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ORIGINAL ARTICLE

Safety Issues during Icing Effects on Offshore Platforms

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ABSTRACT

Over the years, the United States and other countries around the world have seen an increasing energy demand. With this has come the need to explore and drill for oil in areas such as the Gulf of Mexico (GOM). Superstructure icing from sea spray, snow, glaze, frost, and sleet has become a problem for these types of industries and can have a major impact on their operations. With the use of old and new technologies, icing effects can either be mitigated, reduced, or even eliminated. The technologies that have been researched originate from the aviation industry, the electric power industry, and ground transportation systems, including the use of chemicals (NaCl, $CaCl_2$, $MgCl_2$, and KCl), coatings, improved structural design, high-velocity fluids, heat, infrared energy, and manual deicing. Accordingly, the available literature is analyzed to identify research methods and technologies employed and to determine the conclusions reached by each study. The expected results will identify technologies effective in mitigating icing effects on platforms and determine the most effective solutions for reducing their impact. This analysis accounts for a variety of factors, including diverse platform designs that may respond differently to icing conditions.

KEYWORDS: *Ice protection technologies, Anti-icing, Deicing, Superstructure icing, Safety*

INTRODUCTION

There was an increase in offshore oil exploration and production during the 1970s in regions such as Alaska, the North Sea, and the Gulf of Mexico (GOM), and icing has had an impactful effect on these stationary structures since [1]. Icing can affect these operations by reducing employee safety, operational tempo, and daily production count [2]. Superstructure icing caused by sea spray and atmospheric icing resulting from snow, glaze, rime, and frost have been identified as some of the hazards to offshore platforms [3]. Figure 1 shows sea spray icing and atmospheric icing zones on an offshore structure. As indicated in this figure, the sea spray icing zone is above sea level up to near the top of the platform, whereas the atmospheric icing zone extends from the top of the offshore platform to the top of the derrick.

The trawlers' loss of *Lorealla* and *Roderigo* north of Iceland in 1955 was caused mainly by sea spray [5]. Similarly, another disaster involving spray icing caused ship instability and resulted in the sinking of ten Soviet ships in the Bering Sea in 1965 [4]. Among many cases, Chatterton and Cook [6] mentioned the capsizing of three vessels (*Treadewind* in 2002, *Hunter* in 2007, and *Star Trek* in 2007) off the coast of Alaska due to the induced instability from ice accretion. As indicated, offshore industries lose billions of dollars every year due to the effects of icing.

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Figure 1. Sea Spray icing and Atmospheric icing [4]

Some of the hazards identified over the years are still the same hazards that continue to affect the offshore industry today. Even though neither superstructure icing nor atmospheric icing has caused the loss of any oil rig, it is still important to keep in mind that the safety of those who work on offshore platforms is vital to everyone [4]. With the information acquired, anyone can learn by applying these techniques to their job sites [7–9].

Most of the information about these techniques comes from industries such as aviation, the electric power industry, and ground transportation, which can help people learn about what technologies can be applied in different environments [10–11]. There has been ongoing interest in this work because understanding how ice affects offshore industry operations—and what can be done to mitigate its effects—can draw the attention of many people who wish to learn about icing and the mitigation techniques being used today [7]. Not only will we learn how the offshore industry deals with these problems, but we will also gain a better understanding of deicing and anti-icing techniques. Figure 2 shows icing conditions on different platforms.

The figure below shows all the steps involved in conducting this research. In the Introduction, we examine the importance of this work, the history behind it, and its application areas. In the Objectives section, we determine the scope of impacts and identify stakeholders. In the Literature Review, we synthesize prior research to highlight existing gaps, document resources utilized, and outline the research framework. In the Methodology section, we detail the methods and analytical techniques to be employed. In the Results and Discussion section, we present our findings and contextualize them within existing knowledge. Finally, in the Conclusion, we summarize key findings and propose directions for future research.

