THE CHALLENGES OF MAJOR TANK COATING REFURBISHMENT PROJECTS FOR ON-STATION FLOATING ASSETS

(DOI No: 10.3940/rina.ijme.2020.a2.564)

A Westwell, Marine Technical Limits, UK

SUMMARY

The objective of this paper is to acknowledge that major tank coating refurbishment projects to FPSO's and FSU's are likely to be required during the life of these assets. It highlights the key challenges of achieving these major coating projects in an offshore environment, whilst the assets remain operational and in-production. As these floating assets age the original coatings applied to protect the internal (and external) hull, deteriorate. In an industry with a reluctance for extensive dry-dockings, there is an expectation that any coating refurbishment campaigns can be achieved safely and efficiently whilst the assets remain on-station and in-production, in preference to costly steel renewal's which may be required at a future date if coatings are not maintained in good condition. With often complex, congested and hazardous topsides processing equipment and pipework directly above the hull tanks, there's a need for systems, procedures, and specialist equipment to ensure the safety of the personnel entering confined spaces for extended periods. There's also a need to plan and engineer the works appropriately, using best practice and emergent technologies to improve safety, reduce bedding impacts and to ensure the success of the coating campaign. This paper explores the challenges of major coating projects by discussing the importance of planning and preparation, the need to create a safe working environment within the confined space worksites, the role surface preparation plays in the success of coating projects, and finally the application of coatings and the challenges this operation can present. The key considerations are summarised in 10 specific conclusions as guidance to promote successful project outcomes.

1. INTRODUCTION

Worldwide there are over 180 operational Floating, Production, Storage and Offloading Unit's (FPSO's) and Floating Storage Unit's (FSU's) currently in-service, with approximately 60% of those assets being over 10 years old [1]. As vessel's age, the coating systems installed to the hull during construction (or conversion) begin to deteriorate, as demonstrated in Figure 1 below.

Figure 1. FPSO fore peak tank with coating breakdown. Photographed by Marine Technical Limits.

Asset integrity maintenance is crucial to ensuring the safety of an asset and its viability to remain on-station. The Health and Safety Executive define it as:

"*The ability of an asset to perform its required function effectively and efficiently whilst protecting health, safety and the environment.*" [2]

Most integrity maintenance workscopes can be carried out whilst the FPSO or FSU are either in operation or during planned/un-planned shutdown periods, and are often executed by the asset's onboard maintenance team. However, when considering large scale coating refurbishments campaigns, these should be treated as major projects. They should be engineered to allow the work to be carried out safely alongside production due to the extended execution duration.

Confined space entry is a well-known hazardous activity, particularly in the shipping industry. Cargo hold and tank areas accounted for 22.9% of marine casualties and incidents on board cargo ships between 2011 and 2018 [3]. With coating refurbishment projects requiring sustained periods of confined space entry to cargo holds and tank areas, establishing controls to mitigate the hazards presented with confined space entry, along with controls for mitigating the additional hazards presented by the coating refurbishment activities are crucial to the safety of all personnel involved in these projects.

2. PLANNING AND PREPARATION

Appropriate upfront planning, preparation and project management is essential to the success of major coating refurbishment projects.

2.1 SCOPE DEFINITION AND COATING SELECTION

Establishing the scope of the coating refurbishment campaign at the early stages of planning and preparation is key to a successful project.

Identifying areas where existing coatings may be in good condition (e.g. at the deck head) may allow for a reduced scope in these areas, which may result in a significant reduction to the need for major access scaffolding, and unnecessary blasting and paint spraying of difficult to reach areas.

The result of not undertaking coating repairs to in-service tanks should be recognised during scope review and definition. In many cases, extensive and often costly hotwork steel renewals can be avoided if tank coatings are maintained in good condition.

A functional specification for the coating system should be agreed. This will consider the required design life of the coating system, the service conditions and temperature, the substrate type, and the required degree of surface preparation to achieve the design life according to recognised standards. The output of agreeing the coating functional specification will help to determine the most suitable coating type.

Complying with the original shipyard paint specification may not always be the most efficient or practical means of reinstating an effective coating system. Many FPSO's are converted from trading tankers, and as such the original paint specification may no longer be available, may not be practical to apply in an offshore environment, or may not be suitable for the actual service the tanks experience.

