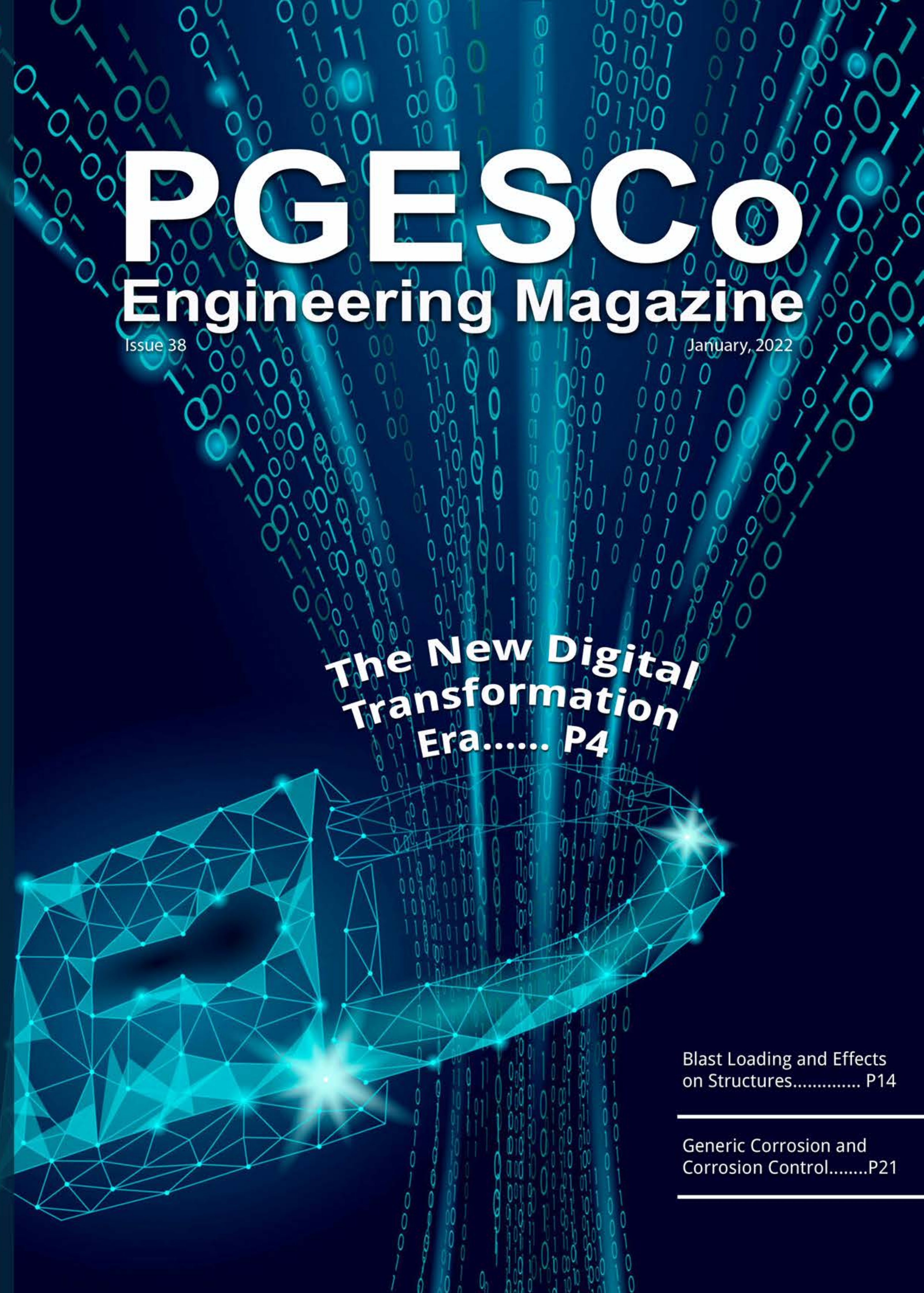

PGESCo Engineering Magazine

Issue 38

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Magazine Team

In This Issue:

Editor's Note..

The editors are very pleased to introduce this **38th** issue of the magazine, which includes three excellent articles and I would hope that they will be appreciated by the interested readers.

The first article is by **Dr. Ahmad ElGhazouly** is titled "*The New Digital Transformation ERA."* The article is an introduction to Digital Transformation ERA and illustrates the difference between digital projects, digitization, digitalization, and digital transformation.