OBJECTIVES

The present study aims to determine the impact of icing on offshore platforms. Icing can originate from either sea spray or atmospheric sources such as snow, glaze, rime, and frost. All of these hazards pose a threat to employees and their operations. Various technologies in use today have evolved from earlier versions—modernized to improve effectiveness—while others are still under research to evaluate their potential usefulness in the industry. Industries such as aviation, electric power, and ground transportation have already contributed technologies that can be adapted for use in the offshore sector. Some of the current technologies will be discussed, along with those still striving to make a breakthrough within this industry and others. Among the technologies currently under development, ice detection systems, pneumatic boots, and different types of coatings are still in need of research.

LITERATURE REVIEW

There have been numerous works conducted by other researchers who have recognized the need to revolutionize this industry with top-of-the-line technological advances [11–13], some of which include chemical, coatings, design, electrical, expulsive, heat, hydraulic and steam lance, infrared, mechanical, millimeter wave, piezometric, pneumatic, vibration, windows, cables, and ice detection. These are just a few of the numerous solutions that have been considered when working on icing mitigation techniques. Another

Figure 2. Icing on offshore platforms [12]

technique that is discussed is modifying the offshore structural design to one that incorporates all the techniques needed for anti-icing/deicing [3]. Coating is a technique that has been used on offshore platforms to combat icing, but more research is still needed to see which one is better suited for the icing [9]. Coating can mean any product that can be placed on top of offshore structures. This can include paint, Teflon, silicone grease, or lithium grease. Pneumatic boot is another technology that is currently being used within the aviation industry that needs to be incorporated on offshore platforms. Ice detection technology also has four types of detection systems that are used on aircraft to detect the presence of ice and its thickness before and after deicing [3]. These technological advances include the use of imaging, remote, conformal, and probe. The technology of ice detection should also be incorporated into offshore platforms so that they can have a better understanding of where there is ice and how this hazard can be mitigated [3].

TECHNOLOGY USED TO IDENTIFY ICING

Research needs to be done by using credible, available literature. When the articles are acquired, every article has to be analyzed and reviewed to get the information that is needed to complete the research on how icing can affect the operations of offshore industries. Important data need to be tabulated in chronological order to see the evolution, change, and improvement in the data. From here, an investigation is completed to see what types of technologies can prevent, mitigate, or eliminate the effects that icing can have on offshore platforms. Most of this information needs to be compacted into PowerPoint slides for the purpose of educating or training others about this topic. Some of the findings will include the technologies available and whether these technologies will stop icing from occurring.

RESEARCH METHODOLOGY

In the available literature, there has been a repetition of the same types of techniques that have been used throughout the years to conduct studies on the icing on platforms. They have all used the same types of techniques, with just some modern version of what the old technology had. In advancing knowledge of the effects that icing can have on offshore platforms, available literature can be used to acquire information by researching articles from previous researchers who have studied this topic and using Microsoft PowerPoint to display a visual presentation. This will help in observing what types of technology were useful in preventing, mitigating, and even eliminating icing on offshore platforms.

It was concluded that there is no single technology that will prevent, mitigate, or reduce the icing that takes place on an offshore platform [1–4]. All of the different types of technologies available are used to protect different parts of the platform. Depending on the type of platform someone will be working on is the type of system that will be used. More than one system is needed, since some have damaging effects on the electrical facilities, and some can even corrode the structural integrity of the offshore platform [2–5].

HAZARDS IDENTIFICATION AND CONTROL IN OFFSHORE PLATFORMS

Sea spray icing on superstructures is one of the most threatening hazards to offshore superstructures [14]. Some of the threats it can pose include reduced rig stability; damage to rig structure due to changes in stress on the structural components; slipping hazards; and the disabling of winches, cranes, antennas, as well as the covering of windows, rescue equipment, hatches, and firefighting equipment [7]. By disabling some of the most important equipment needed for work and rescue, it puts platform operations at great risk for injuries and major hazards. By changing the design of an offshore structure, sea spray can be either reduced or even eliminated to accommodate the operational needs of the crew. Sea spray can't be stopped, as it is a natural phenomenon.

