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Operations

On The Use of Safety Moorings in DP Operations

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Abstract

The paper presents a study on the use of “safety mooring” and “hold back vessels” for DP operations. Combined DP and mooring is difficult to handle since the two will always “hunt” each other. By using “safety mooring” extreme care must be taken to avoid station keeping instability. Analyses should be carried out in advance to know how much pretension to be applied to the connecting hawser or mooring line. Two DP vessels should never be connected.

1 Introduction

The issue of “Safety Mooring” and “Hold Back Vessels” was a hot safety topic quite some years ago, but as new generations comes into the community old ideas pops up as new. Last year IMCA published a guidance note on the use of “Hold Back Vessels” during DP diving operations, ref [1]. A lot of concerns were put on safety aspects of the mooring arrangements, but little on the dynamic forces which a DP system will experience during such conditions. This paper is focusing the theoretical control aspects which have not been addressed by IMCA.

There may arise situations where, as a result of a risk assessment, it is deemed necessary to provide additional safeguards to prevent a potential loss of position of a DP vessel. Additional remedies may be such as securing a towing vessel to the DP vessel to act as an ‘anchor’ in the event of black out or simply deploying one of the vessel’s own anchors. According to the mentioned IMCA report, the situations where the use of hold back vessels may be of use, concern diving operations inside a mooring pattern with a steady prevailing weather condition. But, this approach has also been used for some other type of operations close to e.g. fixed structures.

In this paper we will look into three mooring alternatives as indicated in the figure below:

- Mooring to sea bed
- Mooring via a moored support vessel
- Mooring via a DP operated support vessel

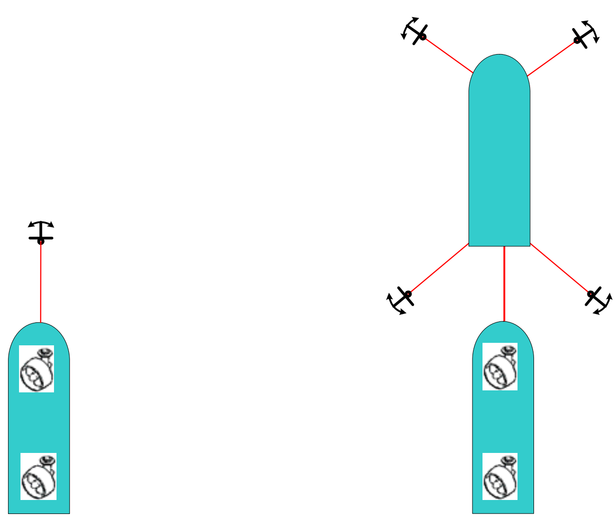

Figure 1 Mooring configurations

Here we are only looking at the problem in one degree of freedom, but the results are just as much valid for the general case.

To the DP control system all three configurations represent the same basic problem. The mooring represents a highly nonlinear and unknown (i.e. not measured and not modelled) force. The restoring stiffness (i.e. restoring force as a function of offset) is generally very high and varies with offset. A DP control system is designed to provide a certain damping based on the restoring providing by the thrusters.

When the vessel is moored the relative damping must be design based on the mooring force as well as the restoring provided by the DP. However, the mooring restoring stiffness is unknown and may be high which again implies that a quite large damping effect should be provided by the thrusters. A result of this is be a nervous control not suitable for practical use.

But since there is no mathematical modelling of the mooring, the DP and the mooring may tend to fight each other. The scope of this paper is to discuss this phenomenon.

2 Experiences from heavy lifting

The figure below shows recorded data from a heavy lifting operation. The vessel is effectively moored to the structure receiving the load through the crane wires.

