspension. The bed movements can cause scour around some parts of a structure and deposition of material in other places.

The abrasive action of sand in suspension may also be significant.

iv) Temperature, Salinity and Density :

The temperature of the offshore environment has a direct effect on materials, structures and activities of divers and other workers.

Temperature and salinity affect corrosion of materials and the growth of plants and animal life in the water itself and on the hulls of vessels and other offshore structures.

Temperature, salinity and pressure determine the density of the water. The latter may change significantly with depth, thus having a direct impact on the design and operation of submarines, divers and other underwater vehicles.

v) Light Penetration :

Studies of light penetration are of increasing importance in view of the greater use being made of divers to make observations, take photographs or carry out operations, and of underwater television to direct operations by remote control.

As light travels through sea water, it experiences dispersion and absorption. Dispersion simply involves an alteration of the direction while absorption occurs when light is converted into heat. The rate of absorption of light in water depends upon the wavelength while degree of extinction (reduction in intensity) varies both with depth and turbidity of the water.

vi) **Sound Propagation :**

Although the sea is an unfavourable medium for the transmission of light and radio waves, it is a good medium for the propagation of sound.

Acoustic devices and techniques have been developed, such as echo-sounders. Asdic and sonar devices, developed originally for detecting and locating enemy submarines, are now widely used for fish detection and geological exploration.

Acoustic beacons may be used to improve navigation in restricted and shallow water areas.

Improvements in sonar systems are, therefore, needed for the accurate location and examination of underwater structures as well as for fish detection and exploration of sea bed.

The propagation of sound in water is determined by its velocity, refraction and absorption.

In sea water, the speed of sound depends upon temperature and pressure, it increases with the rise of temperature and pressure. The distribution of temperature and pressure over the depth of sea water can thus result in a minimum value of the speed of sound at a particular depth. The absorption of sound in water depends upon the frequency of the sound; higher frequencies being absorbed more readily.

Therefore, deep tones are normally used for the transmission of navigational signals.

The greater penetration of sound waves compared with light, in turbid waters has led to the development of underwater acoustic camera, which gives an optical presentation of the sea bed.

vii) **The Sea Bed :**

An accurate knowledge of the topology of the sea bed is essential for the navigation of ships in coastal waters and the approaches to harbours, especially when deep draught tankers are operating.

The geotechnical properties of the subbottom sediments are also required in planning the location and operation of drilling platforms, pipelines and other offshore structures to be installed on the sea bed as well as the operation of small submersibles and divers.

The holding capacity of the sea-bed should be determined for the safe anchorage of drilling rigs. Dragging of anchors may cause serious problems.

For bottom supported rigs, the ability of the soil to resist vertical and lateral vertical and lateral forces are required. The vertical forces are due to the weight of the rig and the lateral forces result from the wind, wave and current forces.

The main factors to be considered in the design of offshore structures could be divided as follows :

a) structures supprted by piles, legs etc.

i - adequate, penetration into soil,

ii - resistance to lateral loads,

iii - platform deflection due to unequal pile loading,

iv - bending and axial stresses in piles,

v - resistance to pulling out.

b) Structures supported by bottom hulls, pads or pontoons :

i - bearing capacity,

ii - settlement,

iii - resistance to lateral loads,

iv - scouring.

It is evident from the above, that the shear strength and soil friction are the main mechanical properties of soil required for the design of offshore structures.

4 — Offshore Structures :

The exploration, exploitation and transportation of the natural resources from the continental shelves are increasing very rapidly everywhere in the world. These demands have required the design and construction of various types of offshore structures such as those used for drilling or producing oil, service, pipelaying, heavy lifting, undersea mining, oceanographic research, aids to navigation . . etc. A brief note on some of the offshore structures required for the oil industry is given below :

a) Drilling rigs :

These units are designed especially to drill for oil and could be divided into :

i - **Ship type :**

These are self propelled units of shipshaped single or multiple hull form designed to operate afloat.

ii - **Barge type :**

These units are without primary propelling machinery and designed to operate in the floating condition.

iii - **Self-elevating or jack-up type :**

These units have a hull with sufficient buoyancy to permit the safe transport of drilling equipment, supplies . . etc. to a desired location . The hull then lifts itself on legs to the required level above the sea surface.