Snow is another issue that can present many hazards to the offshore industry. It can add weight to the floating platforms and contribute to their instability [14–17]. Snow can also create slipping hazards for personnel, damage flare booms, and prevent the operation of valves. At times, snow may occur during sea spray icing, increasing the accumulation of snow on superstructures. Snow is known to impair the flare boom and could potentially cause a fire or an explosion. Glaze occurs when there is a precipitation deposit from freezing rain or freezing drizzle. Glaze produces hazards such as slipping, and it can disable winches and cranes by locking the cables in hard ice. It can also coat valves, firefighting equipment, windows, and antennas. One of the factors that makes glaze so difficult to handle is that it is hard to remove [3]. This is due to its density or simply how hard it can get. The glazing hazard can be mitigated with the use of chemicals or a friction enhancer such as sand.

Rime comes from supercooled fog or cloud drops that are carried by the wind. Any object that is facing the same direction as the wind will accumulate the greatest rime ice thickness. Some of these can include railings, antennas, and cables. Rime that accumulates on stairs can be a hazard to the personnel working on platforms. Since rime is carried by the wind, it can pose a danger to many places on a platform [3].

Sleet can form when falling raindrops freeze before they can hit any surface. These are also known as ice pellets. Sleet can accumulate on decks, stairs, hatches, and helicopter landing pads. It can present a falling hazard for people working on offshore platforms, slow down operations, and cause the operation to lose money due to downtime.

VARIOUS TYPES OF TECHNIQUES USED

Some of the chemicals used in the research that are popular today include sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and potassium chloride (KCl) [3]. The use of aviation technology is also very important, since offshore platforms use the helipad to land the helicopter daily. The landing pad provides a means of transportation not only for personnel but also for the equipment needed to keep the operation going. Chemicals such as sodium chloride (NaCl) are used to treat areas such as decks, stairs, and helicopter landing pads [2].

Another technology that is used is coating, which assists with the removal of ice in piping, cables, under the main deck, and in high sea-spray areas where significant superstructure icing can occur. Coating is also applied to fire and rescue equipment. Infrared (IR) technology is another option for anti-icing fire and rescue equipment, communication antennas, vent openings, valves and handles, and irregular surfaces such as winches, windlasses, stairs, and walkways. Some of these technologies can serve different purposes, but they may come at a high cost to the operational budget or have damaging effects on a person's health [9]. The electrical system and communication antennas are vital areas of the operation that must be taken into consideration when applying any type of technology.
There are about fourteen types of chemicals that can be used in combination to deice or for anti-icing of offshore platforms. These chemicals are derived from highway and aviation technologies. They consist of a combination of solid and liquid chemicals that have been scaled or re-engineered to fit the offshore platforms' needs. Their application is as simple as spraying the chemicals where needed—on decks, stairs, work areas, and even structural components such as the