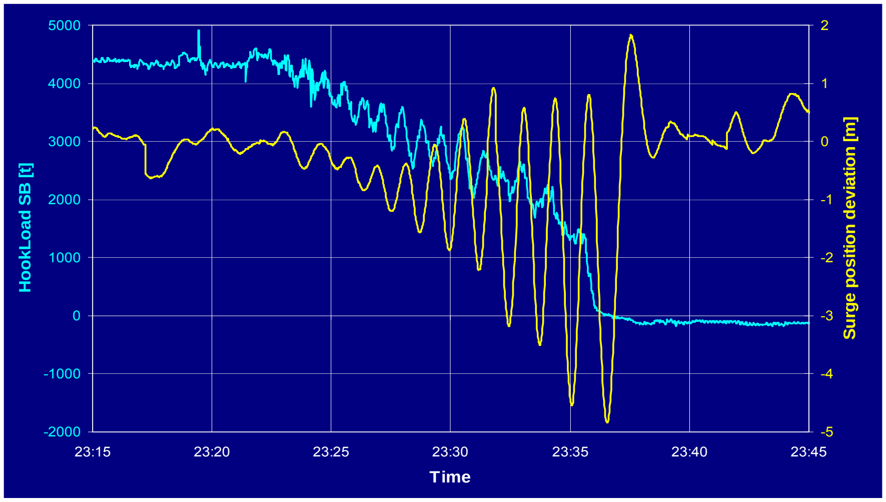

Figure 2 Instability during offloading – courtesy of Heerema

In heavy lifting one challenge is to release the load quickly enough to avoid short term instability resulting in operational problems. When sufficient load is released the system will stabilise. A moored DP vessel is conditionally stable. If the DP damping were very much higher (which is unfeasible) or the gains were very zero (which makes no DP at all) we could get a stable total system. The question is; where is the limit?

A condition similar to Figure 2 is shown in Figure 3 to the right. The mooring load is gradually reduced, and hence also the restoring stiffness (R). We observe that instability is building up until the mooring restoring gets below a certain limit, namely the value of DP restoring (G).

It is a good rule of thumb to say that instability is avoided as long as additional restoring from mooring lines etc. does not exceed the DP restoring.

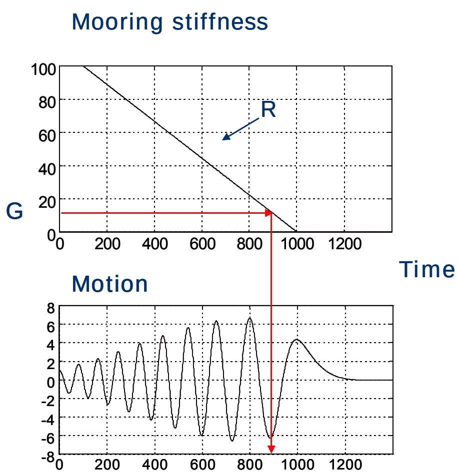

Figure 3 Instability - stability

3 Mooring simulation study

We will now look into the three different scenarios by means of simulations.

Common to all cases is that the mooring must be pre-tensioned to assure stability and avoid collision if blackout. The pre-tension must neither be too low nor too high. May be thrusters must be used (in manual mode?) to provide this. But, the mooring stiffness is unknown and we know from the heavy lifting example that if exceed the DP restoring we should expect problems.

Additionally anchor dragging is a potential severe problem and a line break will represent a disaster.

The DP vessels in question for all scenarios represent a big offshore support vessel. Water depth is set to 200 m. The mooring lines are of steel wire ropes with diameter 66 mm.

3.1 Case 1 - Fixed mooring

In this case the DP vessel is moored to the sea bed with one wire of length 200 m, Figure 4.

In the first case the total environmental load is selected to 250 kN. At start-up the DP set-point is set to the equilibrium position which means that no thrust is needed to stay in desired position.

