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Nets for offshore mariculture

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SUMMARY – The importance of secure and trustworthy cage nets is widely understood in aquaculture. Modern offshore cage farming, using very large cage volumes in very demanding conditions, places a particular demand on the design and manufacture of good quality nets. This paper explores the evolution of the nets currently used in offshore locations, and explains how the current designs were reached, and modifications implemented. Future directions for offshore cage net design and development are discussed.

Key words: Offshore, aquaculture, cages, nets.

***RESUME –** "Les filets pour mariculture en haute mer". L'importance de la solidité et de la fiabilité des filets est généralement bien comprise en aquaculture. Les systèmes modernes d'élevage en mer, qui utilisent des cages de très grand volume et ce souvent dans des conditions très difficiles, nécessitent une grande exigence quant à la mise au point et la fabrication des filets. Cet article passe en revue l'évolution des filets utilisés en aquaculture de haute mer et explique comment on a abouti aux conceptions actuelles et quelles modifications ont été apportées. Les évolutions potentielles dans le domaine de la mise au point et du développement des filets destinés aux exploitations en haute mer sont également discutées.*

***Mots-clés :** Offshore, aquaculture, cages, filets.*

Introduction

Fish cages including nets, the cages themselves and moorings, have to withstand all types of weather conditions all year round. Most insurance underwriters, when asked about equipment failure in fish farming, would say that net failure is an important source of fish loss and hence insurance claims. This paper therefore explores the evolution of the nets currently used in offshore locations, and describes how the current design for such cages in Ireland and Europe was reached, the decisions that had to be taken and the modifications that were implemented.

Early nets

The evolution of net technology follows the same route as that of cage farming. From the simple early cages like Tess, Sterner and small wooden cages (see also Christensen – practical development of offshore mariculture systems: the Irish experience, this volume), the nets were very simple structures and of course small in dimension. Many of the nets would have been about 6 metres square (like some lake nets today) and basically just a square bag. They would not have special stitching or seams and would have been made with simple downropes and probably knotted netting. Even when the cage support structures were not square, the nets themselves tended to be square. It evolved, of course a little later on so that the net would give maximum volume if it followed the shape of hanging structure on the cage. Thus a hexagonal wooden cage would be more efficient if it had a net that was shaped more like a hexagon or circular rather than square. Nets then moved on with the addition of fittings such as "jug handles" on down ropes, which facilitated lifting and changing, and suitable places to tie net weights. Essentially as farmers got more experience operating, the net makers incorporated additions and changes to make the net easier to handle and more efficient.

As cages began to get larger and change shape, and move further offshore, demands for stronger and better designed nets became the norm. As the demands for more exact specifications arose, the designs had to be advanced to suit the demands of the fish farming industry.

Design and manufacture

The initial process will involve taking a brief from the cage manufacturer and/or perhaps the farming company. Key stages are as follows:

(i) The layout of the cage will be important, as will be the position of the net supports.

(ii) The weight of the net will also be important from the cage manufacturers point of view.

(iii) The fibre maker is consulted on the strength of the material most suitable for the net. This will include considerations of determining the best strength of twine, having considered the resistance of the net; the drag on the mesh; the size and diameter of the twine.

(iv) All these will be taken into account to determine the forces that will be obtained on a clean net. These figures are usually determined as kg/m^2 on a net panel. Potential forces on a dirty net must also be noted (see later).

(v) A model of the net may then be made up, after discussing the layout with the cage maker. In some cases a model test will be carried out in a wave tank.

(vi) The cage maker will also have cage models for the wave tank test.

(vii) During model testing, efforts are made to try and mimic the full-scale cage and net as near as possible under wave tank conditions.

(viii) The whole experiment will usually be shot on video and played back in slow motion to examine the movement of the cage and net together.

The tank test will involve making a dimensionally correct model so that the forces can be measured on corners, top floats and the effects of tidal currents, etc. (see, e.g., Carson, 1988; Rudi *et al.,* 1988). Following the tank testing, a full scale net is made for demonstration and testing under field conditions. IC Trawl was involved in this process with Bridgestone for example, in the early years of use of the cages in Europe.

When the first Bridgestone cage was supplied to Ireland in 1985 the net specified by Bridgestone was to be of a 25 mm No. 210/24 knotless nylon. This had a breaking load of 30 kg. The net was constructed and installed but very quickly it became apparent that though possibly suitable in Japan it could not cope with conditions for the west coast of Ireland in terms of strength and design.