The second article is by **Dr. Mohammad Abbas** is titled "*Blast Loading and Effects on Structures.*" The article is an introduction to blast resistant technology in the petrochemical industry, from conventional static loads to simplified dynamic design methods.

The second article is by **Dr. Adel Eid** is titled "*Generic Corrosion and Corrosion Control.*" The article concentrated on the corrosion theories, types of corrosion, factors affecting the rate of corrosion, methods for the prevention of corrosion, and the corrosion cost.

I hope that you enjoy reading these articles, until our next issue after three months.

I'll be glad to hear your opinion and expect your contributions to our next issues.

Dr. Wael Youssef

The Magazine Cover about

>>>> THE NEW DIGITAL TRANSFORMATION ERA.

THE NEW DIGITAL TRANSFORMATION ERA

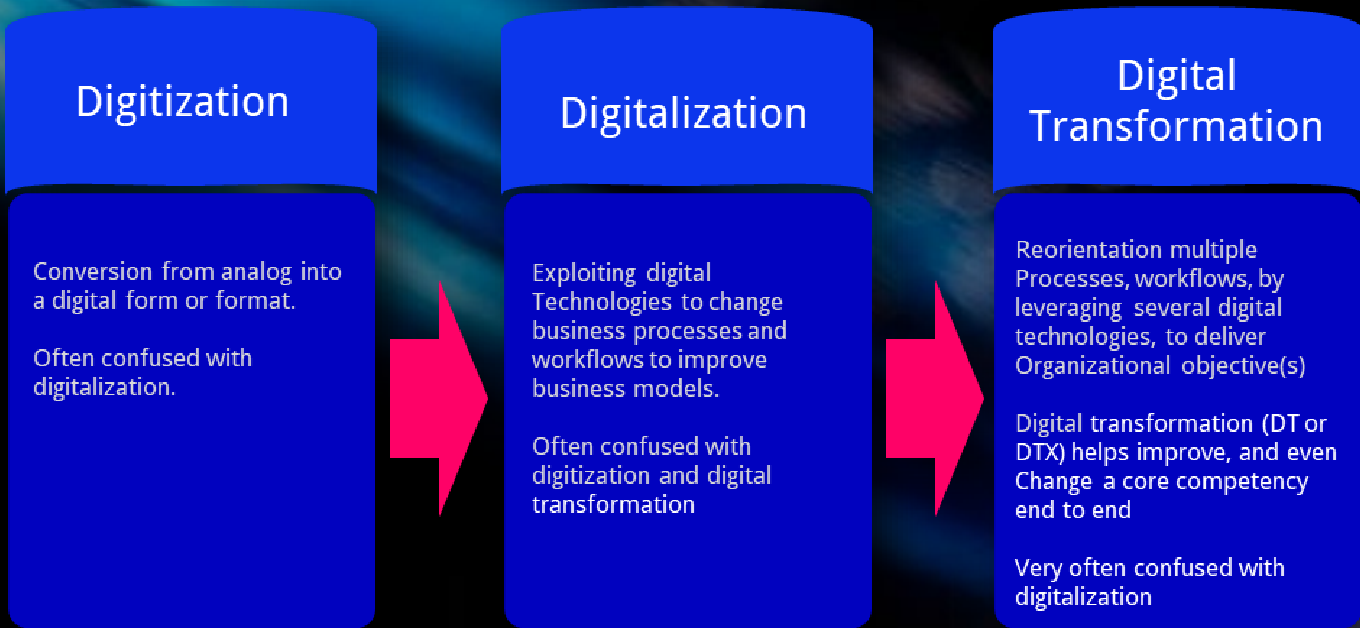
Article By: Dr. Ahmad ElGhazouly

Digital transformation provides a major reconsideration on how an organization uses technology, people, and processes altogether to primarily change business performance. In a world where we can't even work without technology, we live in a digitalized world and constantly expect technology to work for us.
This is reflected on our expectations when it comes to buying products and living experiences. For this reason, organizations in mostly all sectors need to continuously invest in advances that fulfill employees and potential customers business needs.

Organizations that are part of the industrial sector are mostly subject to the changes that digitalization is producing.

"The Digital Era changes how the business operates"

Three terms are commonly misused to describe the digital projects, ***Digitization***, ***Digitalization***, and ***Digital Transformation***, we will try to explain the difference between them here after.



Digitization is the process of **converting information from a physical, manual / non digital to a digital format.** If an organization uses this process to improve business, create revenue or simplify some operations, then it is called ***digitalization***. The results of this process are called **digital transformation.**
Digital transformation requires digitization and digitalization on the way to building a digital business.