Advances in coating systems over recent years has led to numerous options for internal hull coatings, primarily with epoxy-based products. Pure epoxies are often considered to provide the best longevity, but at an elevated cost to modified epoxies which typically have shorter lifespans. Solvent free epoxies offer advantages when painting in confined spaces, with no solvent emissions during paint curing, and therefore better edge retention properties. Surface tolerant epoxies are designed to accommodate surfaces which have not undergone typical surface preparation, and be applied at temperature/moisture levels which would typically cause traditional epoxy coatings to fail. Careful selection of the most appropriate coating system for each project might provide opportunities to reduce hazardous in-tank activities or help to manage challenging atmospheric conditions.

2.2 ASSET/TANK CONSTRAINTS

Establishing asset constraints upfront ensures that the engineering to deliver the coating refurbishment campaign recognises what is achievable on each individual asset.

Reviewing laydown space and proximity to the worksite, crane capacity and reach, deck hazardous area classification, utility provisions (e.g. air, power), allows the project engineering team to engineer the workscopes accordingly for each asset.

It's important to fully understand the structural configuration of the tank(s), to fully define and engineer appropriate means for executing the workscopes. For stiffened bulkheads, for example, safely accessing all of the stiffener free edges for surface preparation and stripe coating is often a sizeable and hazardous task. Figure 2 below provides an example of a heavily stiffened tank structure. Horizontal stiffeners tend to collect dust and debris on the horizontal webs, which can create an additional challenge during grit recovery and clean-up, especially when working at height. Figure 3 provides an example of a scaffold structure built to provide access to internal tank surfaces for coating works.

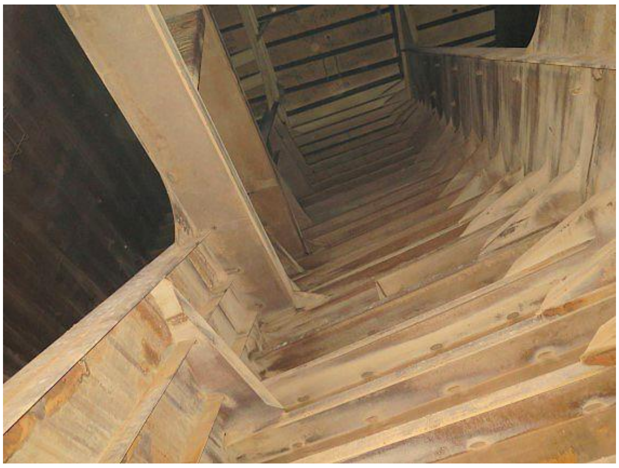

Figure 2. FPSO slop tank internal structure. Photographed by Marine Technical Limits.

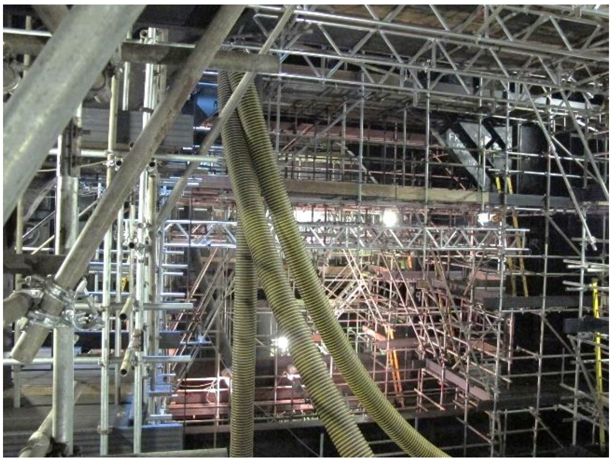

Figure 3. FPSO tank with scaffolding to structure. Photographed by Marine Technical Limits.

2.3 HATCH ARRANGEMENTS

Understanding the FPSO's design can assure a safer working environment for the personnel carrying out the work and those working on the asset.

Typically, access, egress, material handling and rescue hatch arrangements to cargo and ballast tanks are poor – particularly when considering extended periods of confined space entry.

By assessing the most appropriate means of access, egress, material handling and rescue, diligent engineering should identify any challenges that may prejudice the use of scaffolding or any potential issues that may arise should there be a need for casualty rescue. Engineering and preparation for the installation of additional hatches to these spaces should not be considered an impractical obstacle.

2.4 RESCUE PLANNING

Workscope engineering must establish appropriate rescue plans in the event of an emergency or a casualty recovery scenario. This plan will outline the primary escape routes, along with the nominated stretcher recovery route.