With research and model testing, we began the task of redesigning the whole net structure. The result today is a very strong net with many safety features built into the net itself and into the rope frame. From the original size of 210/24 or 30 kg, twine sizes have gone up to 210/300 with a breaking load of 260 kg. The biggest cage nets we have made, probably the biggest in the world were 2.5 t dry and ~4 t when antifouled.

Materials used

In making a net for a specific purpose many considerations are to be taken into account, such as the forces applying on the net, their distribution around the net, the kind of materials the net and rope frame is made from, and the way in which these are used. The main forces on any net structure are those arising from winds, waves and currents, and from the interaction of the cage structure and its mooring system with the resulting movements.

Type of material

The rope and net industry has seen many changes in the last number of years. Initially only steel and natural fibres were on the market as raw material. In the 40s and 50s high tenacity polymeric fibres were developed, such as polyamides and polyester, with many advantages over traditional materials. This opened the way to new low weight constructions with rot resistant materials. Because of their chemical composition, polyester and polymides have intrinsic advantages for use in the marine environment. Water hardly affects their properties and cold-water shrinkage is virtually zero, so they can be regarded as a very stable material. Apart from its insensitivity to water, the chemical composition of polyester and polymide results in properties such as UV weathering and wet abrasion resistance being far superior to those of other materials.

For polyester trawl nets, the towing resistance is about 25% lower than polyethylene and about 15% lower than polyamide. The same low flow values apply to fish farm nets which would be beneficial to water exchange and for the stability of the net cages in currents and winds. The weight of polyester under water is about 3 times as high as that of polyamide. This may have clear benefit in seine/harvest nets, which have a higher sinking speed as a consequence.

However, polyester rope and net is in limited use, mainly as early polyesters had low strength efficiency. Although linear strength was very good, strength in a rope or net was not particularly good, and to get the same net strength as polyamide about 20% extra polyester material has to be used, hence reducing the advantage. AKZO Nobel are actively developing a product called Diolen efficiency which should improve this performance. However, polyester is likely to have limited use for making nets for flexible hi-seas cages as it has very little elasticity.

Knotted and knotless mesh

Traditionally, fishing and farming nets were made from braids of twine by knotting. The advantages of such nets were good resistance against damage and ease of repair. The disadvantages were the low production economy and the knots protruding from the net, which could cause damage to fish, especially in fish farming (see, e.g., Beveridge, 1996) A great proportion of the yarn goes into the knots, which increases the weight but not the usefulness of the net. This proportion increases with decreasing mesh size and increasing diameter of the net yarn. Thus knotless netting has many advantages: (i) for the same area, knotless netting is lighter and the bulk is greatly reduced, by a decrease in mass of up to 50%; (ii) due to the lighter and less bulky netting it is easier to handle; (iii) production costs are lower because of saving on material; (iv) abrasion resistance is higher because of smoother surface; and (v) with the same mass of netting per unit area, the mess breaking strength of knotless net is higher.

Mesh types

There are essentially three mesh types: square, hexagonal and diamond mesh. In our construction we use only square mesh, as is found to give the maximum water flow through the net. Furthermore, its continuous straight line of meshes when mounted on the ropes gives extra strength.

Construction of the net

The net design has been finalized and have evaluations have been completed, manufacture of the net can proceed, approximately as follows:

(i) *Cutting out.* The cutting of the netting, the joining and fitting of the ropes to the netting are done by highly skilled craftsmen, after scrutiny of the netting and taking into account the possible effects of currents and wave forces:

- The construction principle is that the ropes must take the heaviest loads.
- The density and tightness of the knots must be sufficient to secure an even transfer of the loads from the ropes to the netting and viceversa.
- Loads should be transferred over as many meshes as possible, thus reducing the risk of mesh breaks.
- Tight knots are important to avoid loosening during washing, with the rubbing of net twines against mounting twine and meshes breaking, being the result if the knots are not properly tight and secured.

(ii) *Finishing.* Every fish farm has its own special requirements and this means all nets are tailor-made to suit the cage system, depth and other specific requirements of the farm. The company uses only the highest quality netting and ropes, with craftsmen trained to a very high standard. These factors are essential in establishing the reputation for the strength and durability of nets.

The industry is expanding further into more inhospitable areas, with larger cages, and collars being developed for heavier seas. It is important that specially designed and tailored nets, unique in design, are built to withstand the same environmental forces as the cage collar, and at the same time protect the fish during extreme conditions.

