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STUDY ON POLYESTER MOORING MATERIAL FOR DEEP WATER OFFSHORE STRUCTURE

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ABSTRACT

The material of mooring line can be classified as chain, steel wire and synthetic fibre rope. In oil and gas industry, chain and wire rope are used as a mooring line material in shallow water condition normally. However, when the oil and gas exploitation is in deep water region, synthetic fibre is often selected as an alternative material for mooring line. In this paper, the objective is focused on the material characteristic of polyester which use for deep water mooring line. Tensile tests were conducted in this research to analyse the material characteristic of the mooring line materials. In the experiment, the length of polyester rope is 200mm. The selected nominal diameter for polyester ropes are 4mm, 5mm and 6mm. Finally, a discussion and conclusion base on the collected data is presented to compare the different diameter of polyester rope.

KEY WORDS: *Mooring line, Polyester, Steel, Material, Tensile test*

NOMENCLATURE

FPSO	Floating Production Storage Offloading
HMPE	High Modulus Polyethylene
PET	Polyethylene Terephthalate
PSC	Parallel Strand Construction

1.0 INTRODUCTION

In offshore, the exploitation of oil and gas is become deeper. Fixed platform become difficult to install and expensive in the deep water area. Most of the platform in the deep water area are floating platform. Since November 2013, there have around 277 FPUs which is 62% were FPSO (Gordon, Brown, Allen, & Gl, 2014). Floating platform that will use in this research is round shape fpso.

One of differences between fixed and floating platform is floating structure have unique requirement which is mooring and station keeping system. Station keeping is a term that used for the system to keep the platform within a specified distance from a desired location (Chakrabarti, 2005). The station keeping system is consist of mooring line and thruster (Chakrabarti, 2005).

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Mooring is referring as a connection between the structure and the seafloor for the securing structure against environmental loads. Mostly in offshore platform, it is used steel wire and chain as the material for mooring line offshore. This conventional mooring rope has been used more than thirty year experience as the material of platform mooring (Fletcher, Calverley, Cawthorne, & Mohanraj, 2010). When exploitation oil and gas become deeper, the conventional material are reaching their natural limitation. Due to that, it is require innovative solution to ensure performance in critical location by control the weight of mooring line and also to achieve cost effective station keeping (Mohanraj, Cawthorne, Calverley, Fletcher, & Verwaayen, 2013). In this research is focus on the type of material for deep water mooring line.

2.0 MATERIAL PROPERTIES

Today have variety of fiber rope can be considered for use in mooring system such as polyester, aramid, HMPE and nylon (Aasland, Sogstad, & Veritas, 1999). In this topic will be explain about the material that used in this research and applicable for the mooring line. Besides that, will be compare the characteristic, mechanical properties and limitation. The material that be used in this research is polyester.

2.1 Steel Wire

Steel wire are commonly use in engineering application such as crane, lifts and offshore mooring line. Every class of steel wire are suit for different purpose. Steel wire have been use a long time for a mooring line of offshore platform. The weight of steel give restoring force for the platform. When in deep-water, this steel wire rope have reach nature limitation. It have several limitation of steel wire use in deep water. Firstly is excessive line pretensions are required to maintain an acceptable horizontal angle at the fairlead and this reduces the payload of the platform (JIP, 1998). Besides that the larger and expensive handling equipment is required. Normally steel wire use catenary mooring. The catenary mooring take up large area of seafloor if use for the deep water. This can cause the heavy weight of steel and subsea buoy must be strong enough to winstand the hydrostatic pressure at appropriate water depth. In tensile load, the steel wire subjected to bending and torsion moment, frictional and bearing load and tension. The distribution of stress resulting from the loading is determine by the elongation and rotation of wire steel rope. Next will explain about the synthetic fiber will use in this research.

2.2 Polyester

Polyester is a one of types of fiber which is the mechanical properties is quite close to nylon. The abrasion resistance of polyester is better that nylon and so is the tension-tension fatiques performance. Since the cost of both fibres is quite similar, polyester should generally be preferred. In favour of nylon is its lower density (1.14 vs 1.38) and higher energy absorption. Under normal working conditions, polyester is not sensitive to hydrolysis. The melting point of polyester is around 260°C. The UV Resistance is good(BEXCO, 2004).

It have several differences between polyester and other fiber. Firstly, the cost of polyester is more affordable compare than aramid and HMPE (Flory, Banfield, Berryman, & Intl, 2007). Besides that, the strength conversion of polyester is more efficient at converting fiber strength to rope strength compare with aramid and HMPE. For the elasticity of modulus, the rope stretch at 50 % of breaking strength. The abrasion and bucking resistance of polyester yarn greater compare to aramid yarn. The axial compression fatigue is the major problem for the aramid rope but not for polyester rope(Road, 2000). Polyester creep effect is slightly but still stabilize.