3. CREATING A SAFE ENVIRONMENT

3.1 BREATHABLE ATMOSPHERE

There's often a fundamental shortcoming when considering safe confined space entry into large hull spaces on producing FPSO's and in-service FSU's.

Typically, confined space entry on floating assets is managed in accordance with tanker best practice; tanks are isolated and ventilated, gas testing of the atmosphere performed remotely or during initial entry under breathing apparatus, and gas testing performed after any sustained period where the tank has been vacated.

The above controls provide an appropriate level of mitigation against the risks of confined space entry into *tanker* hull structures. However, when considering *FPSO's* and *FSU's*, there are significant differences which require an improved approach. In general, the same controls apply. The tanks still need to be isolated and ventilated. However now, this ventilation needs to be more considered. With complex oil and gas processing facilities introduced above the hull main deck, the ventilation air *must* be taken from a safe area; an area which during *normal* operation should never experience any form of hydrocarbons.

If a team of people are working within a confined space for extended periods and a genuine risk of a hydrocarbon release from the topsides processing facilities exists, then certainty must be sought that in the event of a hydrocarbon release, the people in that confined space are protected from the potential hazards. The tank ventilation fans must shut down instantly should a topsides hydrocarbon release occur to prevent any ingress of gases into the confined space.

To further improve the ventilation arrangements, the air can be blown through in-line gas and smoke detection to verify its quality before being introduced into the confined space.

3.2 INGRESS OF FLUIDS

Preventing the ingress of fluids is also a crucial aspect of any tank entry work. During the planning process it should be established where appropriate tank isolations are needed, and how the risk of spills/rainwater/deluge testing etc. will be prevented from entering the confined space through deck openings and hatches.

Positive applications are likely to be necessary for most coating refurbishment projects, due to the longevity of confined space entry, and the risks posed by the production facilities and the in-service adjacent tanks.

3.3 LIGHTING

Before work can begin, lighting (and emergency lighting) must be installed to these typically large and dark spaces. This ensures access and egress routes are well lit and can remain illuminated upon sudden loss of power.

Appropriately zone-rated lighting should be considered for major tank coating refurbishment campaigns. Depending on the coating type, the release of volatile organic compounds (VOC's) during paint curing can create a hazardous atmosphere within a confined space, which may fundamentally change the usual hazardous rating of a particular space.

4. SURFACE PREPARATION

Surface preparation, cleanliness and the control of environmental conditions are equally as important to the longevity of the coating system as the coating application itself. The key to successful surface preparation and surface cleaning is through detailed planning of the works, and discipline during scope execution.

4.1 CLEANING AND FRESH WATER WASHING

An important aspect of surface preparation's for coating refurbishment is the availability of suitable quality fresh potable water onboard the asset. Establishing any issues with supply or quality prior to offshore commencement will ensure the surfaces can be suitably cleaned and washed without introducing contaminants to the surfaces.

Initial cleaning of the steel surfaces to remove any residual waste deposits, followed by removal of any loosely adhering scale/rust should be carried out. Water jetting using fresh potable water will be sufficient in most instances, with the addition of degreasers, detergents and/or solvents to remove stubborn oil or grease deposits when necessary.

Once cleaned, the tank surfaces should be thoroughly washed down with fresh potable water to remove any salt contamination and any other surface contamination's present. This ensures that any surface salts are removed before blasting, where they could be embedded into the substrate surface profile.

Plans for removal of washing water from the tank and routing it to an appropriate drains tank should be considered; it is not appropriate to rely on the tank piping/pumping systems for removal of residual washing fluids without considering the impact these fluids may have on the piping system and associated pumps. Contamination of the piping, damage to the pumps, and potential environmental release of hazardous substances may result if fluid disposal is not carefully considered.

4.2 DEHUMIDIFICATION

The atmospheric moisture within tanks is often very changeable depending on the time of year, air temperature, and seawater temperature.

The amount of moisture within the air plays an important role in the success of coating refurbishment campaigns, particularly for traditional epoxy-based paint products. Too much moisture, and the cleaned and blasted surfaces may quickly 'flash rust' before site cleaning can be achieved or a coating can be applied, which may lead to premature failure of the coatings. In some instances, surface tolerant epoxies may provide an acceptable alternative to tank dehumidification.