Maintenance

Ultra violet rays are harmful to netting; intensive sunlight can reduce the breaking strength dramatically even after a few weeks. The parts of the net that are exposed to the sunlight, mainly above the waterline, will be more rapidly broken down than parts under the water. However, significant amounts of UV radiation will penetrate to several metres depth in clear water. Therefore all netting should be UV stabilized by adding protectant chemicals during the process of yarn manufacture. Cage nets that are not made from fibres that are UV stabilized will have their breaking strengths reduced to less than 50% of their original strength in a very short time.

Akzo, one of the main fibre manufacturers, has mixed into the yarn polymer, a UV stabilizer (HR system), which gives the yarn better stabilization and protection against daylight degradation. This effect was demonstrated (Table 1) in a laboratory test using a Westinghouse UV lamp at 20°C.

Table 1. Residual strengths of yarns

Exposure times	2 weeks	4 weeks	6 weeks
Polyamide 6 with HR	95%	90%	80%
Polyamide 6 without HR	40%	25%	20%

This is just a laboratory test, and AKZO for example, as part of an extensive programme of testing, test their fibres in the open air, exposed to sun, rain, etc. as well as under water at 50 metres, and in tidal areas. Testing under actual conditions is usually done over a three-year period.

Antifouling

It is imperative that the antifouling used does not affect the flexibility of the net. Some solutions on the market will make the nets stiff and hard, which may cause damage to the nets. Antifouling should last 9-12 months depending on conditions. The usual application rate is 1 litre of antifouling to 1.2 kg of netting.

Repairs

However strong the materials and well made the nets, it is imperative because of the hard working environment that nets are maintained to very stringent standards, which means constant checking. If the farmer fails to maintain his nets, then failure can occur, which could lead to a possible tear and fish escape. It is important always to repair the smallest of tears in a net. It is also important to check the netting when the net is 11/2 to 2 years old and thereafter once or twice a year. When the net has lost 35% of its original strength it should be taken out of service.

Changing, handling, washing and storing nets

It is very important here, especially with larger nets, to remove them carefully and lift them with a crane only at specific points. Because nets are so large now like the octagonal Bridgestone and crane lifting power so great, an inexperienced operator can do a lot of damage especially to a heavily fouled net. A net should never be dragged across a hard surface such as concrete stones. When not used, nets should be cleaned, dried and stored in a cool dark, dry place.

Washing bags (socks) are best used with large nets when putting nets into large netwashers. Again large lifting capacity is needed for dirty nets, e.g., some weigh up to 4-5 tons dirty. This is where the abrasion resistance of the nets is important, and depending on the handling of the net and the effects of the washing process, it may be that the more the net is left out of the water and, the more it is washed, the higher the loss of strength.

Minimum time should be used for drying and the net stored under cover in between uses.

Life of nets

UV treatment, handling, amount of time out of water, exposure to sunlight, cleaning, all affect the life of a net. From the general experience around the world, it would appear that the average net life is three to four years. This of course is dependent on the type of material and the history of the net such as environmental forces and handling to which the net has been exposed.

Other nets

Top nets

Top nets are important, especially on smolt or other fry input, when fish are small and seagulls and other birds can take a lot of fish from a big cage. On large cages offshore, top nets have to follow the movement of the cage and stay out of the water especially when the cage is flexing, otherwise it would damage the fish. On Bridgestone and similar flexible cages, this is usually achieved by raising the handrail stanchions to 2 metres and using special roping techniques.

Predator nets

Predator nets have been very successful in protection against seal attacks but can be difficult to manage on large cages. Some Insurance companies require such nets to be used. They are commonly made of 100/200 mm nylon, and rigged with lead rope at the bottom, to keep the sides of the net tight.

Harvest Nets

Special harvest nets are important in offshore cage farming. They are made from knotless nylon with floatlines attached and braided leadrope containing 0.5 kg to 2 kg per metre at the bottom

The offshore net of today and tomorrow

With stricter environmental regulations and a greater pressure on costs, there is trend towards using larger offshore cages. For all the reasons outlined previously, such as water exchange, there is a perception that more fish can be reared per cubic metre. The consequence of this however is: (i) farming takes place in rougher conditions; (ii) inspection times are usually curtailed with fewer possibilities for maintenance; (iii) higher risk due to increase in number of fish per cage; and (iv) the value of fish is higher, thus high net reliability is desired.

This will continue to be the goal with the utilization of improved netting materials and construction being required all the time.

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