The Digital Era has just begun to change how the business operates. Over time there will be many more innovations and new terms for us to learn and understand.

Digitization is the process of converting information from a physical, manual format to digital one, ***digitalization*** is the process of leveraging digitization to improve business processes, and ***digital transformation*** is the transformation of business actions, behaviors, processes, products, and models to fully leverage the opportunities of digital technologies.

Digitization, digitalization, digital transformation, why does it matter?

Digitization

Digitization is the process of changing information from a physical representation to digital one. It means converting something non-digital into a digital version to be used by computer systems and automate processes or workflows. Digitization enables to create business value, which needs data. **It helps to lay the foundation for business use cases and scenarios that is empowered by the data.**

Examples:

- Scanning a paper document and saving it as a digital document, like PDF.
- Going from notes on paper to typing them up in MS Word or MS OneNote.
- Converting from analog VHS cassettes to CD, DVD or Blu-Ray discs containing digital data.

Digitalization

Digitization and digitalization are closely associated. They are often used interchangeably, but they are two different things.

Digitalization is the process of influencing digitization to improve business processes. Digitalization means using digitized information work for you. This term refers to the **use of digital technologies and data to create revenue, improve business, and create a digital culture** where digital information is at the core. It renovates business processes to be more efficient, productive, and profitable.

Examples:

- Uploading a PDF document to the cloud and sharing it with many people to analyze the data.
- Converting an Excel spreadsheet to a SharePoint list stored in the cloud. The platform provides a structured environment where the data can be shared among several users. Still, the SharePoint itself requires human interaction to keep it up to date.
- Uploading digital training courses from CD, DVD or Blu-Ray discs to an online service like Microsoft stream. People can download them.

Digital transformation:

Digital transformation is **the transformation of business activities, processes, products, and models** to fully get the benefits of the opportunities of digital technologies. The main goal is to improve efficiency, manage risk or discover new value opportunities. i.e., digital transformation **is doing things in a new (digital) way.**

Examples:

- Reading the data from an online PDF or moving the data from a SharePoint into an app or system that will analyze the data. The goal is to provide us with insights to offer new products or improve customer (internal or external) service. This process doesn't need a lot of human interaction because is automated. As a result, it enhances efficiency, reduces costs, and may lead to increased revenue.

Industrial digital transformation

Industrial digital transformation refers to a set of modernized and transitional solutions towards new business models and revenue streams, it is consisting of three fundamental pillars: automation, improved manufacturing processes and production optimization. But this type of transformation is not limited to the technologies that are used; it represents a culture of change integrated into all work areas and a transformation in the way different teams are managed. Only in this way can digitalization have a real valuable impact on the production of any organization.

Benefits of digital transformation

- **Reduces costs**

Technology supports the process of minimizing organizational expenses in face of the future. The integration of digital technologies lead to a transformation of procedures and a digitalization of documents that result in an overall process optimization. In consequence, unnecessary expenditure is cut, resulting in a reduction of labor costs.

Furthermore, digitalization allows organizations to calculate and estimate expenses considerably more accurately, ensuring that budgets are under control. In addition, it eliminates and/or replaces unnecessary tasks within processes, making them much more efficient. This efficiency is reflected in time saving that results in a much more cost-effective production.

- **Creates new business opportunities**

New digital ecosystem enables the production of new products and/or services that were previously seen impracticable to an organization, therefore creating new sources of revenue. In addition, the speed with which new services (modernization or reorientation) are launched is much faster.

Through a good use of big data and artificial intelligence technologies, organizations have the possibility to try, get ahead of trends and predict which new developments will succeed among customers. These technologies can even make it easier for organizations to become environmentally friendly, creating products that are greener and less harmful to our environment.

- **Fosters competitive advantage**

New technologies improve the quality of the production output by adding new functionalities into mainstream systems that improve the outcome. This leverages the differentiation of the output in question and provides added value to the brand. On the other hand, comprehensive quality reviews are generated that ensure compliance with standards and different regulations. Also, it allows our employees to develop their potential and professional skills rather than being engaged in tasks that do not contribute intellectual value to the organization.

- **Boosts internal unity**

The flow of information born from digitalization systems communication between departments, allowing the involvement and collaboration of employees from different areas of the organization in projects and decision making. In addition, it gives organizations an overall view of the different internal entities. This enables more efficient global management. On the other hand, the fact that information is immediately accessible from anywhere and at any time, facilitates the work between different teams.