The legs may be designed to penetrate the sea bed, or to be attached to spuds, or to a mat which rests on the sea bed in the working condition and augments the hull buoyancy in the transit condition.

iv - **Column stabilized type :**

These are working platforms supported on widely spaced buoyant tubular columns. They may be designed to operate when resting on the sea bed, afloat or both. A unit designed for bottom operation only is described as submersible. A unit which may operate both on bottom or afloat is described as submersible/semi-submersible.

The columns are usually attached to a bottom mat or individual buoyant footings which contribute to the buoyancy and provide a larger bearing area for sit-on bottom conditions.

Draught or bearing pressure can be adjusted by ballasting tanks within the columns or footings. Additional primary support for the working platform may be provided by bracing members connected to the columns. Accomodation and storage is also provided in the upper structure, which may comprise several decks.

b) **Offshore Construction Equipment :**

These units are used mainly for pipelaying and heavy lifting. Deep water construction operations create several problems, among them is the accurate positioning of the construction equipment either at a location or on a fixed course, during pipelaying operations. Therefore, building, assembly and testing of oil rigs is required to be accomplished entirely on shore and not on site for safety and economical reasons.

In pipelaying operations, the maintenance of a fixed course could be achieved by the utilization of semi-submersible barges, which may have an internal dampening system.

In deep water the problem of accurate positioning cannot be solved economically simply by adding anchors. It is necessary, therefore, to use dynamic positioning systems. These systems consist of :

i - a positioning sensing device,

ii - a computation system,

iii - a propulsion system to provide the required thrust.

Most of the existing offshore construction equipment is in the form of sea-going barges, which are normally towed . The future offshore units will be self-contained sea-going, equipped with computer controlled propulsion units, which can also act as a course or position stabilizers.

The vessels will be specially damped so as to obtain a steady work platforms in varying sea conditions, and will be capable of cruising at speeds of 15 knots. The lifting capacity may reach up to 2000 tons.

Dynamic positioning in shallow water is more difficult than in deep water and may present serious problems.

c) **Loading Terminals :**

The increasing size of oil tankers dictates that their loading and unloading terminals to be positioned in deeper water. These terminals will, therefore, be exposed to currents, waves and winds. The cost and difficulty of building terminal piers, jetties or docks makes it very dsirable to have economical and simple means for loading and unloading oil cargoes, as well as for deballasting. These demands have produced two methods suitable for deep water loading and unloading of oil :

i - **Single point mooring :**

This unit is used for loading, unloading as well as mooring of large ships in deep water.

ii - **Rotating mooring pier :**

This unit allows tankers to berth alongside it and so offers certain advantages over the single point mooring, namely : higher operational safety and higher crude oil transfer rate. The design is simple as it is constructed of steel tubular structure and is partially supported by a number of buoyancy chambers rigidly fixed to its underside. The rotating pier can turn around its supporting tower through 360°, giving better safety against damage. Arrangements for handling more than one liquid could be easily made.

It shoud be mentioned here that reducing loading and unloading times has a direct effect on the economy of transportation. Also, improved safety during loading reduces pollution risks.

d) **Storage of Oil :**

The increase of offshore oil production may require storing of oil at the well site for direct shipment. The provision of these storing facilities may be more economical than storing in onshore tanks using a submarine pipeline. In shallow water areas, the loading jetty may be constructed in deep water. This situation may require floating submerged offshore storage facilities.

Storage of oil at sea could be carried out in conventional tanks built on fixed piled-platforms. This scheme is practical only for moderate water depths and in firm sea bed conditions. The possibility of placing the storage tank under sea surface is attractive, as it is subjected to a much reduced wave action.

e) **Service Units :**

These units are required for serving offshore rigs, transport drilling equipment and stores, placement and recovery of anchors, providing heavy lifting facilities, towing etc. The motions and forces acting on these units may represent major design parameters.

These units may include :

i - Supply vessels,

ii - Tugs,

iii - Crane boats,

iv - Derrick barges,

v - Workboats.

vi - . . . etc.

f) **Submersible Vehicles.**

The actual work necessary at sea bed level can best be carried out by divers, or by a manned submersible vehicle. Under certain conditions, divers cannot operate and subsea-self-propelled vehicles and diving chambers are required. The speed and endurance of these units present serious limitations on their capabilities.

These submersible vehicles are very useful for underwater survey operations, particularly for floating ship hulls. Underwater repair work saves cost and time for docking. The reduction of the frequency of docking of large ships will improve the economy of transportation. The reduction in ship speed due fouling and marine growth could be singnificantly reduced by underwater scrubbers, operated by skin divers, and underwater painting.