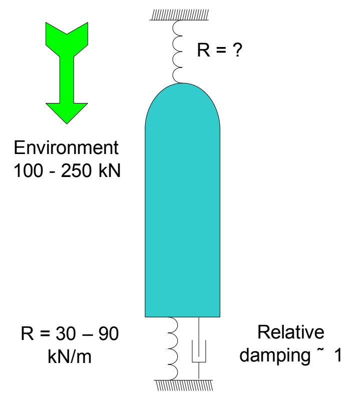

Figure 4 Single point fixed mooring

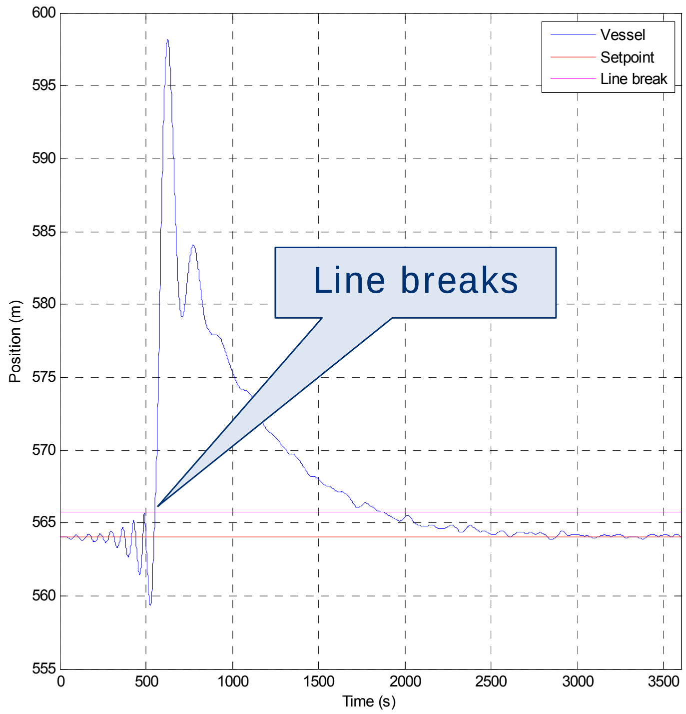

Figure 5 Vessel response at 250 kN environmental load

The results can be seen in Figure 5. Since anchor dragging is not simulated, we will experience wire break in stead as the instability takes place.

There are some disturbances which are exciting the mooring and the DP pumps energy into the system instead of removing it. Due to the too high mooring stiffness or to the to slow DP control and thruster response the system is now longer conservative.

From the Figure 6 we see that the actual mooring stiffness is about 100 kN / m.

The DP position gain is in this case 30 kN / m.

The instability is hence no surprise according to the heavy lift experience.

By reducing the environmental forces to about 150 kN, we see from Figure 7 that the system becomes rather stable with mooring stiffness of about 20 kN / m.

The same could of course be obtained by applying 100 kN of fixed thrust but who would know this in advance. The combination of mooring and DP is a risky business.