- **Improves use of data capacity**

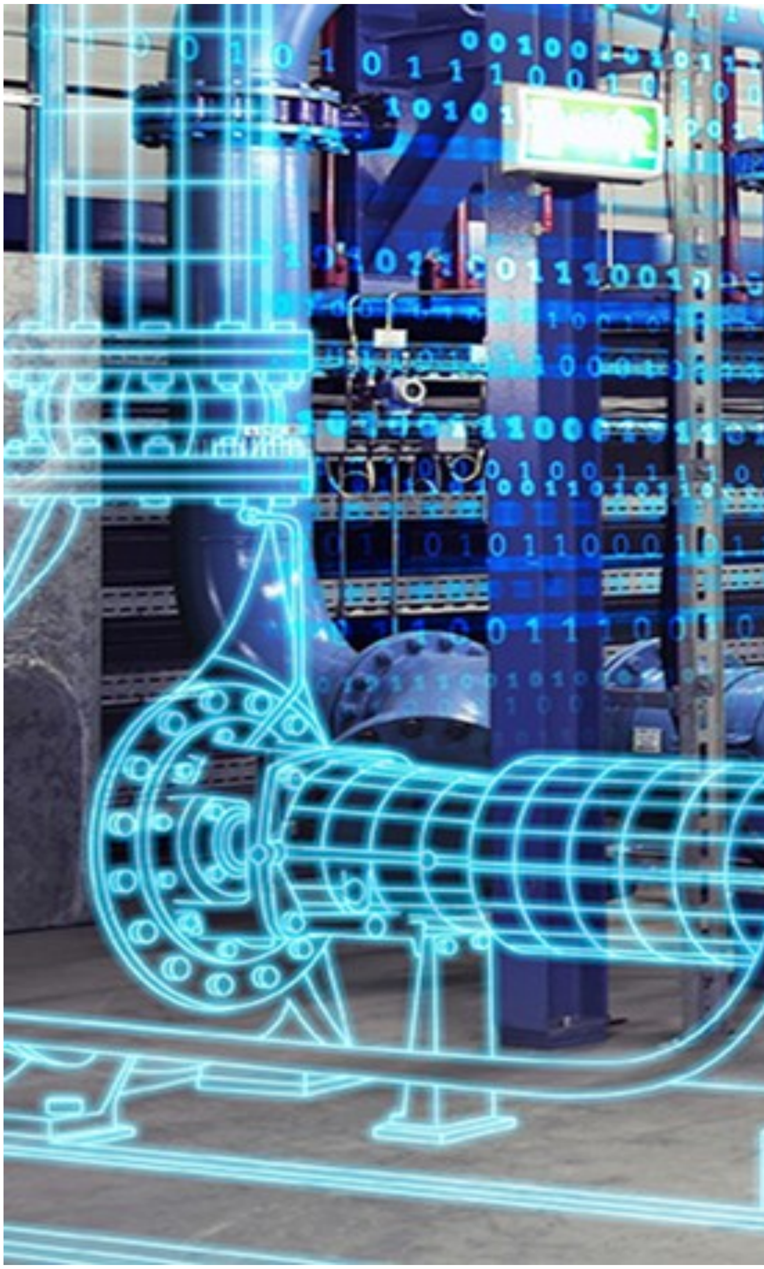
Digital transformation builds a data-driven decision-making culture collected by technology tools. The improvement in analytical systems results in a deepening of data understanding. This strengthens informed decision-making, key recommendations, and rapid responsiveness.

- **Bring new talent's interest**

Digitalized organizations who are up to date with trends and processes attract the most interest from trained professionals with capabilities that are fundamental in this complex and disruptive environment. In addition, if the change is managed in an appropriate and responsible manner, it will benefit all its parts, generating a greater value of job satisfaction for employees. Human motivation, together with effective digital tools, will be reflected in the productivity and profitability of the company.