Tank dehumidification systems should be considered to dehumidify the air within the tanks after freshwater washing, but before any blasting is carried out. By maintaining the tank atmosphere with a dew point of at least 3°C below the steel surface temperature, any blasted surfaces can be 'held' to prevent flash rusting during clean-up activities, improving efficiency during blasting operations, reducing the need for any secondary sweep blasting, and thus reducing overall blasting duration.

There are two types of dehumidifiers commonly used for industrial applications; desiccant dehumidifiers, and condensing dehumidifiers.

Desiccant dehumidifiers use desiccants to remove moisture from the incoming process air via a rotating desiccant wheel. The process air is blown through this rotating desiccant wheel, exhausting dry air to the worksite. The moisture-laden desiccant is then rotated through a heating system to dry the desiccant and regenerate it for process air drying as the wheel continues to rotate.

Condensing dehumidifiers use a refrigerated heat exchanger/evaporator to cool the process air to the required dew point such that the moisture in the air condenses on the cold heat exchanger surfaces. This moisture is drained away, resulting in cold dry air. This cold dry air is then passed over a heated condenser to raise the temperature of the dried air (if required).

A number of factors will determine the most appropriate dehumidification system to install for a given project. Tank volume, ambient atmospheric conditions, coating system requirements, and power availability are some of the aspects which should be evaluated during dehumidification system engineering.

4.3 BLASTING

Firstly, the upfront engineering of the project should establish whether blasting of the steel surfaces is necessary to achieve the required service life of the coating system. If the tank has been previously coated and the steel surfaces have not suffered significant deterioration (yet), there may still exist a suitable surface profile without the need for major blasting operations. In this instance, the use of ultra-high-pressure water jetting equipment to clean and remove surface contaminants and any loosely adhering existing coatings may be beneficial.

There are a number of blasting techniques suitable for major tank coating refurbishment projects; the most common are slurry blasting, and dry blasting.

Slurry blasting uses potable water to deliver the blasting media to the surfaces, which reduces dust accumulations from the blasting operations. Whilst the reduction in dust is a major advantage when working in confined spaces, the formation of water vapour can cause visibility issues, and the reaction of the freshly exposed steel surfaces to moisture and oxygen will cause flash rusting to the surfaces. The prevention or removal of this flash rust prior to coating application is typically necessary to the longevity of the coating system, unless a surface tolerant coating system has been specified. Flash rust prevention additives can be incorporated into the blasting water and may provide a suitable "hold" on the exposed steel until an initial paint coat can be applied, although this will increase overall costs of the blasting process. Again, availability of potable water should be considered, as slurry blasting will consume significantly more potable water than other surface preparation methods.

The predominant blasting process for creating a suitable surface profile into the steel of large hull structures is air (dry) blasting. Air blasting uses compressed air to deliver the blasting media to the surfaces. This process can generate significant amounts of dust and expended waste media if not managed appropriately.

Whilst other less commonly used processes do exist, these are often uneconomical, inefficient or impractical to apply when considering large blasting surface areas.

It is important to select an appropriate blasting media when using air blasting. Large volumes of media can be expended, particularly when blasting large surface areas, which can create a burden of waste disposal if using cheaper single use media. Selecting a media which can be recovered, recycled to remove any entrained impurities, and reused has clear advantages for hull structure blasting, especially when considering the challenges of material handling and storage of waste on an offshore asset (with often limited laydown availability), and the logistical challenges of returning waste to shore-base for disposal. Figure 4 shows a typical abrasive recycling system for large scale blasting projects. Suitable areas to position equipment with a footprint and height of this nature may prove challenging and should be considered during engineering.

Figure 4. Abrasive recycling system onboard an FPSO. Photographed by Marine Technical Limits.

With blasting operations comes a variety of additional risks to the safety of the personnel involved in the tasks and to others onboard the installation. Care should be taken to ensure that appropriate controls are in place to manage the additional risks resultant from blasting operations, such as noise, high-speed and high-pressure hazards, generation of static electricity, and accumulations of hazardous substances.

4.4 FEATHERING

Where areas of existing coatings may remain, feathering back of any sound coatings to create a gradual taper from coated to un-coated surface is important. This ensures fresh coatings can adhere to existing coatings, and prevents hard edges at the coating transition which may promote premature coating deterioration.

Feathering will often be a time-consuming process, so the benefits of feathering existing coatings vs. complete coating renewal should be assessed.

