Diving Vessel Drive-off - Propeller Failure to Full Pitch

Target audience for this LFI

- Vessel Management and Operations Teams on DP Vessels
- DP Technical Support Function of Vessel Owners/Contractors
- DP Assurance Teams of Operators/Charterers
- Vessel Designers, DP Equipment Vendors,
- FMEA Providers
- Classification Society DP Approval Authorities

What happened?

A significant loss of position event was experienced. (Position excursion of around 70 metres in approximately 74 seconds). The potential consequences triggered an incident investigation using the guidance and tools provided by the MTS Techop on DP Incident Investigation.

TECHOP_GEN_03 (Conducting Effective and Comprehensive DP Incident Investigations)

Vessel Particulars

- DP Class 2 - Mono-hull diving support vessel
- Main propulsion provided by engine driven Controllable Pitch Propellers (CPP)
- Electric tunnel thrusters driven by shaft generators

Events

At the time of the failure, the vessel was taking stores from a small harbour boat and preparing to commence diving operations. The vessel was operating on DP and in accordance with the ASOG.

- The vessel was observed to drive off position in the ahead direction
- The port propeller pitch indicator was observed to be at full pitch ahead
- Black smoke was observed from the funnel
- A '*Port Pitch Prediction Error Alarm'* was enunciated on the DP control system
- The Port CPP Fault Indication Light illuminated in the ECR and on the bridge.
- A position excursion of 70m was experienced
- The Senior DPO selected manual control mode.
- The Master of the vessel used the emergency stop to shut down the port main engine approximately 74s after the port pitch alarm was activated.

Why it happened

The cause of the failure has been identified by the CPP OEM. A broken oil line within the shaft to the propeller hub exposed the ahead pitch chamber to high pressure oil. The pitch changed rapidly to the ahead position leading to the drive off.

Failure to full pitch was recognized as a potential cause leading to a loss of position. This was identified and embedded in the ASOG. Mitigation of this potential required intervention by the DPO to recognize and intervene to prevent loss of position.

Observations

- There was an over reliance on operator intervention to mitigate a critical failure effect.
- The DPO did not react in the expected manner
- Critical data from the loggers on the DP System was not captured. Capture of this data is time sensitive.

NOTE:- *The root cause for the failure of the pipes has not yet been established. The investigation into this aspect is ongoing.*

What investigation steps were carried out?

1. The DP event log was reviewed
2. Discussions were held with the following key crew members and timelines obtained:
   a. Master
   b. Chief Engineer
   c. DPO on the desk at the time of the incident
   d. SDPO off the desk at the time of the incident
3. Rough DP log book reviewed
4. DP checklist reviewed
5. Pre-dive checklist reviewed
6. Inspection of main engine / gearbox carried out
7. Oil sample records for CPP checked (last sample July 2017)
8. Oil filling records for CPP checked - no oil added
9. Propeller shaft/hub strip down observed
10. Testing of the effects of propeller system failures witnessed including command and feedback wire-breaks.

NOTE: - *Instructions were given to capture time sensitive data from the DP loggers. This was not accomplished. Data was overwritten:*

- *The lack of data did not impede the identification of the causal and contributory factors.*
- *The regret from the lack of the data was the ability to substantiate the response of the DP control system.*

What was focused on

- Equipment – Fail Safe Condition of Thrusters
- People and Processes (including Procedures)
- Alarms / logs / checklists
- Management Of Change

Rationale for Focus Areas

- The failure effect was not in compliance with rules and guidelines
- Had the failure mode been considered in DP FMEA and Proving Trials?
- Reaction of personnel to the failure effect, understanding of what was occurring.
- User configurable settings were considered to be a contributory factor.

What was the outcome?

- The cause has been identified as a mechanical failure within the hydraulic system
- Analysis of the control system in the FMEA was limited to command and feedback wire breaks and power failure. It did not address all possible failure modes that could have this effect.
- Testing revealed the pitch scaling in the control systems for the two CPPs were significantly different.
  - While this may have not prevented the incident, it could have potentially limited the excursion / excursion rate.
  - This was identified as a contributory factor and an area with significant potential for improvement.
- Undue reliance on operator intervention and human performance to address a failure effect. with high potential consequences leads to unpredictable and undesired outcomes.
  - Further efforts to be undertaken to evaluate potential to design the hazard out.
  - Additional emphasis on training, familiarization and drills.

Confidence level on outcomes

HIGH

Basis of confidence

The propeller OEM's report indicates that the mechanical failure in the hydraulic system, within the propeller shaft, was the cause of the blades moving to the full pitch position. Discussions with stakeholders' technical experts concluded that this was a plausible explanation.

Lessons learned

Current industry practice to analyse and prove the fail-safe condition of thrusters falls short of achieving the objectives in established industry guidance and classification society rules.