This research will use polyester rope as a lightweight material for mooring line of deep-water offshore platform. The effect of the rope expose on seawater is very important in this research. This polyester rope is excellent resistance to the effect of seawater compare with nylon is loses 10% strength and it is abrasion resistance deteriorated significantly in water (Devlin, Flory, & Homer, 1999).

It have several benefit of fiber rope for deep water mooring line. Firstly can reduce offset. As we know that fiber rope is using the taut leg mooring which significantly smaller offset and also easy to install. Beside that, taut mooring line also use less line length with consequent save in storage, transport, installation and inspection. The footprint also smaller gives an advantage in area where considerable amount of subsea equipment deployed. It is also use less equipment because of fiber rope can provide high restoring capacity without using buoys and clump weight. Besides that, it is also reduce handling weight because fiber is lighter than steel wire. The installation fiber rope is simple compare with steel wire and this lighter installation weight can reduce installation costs. The payload will become more because of the fiber rope mooring system apply smaller vertical loads to the moored vessel and thus increase the effective payload.

Fiber ropes made from the assemblies millions of fiber. The characteristic is very complex with the hierarchical structure. The base components is the fiber or yarn are modify by twisting operations. It have several types and components of fiber ropes:

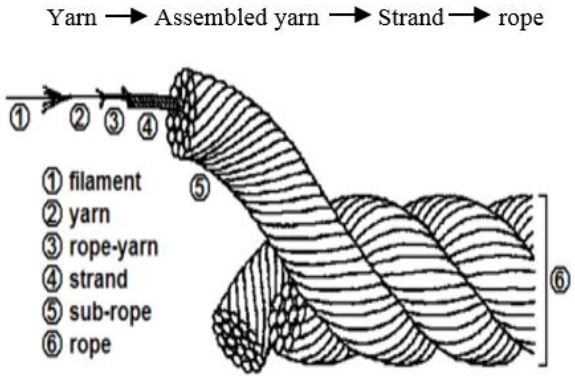

Figure 1: Example of construction geometry of a typical marine synthetic rope (Lechat, Technology, Ecole, & Brest, n.d.)

Breaking point of polyester rope for mooring line can be found at 15% of elongation (Ćatipović, Čorić, & Vukčević, 2012). The high elongation has great influence and should be include to achieve better prediction of FPSO dynamics. Stiffness non-lineality of polyester mooring cable has been studied by Fernandes et al. (1998). In this paper, polyester rope was tested with model scale cables. It is show that the mechanical properties of the polyester is give more benefit when use as the mooring line in deep water area compare with the steel wire mooring line.

In design phase of the polyester mooring rope is to identify the axial stiffness. It is because the response and performance of the polyester taut leg mooring system is depends on the characteristic of the axial stiffness. The axial stiffness must be sufficient to maintain the vessel and also to prevent overloading of the system.

4.0 POLYESTER ROPE TENSILE TEST

In this research, tensile test experiment was conducted to identify the material properties data for polyester rope. For this paper only focus on tensile test polyester rope and test was done by using model scale. Data collected from this experiment is applied to obtain the stiffness of mooring line in model scale. The elongation curve and also minimum

breaking load of wire rope will achieve target to select model scale mooring line. Figure 2 show the polyester rope is set up at tensile test machine.

Tensile test for solid bar and rope is different. The rope require more precaution to obtain acceptable result. It is because the rope is consist of several number of strand. The important during preparation of this tensile test is the clamping tool for the sample to ensure the load can apply to the rope and fully distribution to all strand. It is to avoid the rope break at the lower tension load condition due to bad distribution of force to all strand of rope.

Figure 2: Tensile test machine

In this research, tensile experiment have been done by using material from CORDAGE INDUSTRIAL ROPE (M) SDN. BHD. The length of polyester rope is 200mm and nominal diameter of 4mm, 5mm and 6mm were tested. The sample of tensile test for 4mm and 5mm is showed in figure 3 and 4. In figure 5, 6 and 7 show the graph of tensile test for polyester rope between force and elongation. As can see, the elongation of wire rope 6mm is longer compare to 4mm and 5mm. Also the force is applied on 6mm polyester rope is higher compare with 4mm and 5mm polyester rope. From the tensile test, it show that the minimum breaking load (MBL) of the polyester rope of nominal diameter 4mm, 5mm and 6mm are 2.95 KN, 3.59 KN and 5.93KN.