What are the key technologies

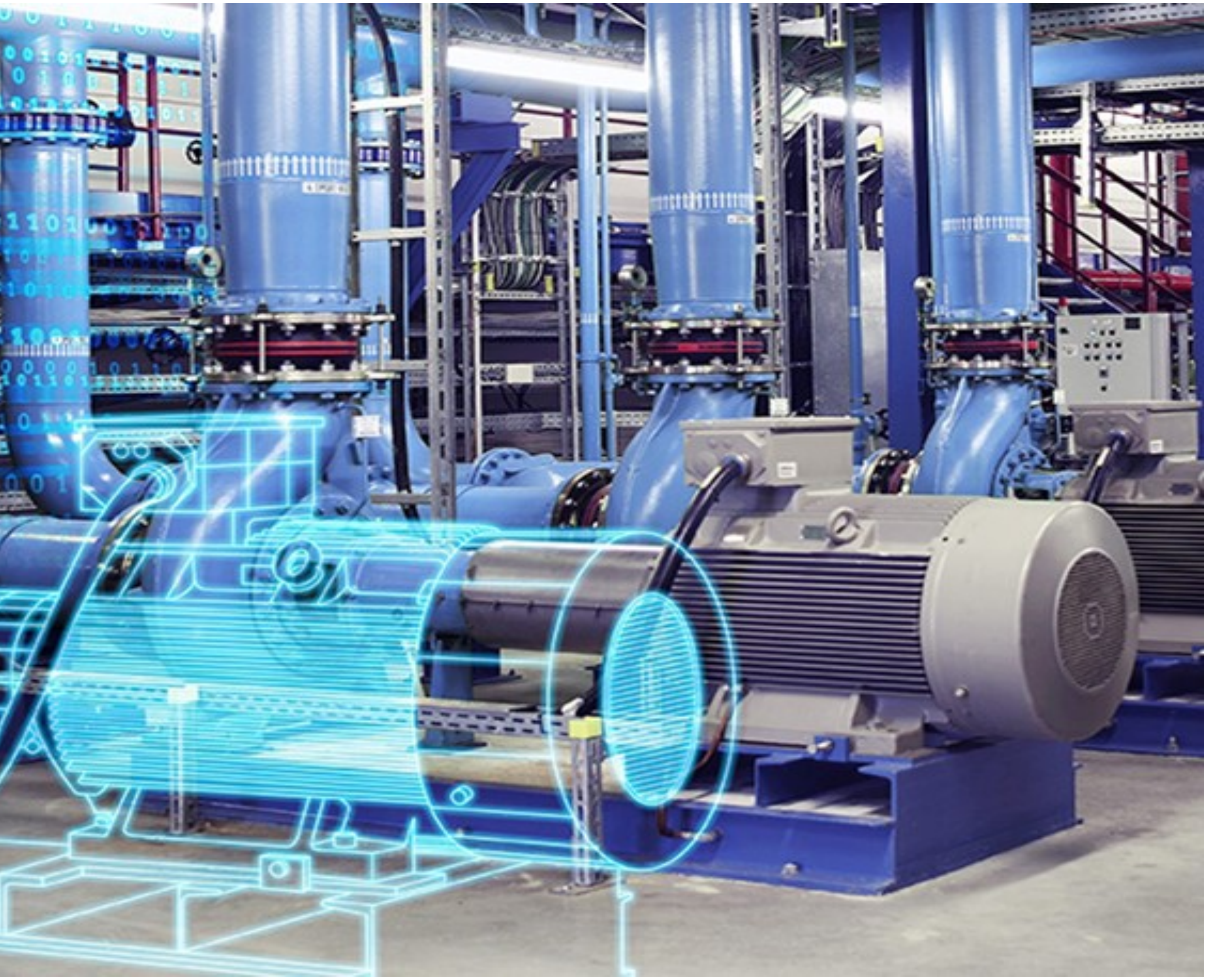
Digital Twin



A ***digital twin*** is a digital representation of physical entities such as products, devices, or systems that enable businesses to make model-driven decisions. Digital twins have a wide range of applications including:

- Product development
- Design customization
- Shop floor performance improvement
- Predictive maintenance
- Logistics optimization

and trends enabling digital transformation in manufacturing?



Another application of digital twins is digital twin of an organization (DTO) which is the virtual representation of the entire business instead of a specific product. DTOs enables organizations to gather insights about:

