# HMPE Rope – Capability with Caution

## Introduction.

***CHIRP*** Maritime recently received a report detailing the use of HMPE (High Modulus Polyethylene) ropes as towing lines.

*The port in question retires the tugs' HMPE lines on the basis of the number of jobs that the line has undertaken. The tugs are fitted with 60mm rope lines which are retired after 2,000 jobs. Upon withdrawal, the lines are then tested to destruction. The expectation of the actual failure of the rope has been based upon a ratio considering bollard pull versus the minimum breaking load (MBL) of a new rope. For an in-service rope the assumption was that failure would not be expected with a ratio of less than 3.6.*

*Results of the destructive testing were alarming. The expectation was that upon retirement, a minimum of twice the bollard pull would be seen to be acceptable. Some of the test results, however, revealed a ratio as low as 1.3.*

*Following a recent failure in service the port has reverted to using 64mm rope (with no added chafing gear). They have also reduced the number of jobs that the line can undertake prior to retirement. This was previously set at 3,200 but ropes of this size are now retired after 2,500 jobs.*

The reporter was looking for any feedback or advice, since there appears to be limited information available when it comes to determining how long an HMPE line should be in use.

This paper addresses HMPE ropes and their complexities then discusses the retirement criteria following discussion with tug operators. Some aspects of the criteria may be equally applicable to larger vessels.

## HMPE Rope and Safe Mooring.

HMPE (High Modulus Polyethylene) rope for ship's moorings and tugs' lines has been commonly used in the industry for over a decade. Steel wire ropes have often been replaced (along with the previous generation of soft ropes) with a lighter, smaller diameter, and higher capability modern rope. This has been welcomed and appreciated within the maritime sector. It has without doubt contributed to safely managing high risk mooring operations, led to reduced maintenance time and associated costs, and delivered a cost-effective enhanced capability despite the inevitable rise in high technology purchase costs.

Safe mooring, however, is the cumulative effect of multiple factors and the type of rope used is only one of those factors. As such, rope failures of whatever type tend to reveal flaws in the mooring operation and its system on multiple levels. Whilst we should not lose sight of this fact, there have been several high-profile incidents where the HMPE construction has been revealed to be a significant factor in the failure. The ***CHIRP*** Maritime Advisory Board (MAB) has focussed upon the HMPE factor in this paper but does not exclude the contributory effect of all other aspects in any mooring incident.

HMPE rope failures or adverse effects upon the mooring system have occurred in a set of circumstances that might best be described as non-traditional. The circumstances of some of these failures are not conforming to traditional failures seen with previous types of rope. As such it has raised the question, "What do we not know?"

Reference is drawn to two key sources of information.

- The MAIB Accident Investigation Report 13/2017 into the failure and injury sustained from an HMPE rope on the LNG carrier ZARGA. The ***CHIRP*** Maritime Advisory Board (MAB) has first-hand knowledge of such failures on sister vessels. MAIB Zarga Report

- OCIMF Mooring Equipment Guidelines 4 (MEG4). Many of the lessons learned from the Zarga report have been included. OCIMF - MEG4 Guidelines

## Complexities and Limitations of HMPE Rope.

The complex properties of high modulus synthetic fibre ropes have advantages but limitations.

Axial Compression Fatigue has been revealed to be a significant factor in HMPE rope failure. Simply explained, it occurs when the rope is tensioned around a lead of smaller-than-optimal diameter. This then prevents the individual HMPE fibres within the rope from moving freely in order to take up their correct tensile or elastic properties.

In addition, jacketed protection of HMPE rope does not allow visual inspection of the internal construction or allow for an accurate condition assessment in any practically meaningful sense without the use of specialist shore-based equipment. There has been a move away from jacketed construction towards a visible lay for ease of splicing and repair. Chafing protection can be woven into pennants or high wear areas.

Separately, the use of HMPE ropes has revealed some alarming incidents. This has involved multiple factors, and in some cases the HMPE ropes were so good that they actually revealed weaknesses in other aspects of the mooring system. Reported examples are noted below, with *"unpredictable"* being the theme:

- Bollards being squeezed like wine glass stems as the figure of eight rope takes the strain and compresses the steel.
- Bollards being ripped from the deck as the breaking strain of a small diameter HMPE rope exceeded that of the bollard.
- Rope tending to be buried deep in the lay upon drums. This appears to be more frequent than with previous larger diameter ropes of the same breaking strain.
- Failure with no snap back at all, as well as high snap back failures. This has inevitably created an uncertainty as to the when and how failure will occur.
- Low load failure from one HMPE rope of a paired mooring – the rope had previously taken loads approaching the breaking strain with ease - completely the same exposure with widely different effect.
- A failed mooring rope was end for ended, only for the same rope to fail in the same place again at low load, but at the opposite end of the same rope!

The importance of reducing levels of peak loading on HMPE rope by using a tail or pennant is highlighted, with the increased elasticity being the important factor in reducing such loads. The use of nylon tails of at least 11 metres in length on larger vessels at sheltered berths, and 22m in length on exposed berths has been recommended to extend the lives of HMPE ropes.

Historically the predominant HMPE rope failure cases have been noted to be clear of fairleads and at low load. This is possibly due to prior high loading, thus causing fatigue damage. The fatigue would lead to future failures in tensile strength due to internal abrasion and fibre creep. The question of what is an optimum HMPE content within the fibre construct to ensure the optimum benefits has been raised.