- Verification and Validation Processes for the Fail-Safe Condition of Thrusters needs to be more robust.
  - The effectiveness of MOC processes must be validated
  - Activities to undertake self-assurance must be in place. (Undue reliance should not be placed on Charterer's 3rd party assurance)- (Example for assurance activities attached as appendix)
- Reliance on Operator Intervention and Human Performance is not a reliable method of limiting the severity of a drive off.
- Data capture following an incident is key. Procedures with sufficient level of detail must be developed and implemented. Training in execution should be provided to personnel key to the delivery of DP operations.

Recommendations

Vessel owner(s) should evaluate their vessels to establish whether they are vulnerable to this type of failure. In particular, they should review the design of their thruster control systems and any associated protective functions to determine whether they address all possible failure modes leading to failure effects that produce significant quantities of unwanted thrust in both magnitude and direction.

Short term remedial actions

- Verify DP operator familiarity with procedures and response capability to identify and address unwanted thrust through documented drills and exercises.
- Seek ways to relieve the cognitive burden on the DPO.
- Place additional emphasis on awareness of this issue through ASOGs, vessel specific procedures and Master's standing orders etc.
- Developed verification and validation process for addressing configurable settings and performance of equipment. (Attached as appendix)

Medium term remedial actions

Engage with manufacturers, DP FMEA providers and classification societies to ascertain and establish that verification and validation processes are adequate to satisfy requirements to prove the fail-safe condition of thrusters.

Long term remedial actions

Engage with relevant stakeholder to seek ways to eliminate this hazard (unwanted thrust) by design.

NOTE:- *There appears to be growing consensus that the fail-safe condition for thrusters while on DP should be to fail to Zero Thrust.*

Additional notes

IMO, classification societies and industry bodies all have clear requirements that thrusters should fail safe as follows:

- IMO 1580 Section 3.3.5 'Failure of a thruster system including pitch, azimuth and/or speed control, should not cause an increase in thrust magnitude or change in thrust direction.'
- ABS Guide for Dynamic Positioning Systems. Feb 2016, Section 4, Thruster System, Part 3 Thruster Capacity, 'a single fault in the thruster system, including pitch, azimuth or speed control, is not to result in unintended operation of pitch, speed and direction.'
- DNVGL-RU-SHIP July 2017, Part 6, Chapter 3, Section 1, 7.3.3, 'A single failure in the thruster control system should neither cause significant increase in thrust output nor make the thruster rotate.'

Note:

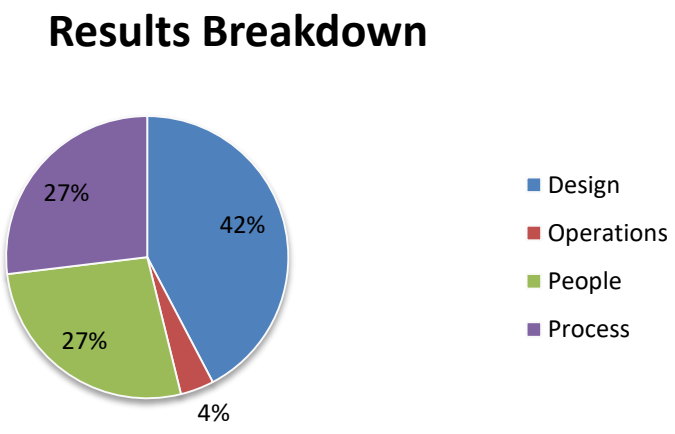
1. The most recent rule references have been provided above but the same requirements date back to at least 1994 in IMO MSC 645. The DP incident report record suggests these requirements are not being satisfied by current industry practice.
2. This approach should be applied to rudders, if used for DP, where rudders could fail in a manner that produces unwanted thrust direction.

LFI Tool - Results breakdown

The MTS LFI tool produces a breakdown of the causal and contributory factors in the incident as defined within the four criteria of Design, Operations, People and Process. The results in the chart below suggest that deficiencies in equipment '*design*' and their associated verification '*processes*' had the most significant contribution. Although **'***people'* also featured in the results, lessons learned from this and similar incidents confirm that operators may not act in a predicable manner during a developing DP incident and methods should be sought to eliminate this hazard through design.

Causal and contributory factors

Design	**11**
Operations	**1**
People	**7**
Process	**7**



MTS DP COMMITTEE THANKS THE SUBMITTER OF THIS LFI ON BEHALF OF THE DP COMMUNITY. LFIs ARE PUBLISHED ON THE MTS DP COMMITTEE WEBSITE TO PROMULGATE LEARNINGS FROM INCIDENTS WITH A VIEW TO ENABLE PROACTIVE MANAGEMENT OF SUCH VULNERABILITIES AND MINIMIZE POTENTIAL FOR DP LOSS OF POSITION INCIDENTS.

Design sub topics

- Ergonomics was not a causal or contributory factor
- Commonality was not a causal or contributory factor
- External Interfaces were not a causal or contributory factor

The above design sub topics have been found to be causal or contributory factors in many learning from incidents and are thus highlighted separately.