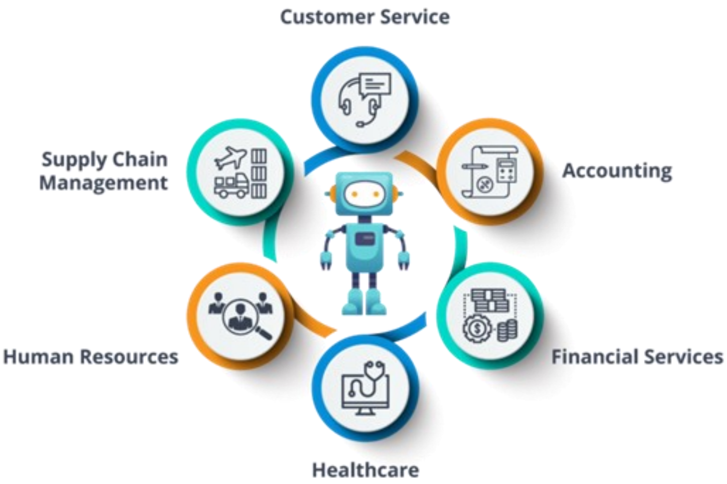
- Previous performance
- Business goals
- Business models
- Business processes
- Performance KPI indicators with target levels
- Detailed transaction-level situational process analysis

Augmented and virtual reality

According to PwC, augmented and virtual reality (AR/VR) technologies have the potential to add 1.5 trillion USD to the global economy by 2030. Applications of AR/VR include:

- **Fast prototyping** by enabling designers to see how a product would look like without physically creating it.
- **Inventory management** involves processes that cannot be automated 100%. AR/VR-enabled devices can instruct human workers in a warehouse and provide information about items on shelves.
- **Maintenance**: Different machines require different maintenance processes and having maintenance instructions accessible in your glasses makes maintenance significantly easier.

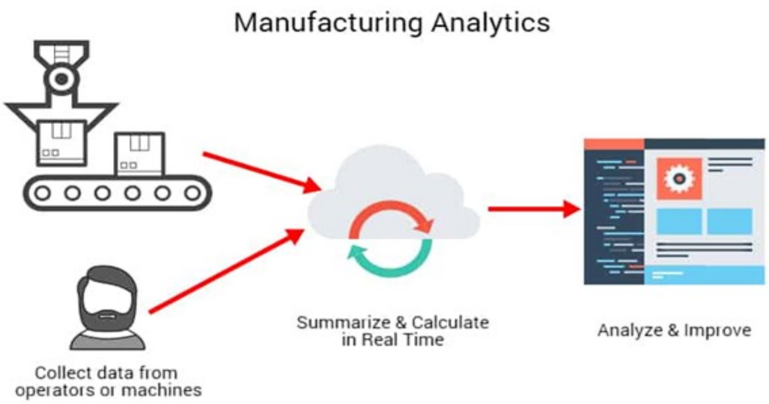
Robotic Process Automation RPA



Robotic process automation (RPA) can decrease the need for human interference in ruled-based and repetitive tasks and reduce process errors. The processes that can benefit from RPA tools include:

- Supply chain optimization
- Invoice processing
- Inventory management
- Manufacturing data management
- Order fulfillment

Manufacturing Analytics



Manufacturing analytics provide insights about machine, processes, and operators, to predict machine future use and maintenance requirements, prevent failures and pitfalls, forecast business, and inventory requirements, and identify areas for improvement. Leveraging analytics in manufacturing can be used to optimize:

- Demand forecasting
- Inventory management
- Order management
- Maintenance (predictive and preventive)
- Risk management
- Automation and robotics
- Transportation allocation
- Product progress measurement
- End user experience estimation
- Price optimization

Trending Technologies in Digital Transformation

Cloud Technologies (Public, Private and Hybrid Cloud)

Due to the increasing volume of data, Software-as-a-Service (SaaS) and on-premises solutions on the cloud are getting more popular among businesses. Cloud solutions address the need for scalability so that organizations don't need to transfer data between systems as the business grows. Along with scalability benefits, cloud technologies can also provide compliance with privacy and security regulations. However, companies need to keep in mind that cloud costs may be too expensive for the fees that have to be paid for unused functions. Cloud compute storage and networking cost can easily add up. In this regard, working to **optimize cloud costs** can increase the profitability of cloud users.

Cybersecurity

The objective of the Digital transformation is leveraging data and technologies that turn data into insights to deliver better services and operational excellence. As the volume of data become huge, businesses must secure increases and we hear different data breach stories that cost organizations millions, the demand for cybersecurity technologies will continue to grow. The types of security solutions you can implement:

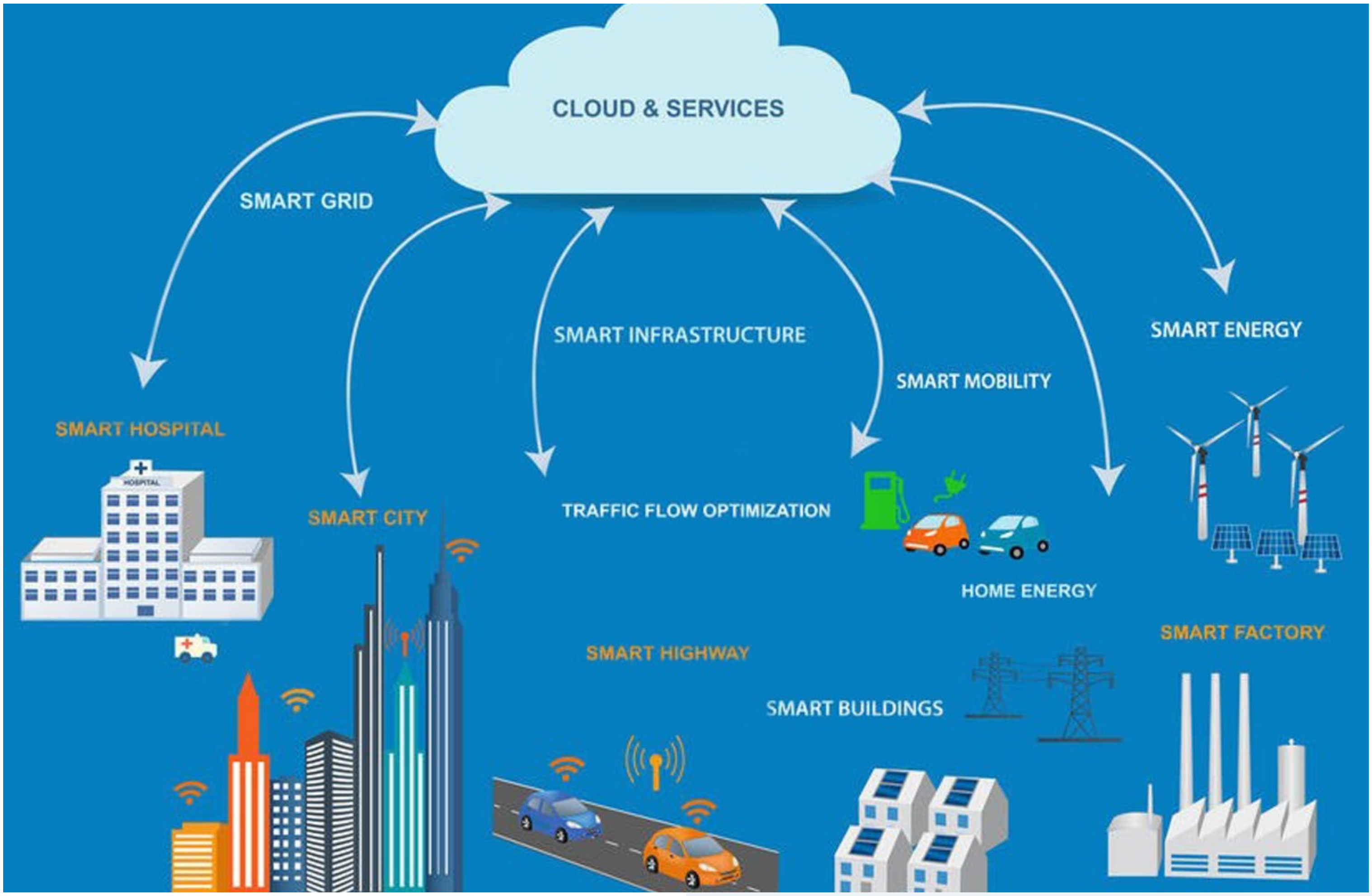
- **Cyber threat intelligence (CTI):** Data collection and analysis to gain information about existing and emerging threats to an organization so that they can act before the data breach occurs.
- **Endpoint security solutions:** Securing organizational assets such as desktops, laptops, and mobile devices that are connected to the organization's network from malicious activities.
- **Identity and access management:** (IAM) ensures that the right people and job roles in an organization can access specific tools and data sets.
- **AI-powered cybersecurity solutions:** Using AI solutions will improve cyber and physical security. However, such solutions may not be mature and very effective now.

Data Privacy

Data privacy regulations such as *General Data Protection Regulation*" GDPR ", in the European Union force organizations to invest in privacy-enhancing technologies (PETs). Some technologies such as data masking solutions have been part of many international organizations' hot projects for a long time. This becomes more important due to implementation scenarios such as:

- Advances in artificial intelligence increase the appetite for sharing data with third-party analytics vendors to build machine learning models for automating operational decisions
- Realistic test data is crucial to a robust quality assurance process. Test data management (TDM) solutions enable organizations to use realistic data while securing private information using technologies.