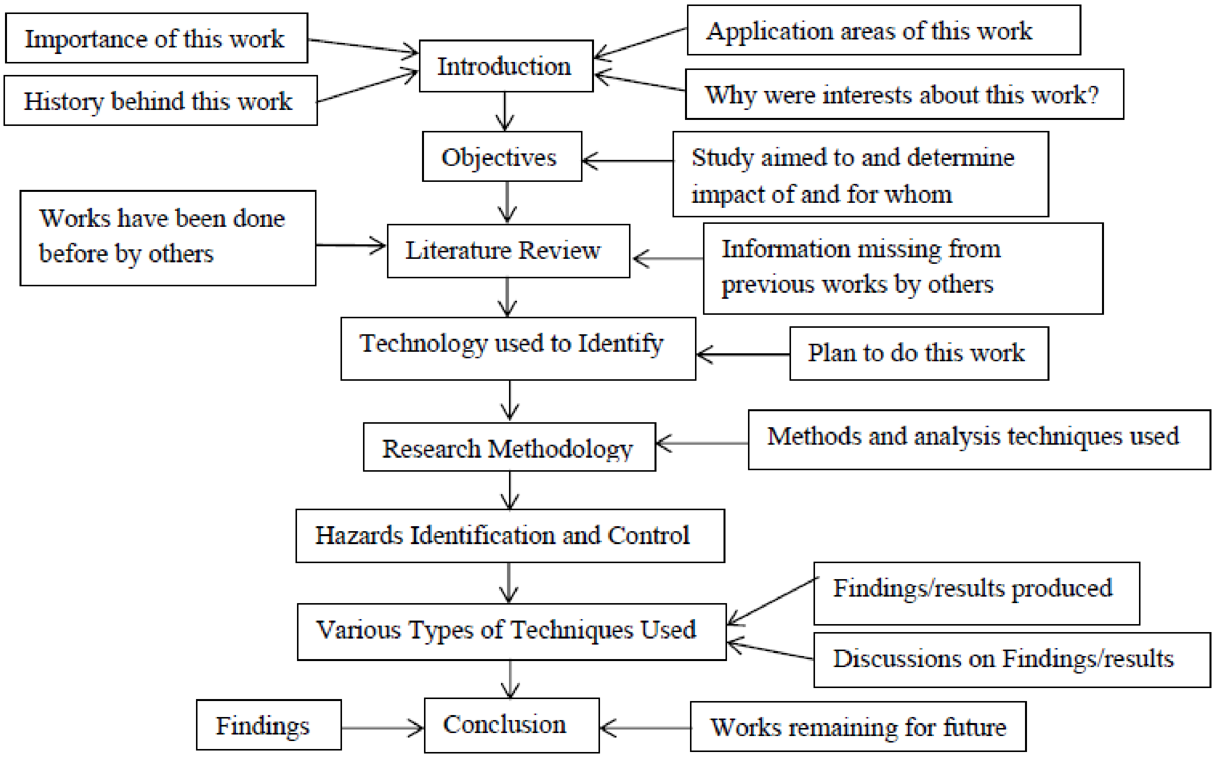

Figure 3. Flowchart of research steps

cellar deck or the moon pool. The areas that benefit most from chemicals are decks, stairs, and helicopter landing pads. One of the major problems with using chemicals is the potential for dilution and wash-off by waves and heavy spray.

Among these chemicals, some agricultural chemical products are made from sugar beets, corn, and alcohol. These agricultural products have low corrosivity, function at low temperatures, possess higher viscosities than other deicing chemicals, and can provide a residual effect between storms. Although the cost of agricultural products is high, they have been accepted for use in on-highway operations.

Coating is another technology that is currently being used in the operations of offshore platforms for icing. Coating causes the ice to fall off with wave impact or due to the vibration of the structure. Some of the coatings currently in use include paint, silicon, grease, or Teflon. When coatings are applied to offshore components, their rapid removal can help prevent damage to sensitive sensors, valves, and composite structures. Coatings can also provide coverage to antennas, which helps maintain communication. However, when coatings become wet, they can create hazards on decks, stairs, work areas, and helicopter landing pads. This hazard needs to be considered before applying coatings to such areas.

The structural design of the offshore platform can also provide more answers to the ongoing problems of icing. Sea spray can cause the most problems in offshore structures and increase the height of the platform, which can lead to a major breakthrough. The person designing the offshore structures can also consider enclosing areas such as walkways, decks, stairs, the derrick, and moon pool areas to reduce icing in these places. Icing can bring many hazards to offshore platforms, but changing the design being used can reduce the effects that some of them have.