Figure 3: 4mm tested polyester rope sample

Figure 4: 5mm tested polyester rope sample

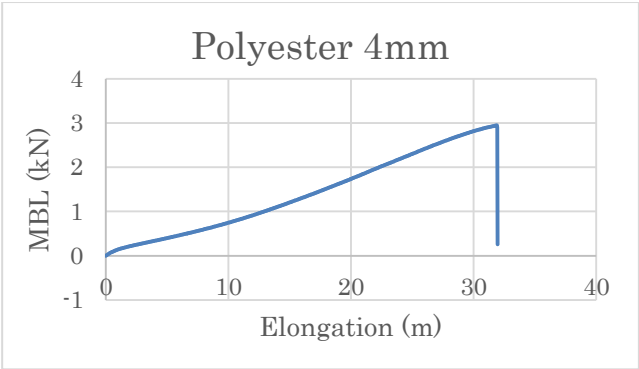

Figure 5: Tensile test result of 4mm nominal diameter polyester rope

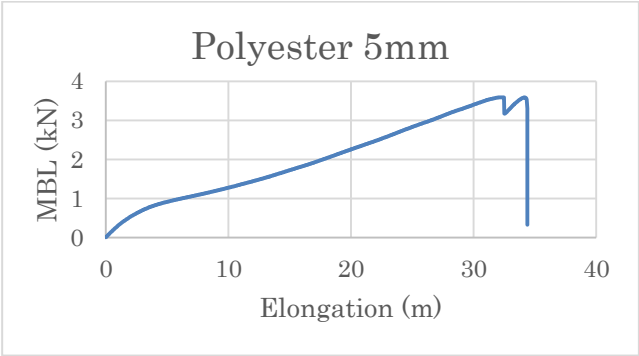

Figure 6: Tensile test result of 5mm nominal diameter polyester rope

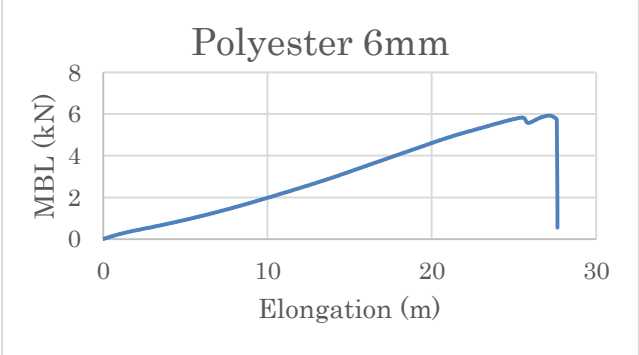

Figure 7: Tensile test result of 6mm nominal diameter polyester rope

The elongation of fiber mooring is depend on the applied force acting on the rope stiffness (JIP, 1998).The stiffness of fiber depends on many parameters. The most important are load, strain range, loading history and some of cases is cycling frequently. Table below show the differences elongation and minimum breaking load (MBL) of polyester between the previous data and the experiment with different diameter of polyester rope.

Table 1: Elongation and MBL of polyester rope

diameter	elongation original	elongation experiment	MBL origina	MBL experiment
4	28.75	26.91	2.92	2.95
5	30.375	27.31	3.625	3.59
6	26.125	22.14	5.67	5.93

The graph below showed that the diameter and minimum breaking load (MBL) compare between the previous and experiment data. The result showed that the percentage elongation of polyester is 10 to 15 percent.

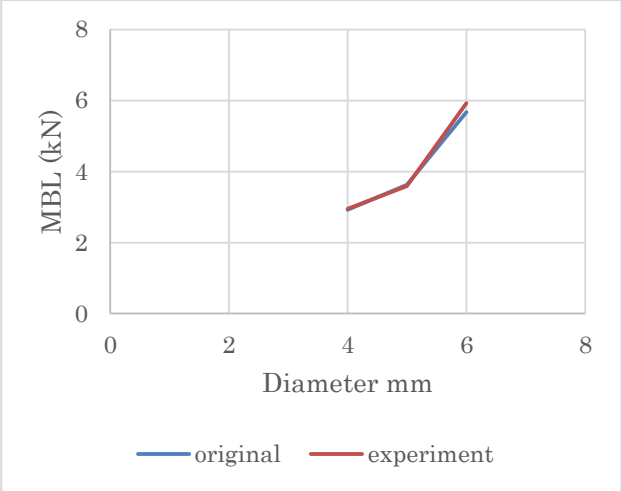

Figure 8: Diameter vs minimum breaking load of polyester rope

5.0 CONCLUSION

The conclusion of this review paper is show the limitation of steel wire and advantage of polyester rope foe deep water mooring line. Besides that, polyester rope also is potential as an alternative for the future mooring line especially for deep water platform. The future research will continue on identify the stiffness and axial compression of polyester rope mooring line.

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