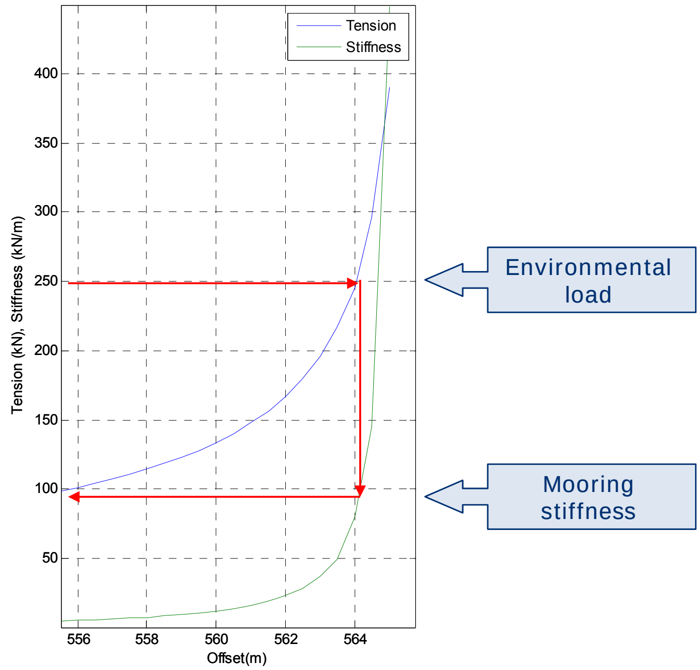

Figure 6 Mooring and DP stiffness, 250 kN tension

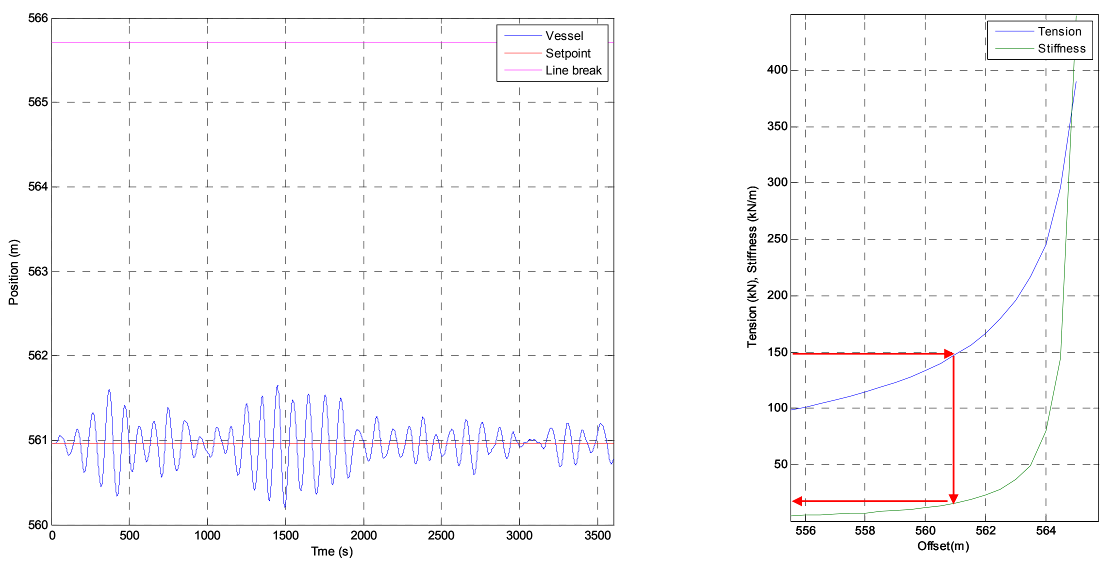

Figure 7 Response and mooring at 150 kN horizontal tension

3.2 Case 2 - Moored to another moored vessel

The configuration is outlines in Figure 8.

The DP vessel is attached by a steel wire rope to the support vessel of the same displacement as the DP vessel with length 300 m.

The support vessel is positioned with a four point symmetric steel wire rope mooring. Each mooring line has a length of 800 m.

Water depth is set to 200 m.

Again we apply 250 kN environmental load, the same as the starting point of previous case.

In this scenario the DP vessel will experience a somewhat lower mooring stiffness due to the series of springs, but the great difference is that there are now two bodies in motion.

Simulation starts at equilibrium of both vessels.

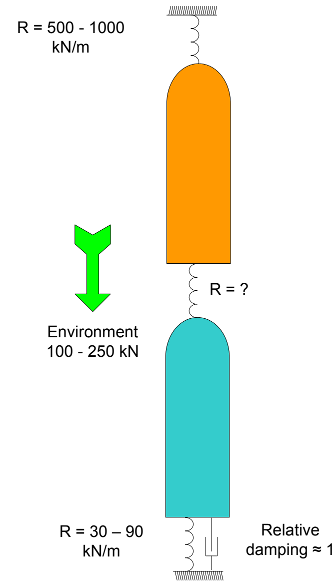

Figure 8 Double mooring

The results in Figure 9 and Figure 10 show the disastrous result. The two bodies are hunting each other until the wire breaks.

