COLD TEMPERATURES & MARINE ENVIRONMENTS EFFECTS ON STEEL LIFTING EQUIPMENT

Harsh Environments | White Paper

Cold temperatures and marine environments' effects on steel lifting equipment

All lifting equipment is affected by the environment at all stages of their service life. Two common but extreme environments we face in the lifting and material handling industry are cold weather and marine environments. If we take the US an example, more than a third of the population (130 million) live in counties directly on the shoreline, and if you take the population residing within 100 miles of the coast that number doubles. However, corrosion is a challenge not just in costal and marine environments but also in industrial plants and buildings with high humidity. Many people also live in areas where the temperature becomes a factor in the winter, in fact more than half of the states in the US and all of Canada sees averages below freezing, as do parts of South America as well much of Eurasia. Consequently, both of these environments become an important aspect to consider when designing, manufacturing, procuring and using lifting and material handling equipment.

"we have built leading know-how in combating the challenges of lifting in extreme environments"

The Crosby Group has a long history of designing and manufacturing lifting equipment that is used on everything from offshore platforms in the Gulf of Mexico to fishing vessels operating in Arctic climates, and we have built leading know-how in combating the challenges of lifting in extreme environments.

Cold temperature's effect on steel lifting equipment

What do manufacturers consider cold temperature? Once the ambient temperature drops below freezing (32° F or 0° C), equipment will be affected. However, today equipment is commonly designed to work down to -4° F (-20° C), and equipment specifically designed for cold weather may even be designed to work in -40° F (-40° C). Below -40° F (-40° C) there is a significant risk of parts of the system not being designed for this environment as there are many components in a lifting system that are affected in cold temperature: fluids, structural or load bearing steel, electronics, hydraulics, engines, etc. Consequently it's always recommended to consult the manufacturer of each individual component (e.g. hook) or system (e.g. crane) to assure you are taking the right precautions and avoid accidents. In this article we will be focusing on steel lifting accessories. In addition to the consideration of the equipment properties, there is also the human factor with serious risk to injury or even death if part of the skin is unprotected.

The main challenges for any material in extreme cold temperatures are durability, strength, toughness and brittleness as the properties of the material change when the temperature drops. Lifting equipment is designed to elongate before it breaks, acting as a safety feature as the operator can see that the product is being incorrectly used and can stop the operation before a catastrophic failure. However, as the temperature drops steel passes through something called "Ductile – Brittle Temperature Transition". As shown in Diagram 1 to the right, this transition is where the steel becomes more brittle.

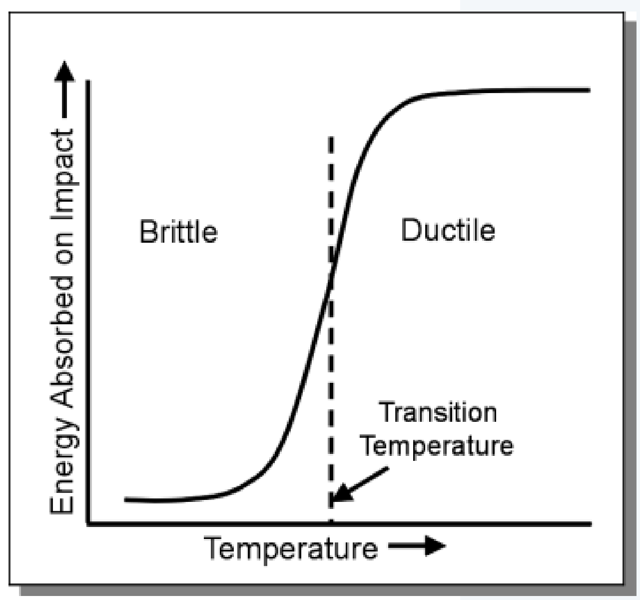


Diagram 1. Ductile-brittle temperature transition. Reference Source: own work, based on Comprehensive Structural Integrity, I. Milne, A.R. Dowling, 2003

Cold temperature's effect on steel lifting equipment

The transition temperature is determined by a standardized Charpy Impact test which measures the energy required to break a sample of the steel at the design temperature. The transition temperature is important as once a material is cooled below the transition temperature, it has a much greater tendency to shatter on impact instead of bending or deforming. As the steel passes the transition temperature and becomes more brittle, the way it will react to a force from a load changes and consequently the way it fractures also shifts. Diagram 2 shows the differences in fracture types, with (a) and (c) showing the extremes and (b) showing a typical fracture of ductile steel under normal conditions.