Axial Compression Fatigue is amplified by bending an HMPE rope around curves in inappropriately tight leads which are not suitable for the diameter of the rope. The result is that the fibres twist and bend in excess of normal operating usage, reducing the rope life by loss of the tensile strength. The rope construction then hardens and loses elasticity due to fatigue. The effect is cumulative, latent and very difficult to detect by conventional means. This can result in a rope not failing at high loading the first time it is exposed to such a situation but failing at much lesser loading the next occasion. This is quite contrary to established experience with previous rope types.

Larger diameter and properly maintained leads, which are better matched to the size of the HMPE rope, are the way forward. Technical considerations relate to the D:d ratio of the inside and outside curvature of such a rope around the diameter of a lead. This D/d ratio is the diameter of the curvature divided by the diameter of the mooring rope. MEG4 recommends this ratio to be as high as possible with minimum bending and an absolute minimum factor of 15 applied. Note Panama leads have variable curvature with the tightest at the apex and are not easy to measure, whilst roller leads, bitts and bollards will be much easier to assess. It should be appreciated that the difference of stress levels upon the fibres of the rope will be greatest in a tightly curved lead. **The tighter the curvatures the shorter the rope life.** It is appreciated that on smaller vessels and tugs, the operators may not know what the diameter of the leads are, so it may be difficult to make a calculation of this figure.

## Retirement Criteria.

***CHIRP*** Maritime asked some tug companies for their views with respect to the retirement of ropes and as to whether there was any recognised industry standard or practice for retirement of ropes. The consensus was that there is currently no industry guidance available, but that tug companies invariably have a close working relationship with the rope manufacturers.

Tug companies have, in many cases, adopted their own procedures as to length in service of HMPE and the retirement criteria, based on hours in service or the number of jobs. Feedback from major tug operators has suggested end for ending every 1500 jobs and changing out every 3000 jobs. However, where a more elastic nylon type pennant is utilised then this can be increased by 1000 to 1200 jobs. Monthly inspection of a preferred non-jacketed construction has been adopted.

The foregoing is very general, and there are a large number of variables to consider, some of which include;

- Generally speaking, the life cycle of both ropes and pennants will depend upon the experience of a tug and port. It will be difficult to come to an accurate analysis unless retired ropes are subjected to destructive testing. Some companies do test on retirement of the rope so life span can be continually assessed.
- Ropes often fail due to the cumulative effects of a number of events and not a single isolated incident.
- One anomaly is that the test piece of a failed rope may still be strong and thus may not part under test conditions as anticipated
- Different materials and size of rope will inevitably mean differences in hours and/or jobs undertaken prior to retirement.
- The experience and knowledge of tug crews are vitally important and any concerns that they have should be followed up.
- Material, construction, shock loading, angles, heat, internal friction and abrasion all have a negative impact and are impossible to measure without new technology. In towing ropes, this varies considerably according to the type of towing and the vessels being towed.
- Invariably, cost is an additional factor – high quality ropes are expensive. Some tug companies will have contracts where tow lines are supplied from ports or terminals. This potentially could mean that cheaper ropes are supplied, with a consequential loss in quality.

A good relationship between the rope manufacturer and the tug or vessel managers is critical for guidance in usage. Experience will be gained through destructive testing following retirement or unexpected events, which should enable manufacturers to improve their products in order to improve service life. The issue of how to purchase a new rope is comprehensively covered in OCIMF - MEG4 Guidelines and will have a positive impact in how ropes are not just manufactured but also purchased. This will be a key factor and will have positive impact on rope life duration.

In February 2011, an HMPE Users Group was established to pool knowledge and contribute to industry guidance. This was mentioned in the MAIB report for consideration in OCIMF's MEG4. Additionally OCIMF and SIGTTO have issued a guide to purchasing High Modulus Synthetic Fibre mooring lines and the first section has a table detailing factors that may impact upon the service life of a rope.

## Conclusions.

Key lessons learned may be briefly summarised as follows:

- HMPE rope is prone to Axial Compression Fatigue failure when not used in accordance with manufacturer's guidance.
- Such manufacturer's guidance needs to be strictly followed by managers and updates promulgated to vessels so that the seafarers can safely use HMPE ropes to their full potential.
- The complete mooring system, and the fitness for the size of HMPE rope fitted needs to be considered to ensure the best match. Only when the system is perfectly matched will it be as safe as it can possibly be. This is particularly so when matching the radius of tight leads to the size and properties of the HMPE rope to prevent Axial Compression Fatigue.
- It is therefore essential that the type of rope to be utilised is considered along with the winch and the tug (or vessel for that matter) at the design stage, and **not** as an add-on later.
- The Code of Safe Working Practices provides a wealth of supporting advice to mitigate mooring risk in addition to MEG4.
- The so-called "snap back zone highlighting" is commonplace **yet ineffective** in preventing snap back exposure. Tugs will of course clear their mooring decks completely when their ropes are in tension, but larger vessels may be unable to do so. Consideration should be given to previous ***CHIRP*** advice relating to "Tension Spots" in order to highlight limited safe areas for mooring operations. **It should be noted that the Code of Safe Working Practices discourages snap back zones as being unsafe.** A thorough risk assessment identifying a "spot" which is safe from rope "tension" should be conducted. No movements of personnel engaged in mooring operations from these "Tension Spots" should be permitted whilst operations are in progress. An ideology not of "unsafe where to go" but "safe where to stay" should be adopted.

***CHIRP*** Maritime welcomes Near Miss reporting on any incident relating to HMPE rope. The diverse nature of characteristics and failures shows the value of open reporting, so that incidents can be investigated in depth and lessons learned can be shared for the safety of all. It has become apparent in many cases of HMPE rope failure that these ropes do not behave in ways we have previously been conditioned to consider. **New technology means new lessons**. The key is open reporting so that we may continue to learn.