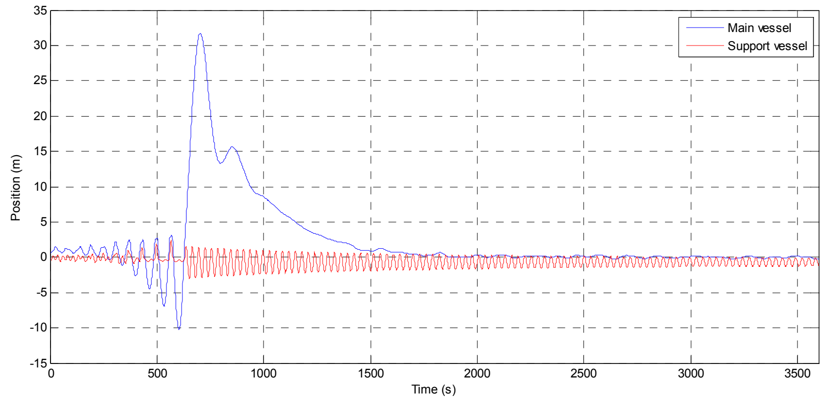

Figure 9 Position response at 250 kN environmental load

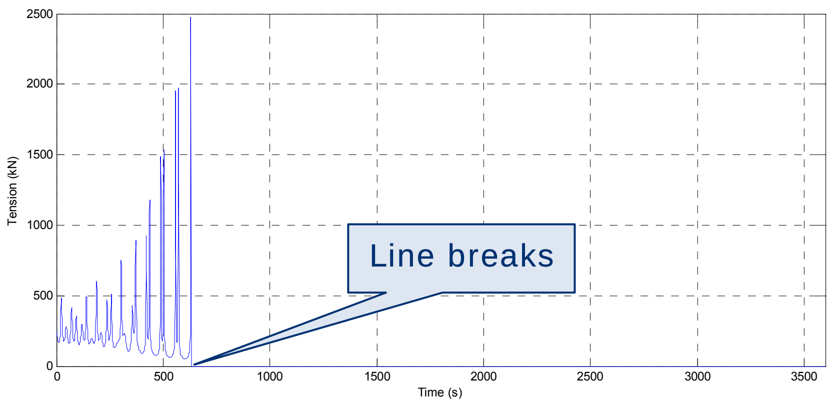

Figure 10 Hauser tension at 250 kN environmental load

This time we need to reduce the environmental load to 140 kN, i.e. 10 kN more than what was needed when the DP vessel was moored directly to the sea bed. See Figure 11. Note also the very small excursions. Due to the non-linearity of the mooring any large excursions will make the system unstable.

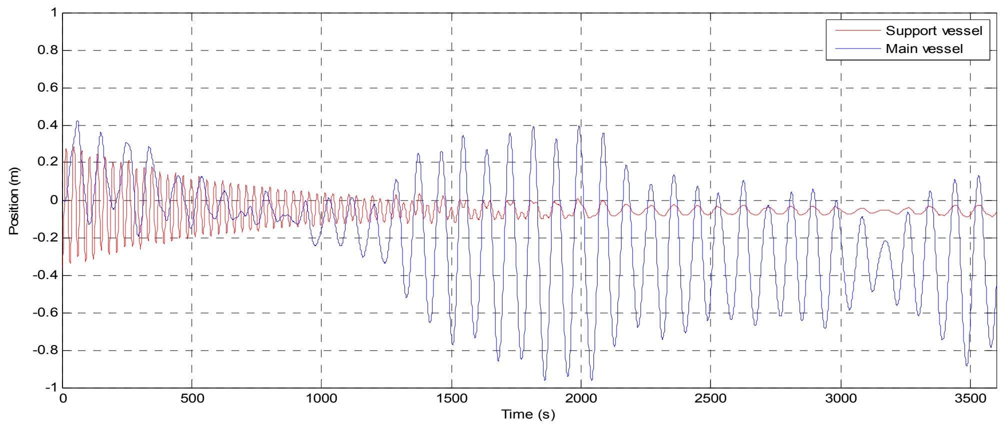

Figure 11 Position responses at 140 kN environmental load

3.3 Case 3 - Moored to another DP vessel

The configuration is shown in Figure 12. Two identical DP vessels are connected.

The restoring stiffness in this case is definitely smaller seen from the main DP vessel since the DP stiffness is well below that of the four point mooring. But in this case we have two active systems working together.

Again we apply the same hawser and the same environmental load, 250 kN.