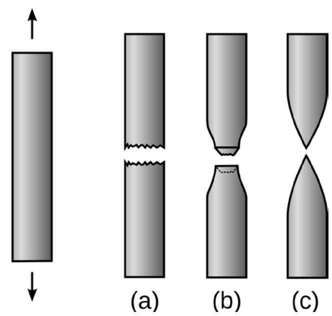


Diagram 2. Schematic appearance of factures. Reference Source: Wikimedia commons

For the manufacturer, there's several ways of combating the challenges of cold temperature and it starts with the raw material design. The three main factors in the steel design are grain size, carbon content and alloy contents. By decreasing the grain size and carbon content, as well as adding alloys into the material such as nickel, vanadium and manganese, the manufacturer can create a steel that has a low hardness, a high ductility and is resistant against embrittlement in cold temperatures. The production process is also important since the forging, any welding and heat treatment all affect the final characteristics of the product. Certain stainless steels (e.g. 316SS) are also an option - although more costly - as they don't go through a ductile-brittle transition due to the nature of their crystalline structure.

For the person procuring and using the lifting equipment there are also precautions to take:

MITIGATING EFFECTS OF COLD TEMPERATURE

MANUFACTURER

DESIGN FOR EXTREME COLD TEMPERATURE

The transition temperature at which brittle fracture occurs is lowered by:

- a decrease in carbon content
- a decrease in grain size
- an increase in content of alloys
    - e.g. Vanadium, Nickel, Aluminum

PROCURER / OPERATOR

PRACTICAL PRECAUTIONS

Make sure that you have the right equipment

- Think of the system! The lifting gear might be useful down to -40°C (-40°F) but is the winch, block and crane rope?
- Do not exceed the limits specified by the manufacturer

Decrease velocity of lift if possible (never shock-load)

Lifting operations are always hazardous and cold temperatures make it even more so, for both man and machine, so ensuring sure you have the right equipment and correct operation practices is critical.

Marine environments' effects on steel lifting equipment

When operating in coastal areas and around or in water there are three main challenges: fatigue, corrosion, and brittleness. All three factors affect the steel and the interaction amongst them affects the service life of the product. We covered brittleness in the first section and the risks and effects of brittleness in a marine environment, as well as the precautions, are similar to those experienced in cold temperatures. However the sources of the brittleness are different in a marine environment. In these applications the brittleness comes from hydrogen, in a process called hydrogen embrittlement. Hydrogen can enter the steel in the steel making process, through the production process (for example if exposed to acids), through the chemical reaction that takes place during corrosion and through absorption from certain environments. As a result hydrogen embrittlement might cause unexpected brittle fractures at loads below the stated working load limit. This in turn can result in catastrophic failures of the lifting equipment and potential damage to person and property.

Marine environments' effects on steel lifting equipment

Corrosion is the most obvious challenge you're dealing with in a humid or marine environment. Corrosion is a naturally occurring chemical process where processed steel turns into a more chemically stable form such as an oxide. The corrosion rate is affected by multiple factors such as temperature, depth, currents, salinity, humidity levels, wear and pollutants. ISO 9223 defines levels of corrosion rate from C1 (very low – for example air conditioned warehouse and certain deserts) to CX (extreme – for example offshore structures in the splash zone). A C1 corrosion rate is less than 0.1 μm/yr (0.004 mils/yr) on a galvanized steel plate and a CX is more than 8.4 μm/yr (0.33 mils/yr), see table 1 below.

Category	Corrosivity	Typical Environments	Rcorr (μm/yr)	85μm mean coating thickness for steel > 6mm (years)
C1	Very Low	Dry zones with no pollution (certain deserts, AC offices)	Rcorr≤0.1	80 < Service life
C2	Low	Temperate zone with minimal pollution, rural areas, subarctic climate	0.1<Rcorr≤0.7	80 < Service life
C3	Medium	Temperate zone with medium pollution or some chloride (1-20 miles from coastal areas)	0.7<Rcorr≤2.1	40 < Service life ≤ 80
C4	High	Temperate zone/subtropical with low to high pollution or high chloride effect, less than 1 mile from the coast but out of splash zone	2.1<Rcorr≤4.2	20 < Service life ≤ 40
C5	Very High	Subtropical to tropical, periods of wetness , high pollution, or very high chloride effects, coastal areas	4.2<Rcorr≤8.4	10 < Service life ≤ 20
CX	Extreme	Subtropical to tropical, extended periods of wetness, very high pollution, or significant and extended chloride effect. For example offshore structures within the splash zone	8.4<Rcorr≤25	3.4 < Service life ≤ 10