4.5 BLASTING TECHNOLOGY

Recent technological advances may offer some improvements in the blasting process.

For coating breakdown to specific structures, the emerging technology of vapour abrasive blasting may provide a suitable compromise between the traditional wet and dry blasting technologies. Vapour abrasive blasting uses water *and* compressed air to deliver the blasting media, resulting in less potable water usage, less media consumption, and reductions in waste generated. This technology also minimises dust accumulations, allowing increases to productivity.

Similar to the uptake in using remotely operated vehicles and unmanned aerial vehicles, the development and use of remotely operated crawlers are gaining in popularity in shipyards for blasting, particularly for large flat areas of plating.

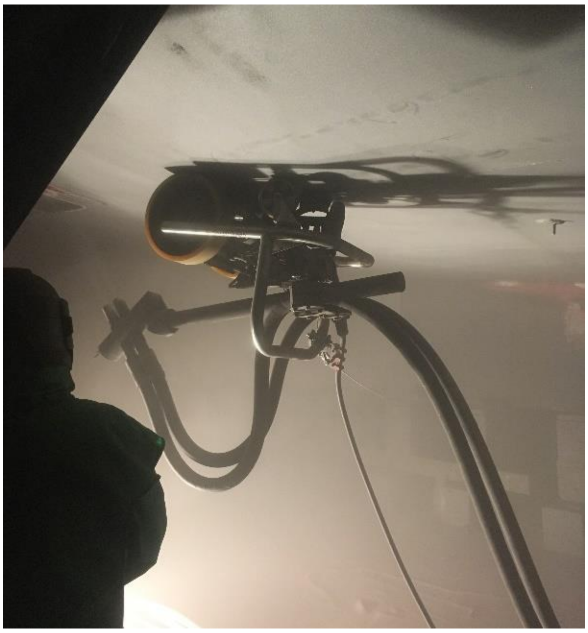

Figure 5. Robotic crawler performing dry abrasive blasting activities on a ship’s hull. Photograph courtesy of VertiDrive.

Controlled by a single operator and using the same blasting equipment that would be used by a conventional blasting operative, these systems have high production rates, and are able to access at height areas without the need for scaffolding or rope access techniques. Figure 5 provides an example of this technology being used, and shows the benefits it can provide to difficult to reach at-height blasting locations.

These systems are not the answer to all blasting requirements but should certainly be considered during project engineering to reduce manpower requirements and improve blasting efficiency.

5. COATING APPLICATION

Upon satisfactory cleaning, freshwater washing, and blasting of the surfaces (if necessary), all of which should be verified through appropriate quality assurance or control processes, the surfaces should now be ready for coating application.

5.1 ENVIRONMENTAL AND SURFACE CHECKS

Depending on the type of coating being applied, atmospheric checks to verify the moisture content of the air may be required before paint application. Typically, ensuring the dew point is less than 3 °C below the steel surface temperature will improve the coating adherence to the steel and provide the best opportunity for long-lasting coatings.

There may be opportunities to influence the atmosphere to align with the requirements of the coating system. Depending on the asset's location, the season and weather conditions may affect the atmospheric moisture content; planning the coating campaigns for an appropriate time of year may prove beneficial. Introducing hot inventory into adjacent cargo hold spaces may alter the atmosphere to the benefit (or detriment) of the coating application; this should be considered during planning. Performing atmospheric dehumidification will guarantee a suitable atmosphere for coating application, providing that the specifications of the dehumidification equipment have been clearly defined and appropriately engineered.

Alternatively, using a surface tolerant epoxy coating may be an acceptable approach to mitigate difficult to manage atmospheric conditions.

Of equal importance to the atmospheric checks, the steel surfaces must also be checked for non-visible contaminants, for example dusts and soluble salts, prior to coating application. Quality assurance procedures and acceptance criteria should be defined and adhered to, and recorded throughout each stage of the coating project.

5.2 STRIPE COATING

Stripe coating is the process of applying a coat of paint to only the free edges, welds and corners, to ensure these areas retain a sufficient paint film during full coating.

Stripe coating should be carried out using a paint brush and should be applied either before or after the first full coat and repeated before the application of any subsequent full coats. For large areas of prepared steel, it is sensible to apply the initial full coat, followed by the initial stripe coating of the free edges, welds and corners. This will ensure that the large areas of prepared steel do not suffer from flash rust prior to the application of the first coat. Figure 6 shows the application of stripe coating to the free edges of stiffeners within a ballast tank.