The result, as shown in Figure 13 and Figure 14, reveal a just as bad result. It just takes longer time.

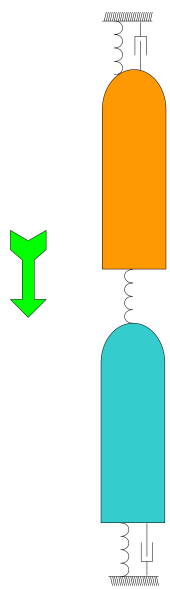

Figure 12 DP to DP mooring

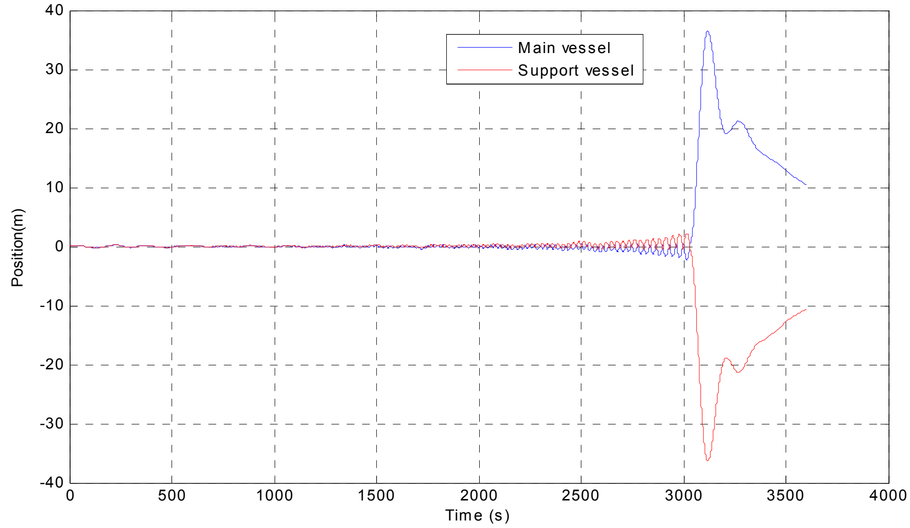

Figure 13 Position response at 250 kN environmental load

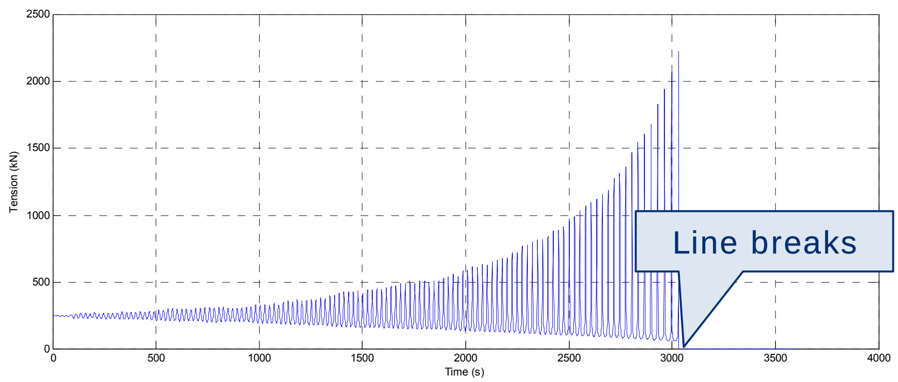

Figure 14 Hawser tension at 250 kN environmental load

To make the system work we need to reduce the environmental forces to 70 kN. See Figure 15.