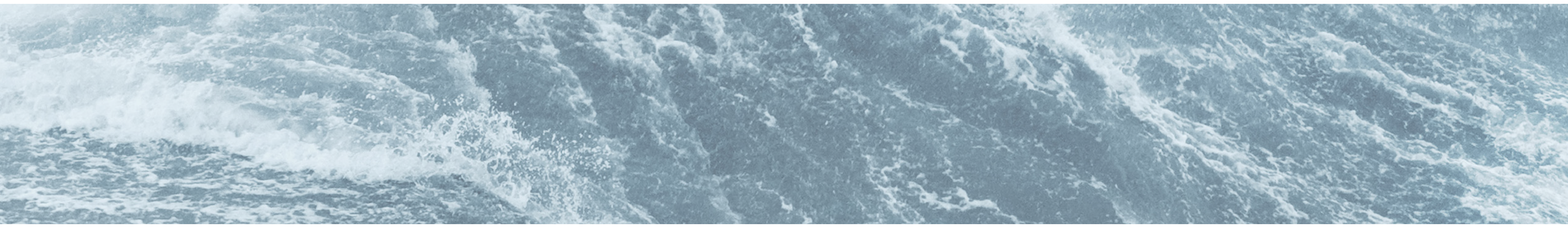
Table 1. Corrosion Rates for Hot Dip Galvanized Coated Steel (Ref ISO 1461:2009 and ISO 9223:2012)

On an uncoated steel surface the corrosion rate along with wear and erosion can certainly be more than what is outlined above and will be clearly visible to the eye. Apart from changing to a stainless steel, using a sacrificial coating such as a zinc rich paint, a zinc thermal diffusion coating or hot dip galvanization (HDG) is one of the most effective ways of protecting a steel product against corrosion and a much more economical alternative. For this reason, many products at risk of corroding are hot dip galvanized. These sacrificial coatings also provide additional benefits including: 1. protecting the steel through acting as an anode corroding in place of the load bearing steel, 2. easier inspections as there is no risk for corrosion under the coating, 3. high impact and wear resistance – while retaining a higher capacity compared to an equivalent product in stainless steel.

Marine environments' effects on steel lifting equipment

The corrosion that takes place in marine environments, in combination with the forces that act on the lifting equipment in operations, can cause something called stress corrosion cracking. The corrosion takes place in microscopic cracks which can make the lifting equipment seem in good condition on the outside but then cause an unexpected and catastrophic failure. Alloys, which are used in most lifting equipment and especially in conjunction with a high hardness (generally defined as above 41 HRC) are at a higher risk for stress corrosion. Therefore, one way of reducing the risk for stress corrosion is to choose lifting equipment with a lower hardness and good Charpy-V values.

The third factor affecting steel in a marine environment is fatigue, which is the weakening of material caused by the repeated action of applying loads. All steel products have some microscopic discontinuity, essentially a crack so small that it cannot be seen with the naked eye. As loads are lifted and unloaded the stresses on the material causes these small cracks to grow and finally reach a critical size where the material fractures. The number of stress cycles (or lifts) a material can handle at a determined load is called the fatigue life. The heavier the load in relation to the maximum capacity of the lifting equipment the fewer cycles the material can handle, as can be illustrated by a S-N curve *(shown in Diagram 4).*



Marine environments' effects on steel lifting equipment

The curve shows the number of cycles the equipment can be loaded before it reaches the fatigue limit. At break force (BF) you can lift half a cycle, meaning you can load it once but you cannot unload it in its current state as it is broken. If you lower your load a little you can now lift 1 cycle, then 2, then 10, then 100, and so on. So, as you can see you increase the number of cycles you can lift until 20,000 cycles at 1.5 x WLL, and then 2 million at WLL and then you reach the endurance limit, at which you can theoretically lift an unlimited amount of times. However, this is under perfect circumstances and there are multiple factors that influence the fatigue limit such as:

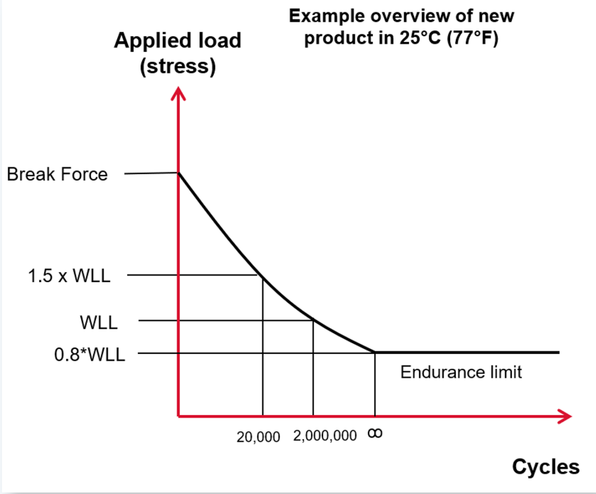
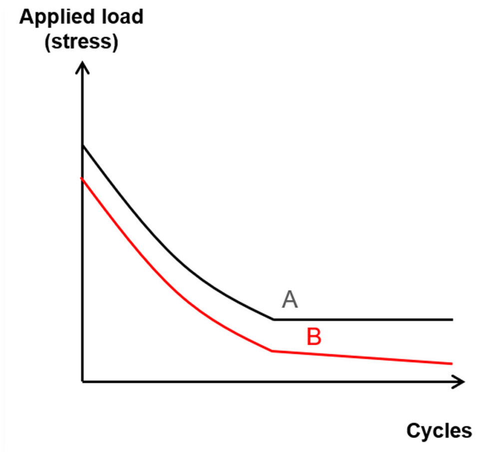


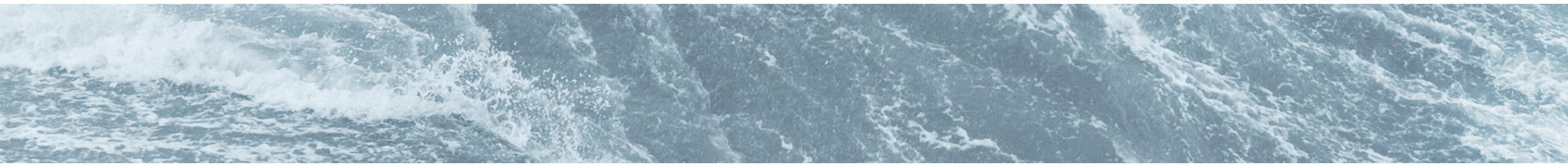
Diagram 4

- Damage (notches, cracks, gauges)
- Corrosiveness of the environment
- Residual stresses from manufacturing
- The properties of the steel
- The applied load in correlation to yield strength of the steel

Here we can see an example of what happens when corrosion affects the steel, line **A** is with no corrosion, as we saw before. **B** is with corrosion, which leads to:

- Lower ultimate strength
- Fewer cycles at same stress
- Elimination of endurance limit





Fatigue resistance will consequently be one of the limiting factors when determining service life of any lifting equipment. It is important to understand that fatiguing will always be a risk in any lifting application and can occur at lower load than WLL, especially in harsh environments.

For the personnel utilizing lifting equipment in marine environments, coastal areas or other humid environments the following considerations are important as they relate to work-place safety:

- **Hardness and Charpy impact values are more important than the grade of the material. A higher grade material can be more suitable for a marine environment than a lower grade steel, depending on how the product has been designed and the production process.**
- **Protection of the products (for example hot dip galvanizing) not only makes them safer but also significantly improves product life-time and long term cost.**
- **Steel lifting equipment might look very similar (e.g. master links); the difference is in the details.**
- **Stay safe!**

⚠ Always consider where the products are going to be used, and where they might end up.

⚠ If operations take place close to the maximum capacity (working load limit) of the product, consider going up one size to increase the overall strength of the equipment.

⚠ Always follow manufacturers' recommendations (both for liability and safety concerns).

⚠ Adapt your inspection frequency and procedures for the environment and application.

⚠ Do not modify (for example galvanize or weld) any lifting equipment that is not designed for it as it can have a severe effect on the mechanical properties the steel as well as transferring the liability to the person or company doing the modification.

To summarize, lifting – even just 50 lb/25 kg – is always risky. Extreme environments like cold temperature and marine environments require additional evalutation. it is of outmost importance to take proper consideration in the selection, procurement and use of lifting equipment. Always consult the manufacturer if you are unsure about the properties or the suitability of the equipment.