Figure 6. Stripe coating applied to ballast tank internal structure. Photographed by Marine Technical Limits.

Contrasting colours of paint for the stripe coating and full coating should be used where possible to ensure easy verification of areas which have been stripe coated and subsequently fully coated.

Figure 7. Stiffened structure with signs of deterioration. Photographed by Marine Technical Limits.

The structural configuration of the tank being painted will dictate the ease of access for stripe coating. For heavily stiffened bulkheads, it may be more beneficial to erect scaffolding to aid access and improve efficiency of stripe coating these areas. For more remote and/or isolated areas of stripe coating, it may be more efficient to perform the stripe coating using rope access techniques. Figure 7 above shows an example of a fully coated tank and the access challenges which may be presented should a full coating refurbishment be necessary.

5.3 SPRAYING

For the application of the full coats of the paint system, for large hull structures it's often most productive to use airless spraying systems to apply the paint.

Depending on the configuration on the tanks and the coating system being applied, the ventilation arrangements need to be assessed and adjusted to ensure that any vapour accumulations (which are typically heavier than air) are suitably displaced or removed from the tank. If removing vapours from the tanks, the ducting exhaust should be carefully considered to ensure solvent vapours are not introduced into an area where equipment may not be suitably rated for an explosive environment.

6. CONCLUSIONS

Achieving major coating refurbishment campaigns onboard operational and on-station floating assets is not without its challenges, but they can be successfully achieved by following the guidance outlined in this paper, and as summarised below: -

- Recognising that tank coating maintenance will most likely be required whilst an asset is on-station and remains in production should be acknowledged.
- It is more efficient and cost effective to perform coating maintenance than subsequent hotwork steelwork renewals, whether this is in an offshore environment, or whilst at dry-dock.
- Scheduling coating works into planned future dry dockings may not be the best solution for maintaining the integrity of tank(s) experiencing rapid corrosion due to coating deterioration and/or breakdown.
- Appropriate upfront planning, engineering and project management is essential in establishing the scope of works, the asset specific nuances, and the appropriate methodologies, techniques, and controls required to achieve success.
- Access constraints during blasting and coating application should be considered and accounted for during project engineering. Ventilation arrangements during paint spraying should be assessed and adjusted as necessary, whilst ensuring this does not impact on any topside restrictions.
- Defining the coating functional specification and selecting an appropriate coating system may influence surface preparation and moisture control requirements for the project, resulting in a shorter execution campaign.
- Confined space entry activities should be managed suitably to mitigate the risks of the live production facilities above the worksites and the operatives executing the works. Routine confined space entry controls and equipment may not be sufficient.
- Controlling the tank atmosphere during blasting and painting is likely to have a positive impact on overall project efficiency and task durations.
- Blasting media should be carefully selected to ensure recyclability and reduction in expended media waste accumulations.
- Blasting technology should be reviewed to see if these technologies can be incorporated into aspects of the scope. By doing so, this may reduce manpower for confined space entry, and ultimately reduce overall blasting durations.

If coating refurbishment campaigns are acknowledged as major projects, and managed accordingly, then there should be no barriers to safely and efficiently undertaking the work to a high quality whilst the assets remain on-station and in-production.

7. ACKNOWLEDGEMENTS

The author would like to show his sincere thanks to Mr. MacLean and Mr. Lewin for providing the opportunity to develop this paper, and for their guidance and input throughout. The author would also like to acknowledge the contributions of the peer review panel for their input and helpful suggestions for improving this paper.

8. REFERENCES

1. Offshore Magazine, *2019 Worldwide Survey of Floating Production, Storage and Offloading (FPSO) Units*, https://cdn.offshore-mag.com/files/base/ebm/os/document/2019/09/FPSO_Offshore2019_DIGITAL_D7.5d8b81a18c776.pdf [accessed on 7 February, 2020].
2. Health and Safety Executive (HSE) Offshore Safety Division, *Key Programme 3 – Asset Integrity Programme*, https://www.hse.gov.uk/offshore/kp3.pdf [accessed on 10 February, 2020].
3. European Maritime Safety Agency (EMSA), *Annual Overview of Marine Casualties and Incidents 2019*, http://www.emsa.europa.eu/accident-investigation-publications/annual-overview/download/5854/2713/23.html [accessed on 7 February, 2020].