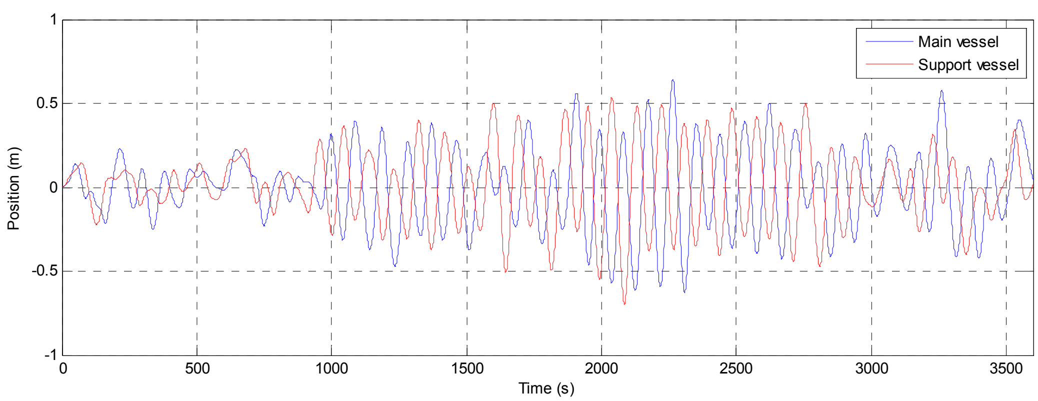

Figure 15 Position response at 70 kN environmental load

3.4 Case summary

The three cases are summarised in the figure below.

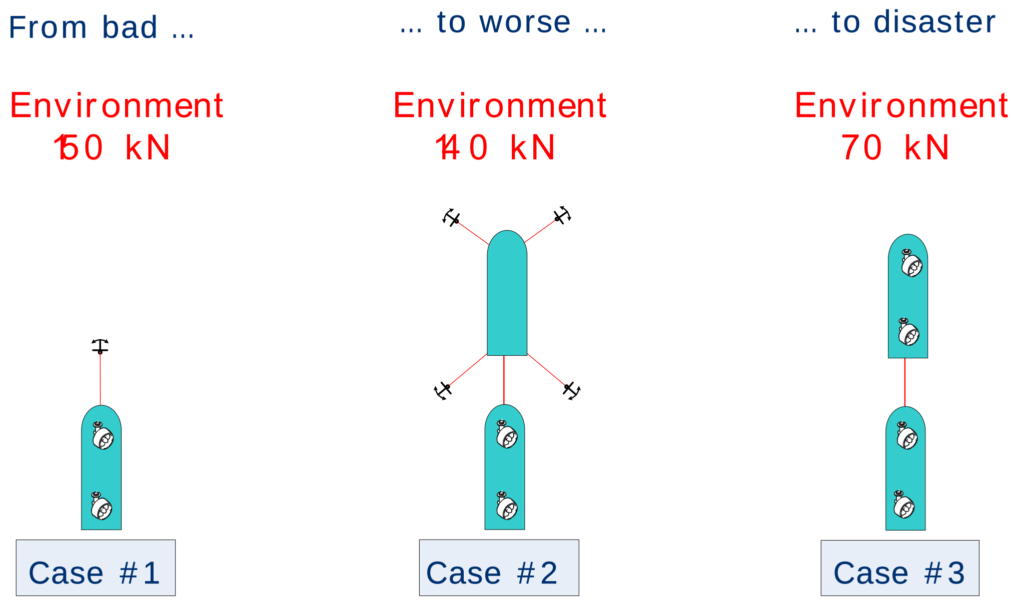

Figure 16 Summary

It may be worth noting that the DP vessel itself would have no problems coping with an environmental load of 250 kN.

4 Alternative risk control measures

The IMCA guideline, ref [1], clearly states:

Before considering attaching a hold-back DP vessel:

- Reschedule operation to a time when principal hazard does not exist
- Wait for environmental conditions
- Use sea bed anchor
- Connect to another moored vessel
- Moor to a fixed facility

The document also gives a lot of good advices regarding other operational issues regarding mooring equipment in this context.

5 Conclusion

That one should avoid connecting two DP vessels is evident. The question is whether mooring should be used at all. Analyses must at least be carried out in advance to set the proper pretension in the hawser to avoid instability (al least based on the rule of thumb proposed in this paper), and there must be practical means set it and adjust it as the weather conditions may change. Safety margins are not large. The crew must know what they are doing. It is difficult, so “safety mooring” may easily become just the opposite.

6 References

[1] Considerations About the Use of Hold-Back Vessels During DP Diving Operations, IMCA M185, 2007