Infrared energy is another technology that can deliver heat to an object from an electronically or gas-fired emitter. This technology can be used either to melt ice or to prevent ice from forming. The ice will absorb the infrared energy, which will cause it to melt, or the surface of the object will be warmed to prevent icing. The problem with this technology is that it can overheat materials and cause the ignition of explosive gases. This technology is useful for fire and rescue equipment, communication antennas, vent openings, valves and handles, and even surfaces such as winches, windlasses, stairs, and walkways.

Since the early days, the use of manual deicing has been paramount to offshore operations. This method has involved the use of wooden baseball bats, mallets, and shovels. Manual deicing can be very dangerous, especially if personnel are exposed to high winds. It can also be costly, as it requires many personnel working to break the ice, and it can be a major hazard since workers can slip and fall overboard. This system may be used if other systems have failed to work. Because it is hard to know where a person is hitting to break the ice, many components can be damaged or destroyed [15, 17]. Not all areas on a platform can be deiced, since manual deicing can only be performed where there is accessibility. Another deicing tool that can be used on windows and composite structures is a scraper to remove the ice manually.

Many tools have been used to control the effects that icing can have on an offshore platform. Some technologies may produce better results than others, but they are all used for the same purpose—solving a long-standing problem that offshore platforms have with ice [5, 7]. Up to now, chemicals have had the most impact on this industry. Other technologies have joined the evolution, but some are still in the test phase. A structural design change can also influence the industry by reducing the number of icing hazards. One of the most important points about these technologies is that there is no single solution that will fully reduce the effects icing has on platforms [8, 13].

More than one technology has to be used to help combat the problems that icing brings to this industry. For this reason, there should be a selection of the areas that need to be protected, and the methods of protection should be chosen accordingly [10–12]. The areas where there are more dangers are the areas that require more consideration and care to prevent accidents from happening. One of the most important goals is to increase the safety of personnel first, and then protect the platform from hazards that can damage its integrity and structure. For hazards to be eliminated or reduced, there must be identification and protection of these hazards. This paper helped to identify the major hazards on offshore platforms and to discover which technologies work best for them [11, 14]. Even though there is more than one technology available to use, safety personnel need to understand the individual needs of their platform to apply the technology most beneficial to their operation. Some of the technologies used are new, some are old, while others come from a combination of new and old versions [9, 13]. Working in conjunction with the electrical industry, the transportation industry, and the aviation industry, offshore platforms have taken advantage of how these sectors operate to mitigate the effects that icing has.

CONCLUSION

There is no single technology available today that will solve the effects that icing has on offshore platforms. More than one technology is needed when preparing any plan to mitigate its potential hazards. The use of chemicals remains the most popular method to control ice on platforms. Even though chemicals remain widely used, there are also some disadvantages associated with them. These include corrosion of the structural integrity of a platform, and the fact that some chemicals are slippery to personnel and can cause injuries, such as broken limbs. This is in addition to how expensive they can be for the offshore platform's budget. While chemical spraying has proven effective in the transportation field on highways, it presents challenges when applied to different components on platforms. The aviation industry also uses chemicals for deicing runways, but they must be washed off because they can damage aircraft. On platforms, these same chemicals must be used so that helicopters can land safely.

There are still many questions regarding new technologies that have emerged, such as coatings. Since different types of coatings are being used, ongoing research is required. With the use of various coatings come new hazards that can hinder offshore operations. Perhaps the most important area of research that remains is ice detection technology. With these technologies, offshore platforms will be able to detect the presence of ice and its thickness before and after icing. This technology is currently being used in the aviation industry but must still be adapted for use on offshore platforms. It involves imaging, remote, conformal, and probe techniques. Ice detection technology will help the offshore industry pinpoint the precise location of icing, enabling better decisions on how to mitigate the hazards it presents. Pneumatic boots are another technology that can help combat icing hazards. Currently used in the aviation industry, these boots allow snow to accumulate, and when enough ice has formed, the boot inflates to break the ice off the surface. This technology is used on airplane wings to combat ice buildup. Its application on offshore platforms could help remove ice in high-risk areas. It simply needs to be integrated into platform systems.

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