5 — **Factors Affecting the Design Of Offshore Structures :**

a) design requirements :

The design of an offshore structure to operate successfully in winds and among waves should be based on the following requirements :

i - Minimum motion,
ii - Maintenance of position during operation,
iii - Sufficient structural strength.
iv - Adequate stability,
v - Adequate safety.

In order to fulfil these requirements, it is necessary to estimate the maximum wind and wave forces that may act on the structure over the expected service life, which may be 25, 50 or 100 years.

b) factors affecting design :

The main factors affecting the design of an offshore structure can be broadly divided into :

i - Water depth,
ii - Wind, wave, tide and currents,
iii - Bottom soil conditions,
iv - Loads to be carried,
v - Number of crew men,
vi - Desired maximum motions,
vii - Mobility,
viii - Safety requirments,
ix - Structural strength,
x - Stability requirements.

A brief note on the last three items, as they represent major engineering design requirements, are given below :

i) **Safety :**

Broadly speaking, safety includes strength, stability, subdivision, fire and explosion protection. The need for improved safety precuations for offshore structures cannot be over-emphasised.

ii) **Strength :**

Floating ship or barge rigs can be treated like any floating vessel having regard to longitudinal strength. As offshore waves may be steeper than deep water waves, the height of the design wave should be determined from statistical data collected over a sufficient length of time.

For local strength, a three dimensional structural analysis procedure should be carried out. However , under certain conditions, two-dimensional analysis may be sufficient. Problems of stress concentration and fatigue should be thoroughly investigated.

iii) **Stability :**

Floating ship or barge rigs have the same stability problems as those of ordinary ship types. The high winds acting on the high stucture will create a substantial wind heeling moment. However, stability problems of offshore structures represent current research projects in several countries.

Catamaran hulls, or the outrigger-type ship, have very large metacentric heights. The same could be said about the jack-up type platforms, which usually have large lengths and breadths. However, when afloat, the range of stability may be insufficient , as the deck may be immersed at a rather small angle of heels. This situation could be rectified by increasing freeboard. When these platforms have individual buoyant pads at the bottom of each leg or a common buoyant lower hull, stability may require special study.

c) **Selection of Rig Type :**

The selection of a rig to perform a certain function depends on several factors, among them is the water depth. The following gives a guide for the operational depths of the different types :

i - water depths less than 50m, the fixed height submersible could be used.

ii - water depths less than 80m, the jack-up platform could be used.

iii - water depths less than 200 m, the semi-submersible or floating rigs could be used. In this case anchors could be used for positioning.

iv - water depths greater than 200m, the semi-submersible or floating rigs could be used but should be provided with a system of dynamical positioning.

6 — **Lines For Future Developments :**

In order to improve the present state of offshore technology to meet the future demands, it is necessary to advance developments in the following directions :

i - New materials suitable for offshore structures and operations.

ii - Efficient anti-corrosion and anti-fouling systems suitable for steel structures.

iii - A rational design procedure for offshore structures.

iv - Tools and mechanical devices to carry out underwater work.

v - A construction scheme for maximising construction on shore, so as to minimise erection on site.

vi - Collection of detailed information on winds and waves for the Mediteranean and Red seas as well as the Arabian Gulf so as to determine reliable mathematical models to be used in the design of offshore structures expected to work in these areas.

vii - Collection of data on the deterioration of materials underwater with particular reference to steel and concrete .

viii- Efficient underwater welding.

ix - Suitable system for hull cleaning while afloat.

7 — **Education and Training :**

In order to provide the expanding offshore industry with sufficient number of qualified personnel, it is necessary to introduce the relevant subjects of offshore technology, for both under and post graduate university education. Alternatively, a separate institution for offshore technology may be established for providing the required qualified personnel.

The new field of offshore technology will certainly develop at a high rate and will form a major sector of the national economy.
In order to provide this field with the proper personnel, special education and training is required so as to carry out the required work efficiently, safely and economically.

8 — **Concluding Remarks s**

Offshore engineering and technology is a new field devoted to the exploitation of offshore resources. Presently it is totally in the hands of specialized firms, who have access to both the capital and the know how. It is not, however, a formidable task for the Arab World to venture in this field, as the capital and some of the technology are both available. The lesson of exploration and exploitation of oil within the last 30 years, should give us the driving force to pave the way to a cooperative Arab approach for the exploitation of our offshore resources.

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