IoT and Edge Computing



IoT devices have been seen in in different use cases, such as predictive maintenance, environmental data collection, pollution alarming, and transportation data collection as examples. However, advancements in edge computing and analytics are enabling businesses to invest in IoT, Businesses should benefit from these two technologies when:

- Conditions, where data should be collected, are not suitable for human measurement
- Rapid changes and late responses to the change in the business environment can significantly harm productivity.

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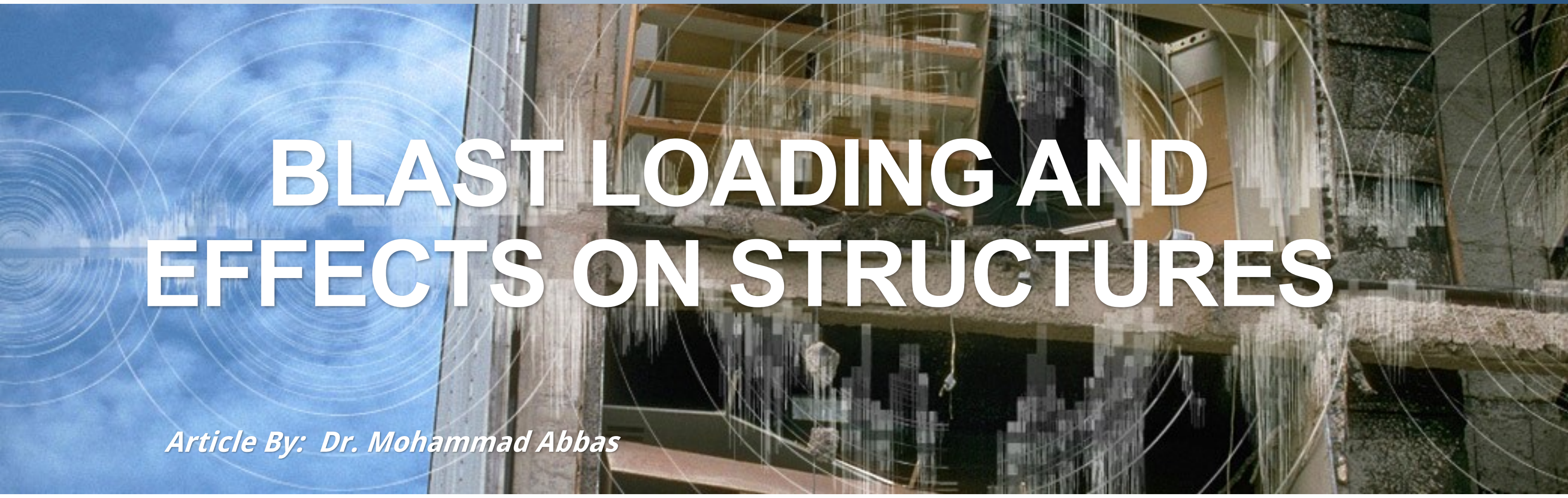
Dr. Ahmad Mohamed ElGhazouly

Ahmad is an Information Systems & Technology / Information Security Manager offering 20 +_years of solid and robust IT expertise in Digital Transformation, Information Security and IT governance and management. Ahmad holds Doctorate of Business Administration and several professional certifications to credit from PMI, ISACA, BCI and others , he is PMP, PMI-RMP,PMI-PBA,PMI-ACP, CGEIT, CISM, CRISC, CISA, BISL, CSM, AMBCI, Togaf certified professional, Certified data center designing and operations, PECB & LRQA certified Lead Auditor in Information Systems, quality and integrated management systems , Member of ISACA, PMI, BCI in addition to CISO 2021 award winner finalist from IDC.



BLAST LOADING AND EFFECTS ON STRUCTURES

Article By: Dr. Mohammad Abbas

INTRODUCTION

The use of vehicle bombs to attack city centers has been a feature of campaigns by terrorist organizations around the world. A bomb explosion within or immediately nearby a building can cause catastrophic damage on the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems. Loss of life and injuries to occupants can result from many causes, including direct blast-effects, structural collapse, debris impact, fire, and smoke. The most study and engineering focusing on Process plants in the petrochemical industry handle hydrocarbons and other fuels that can and have produced accidental explosions.

BLAST LOAD PHENOMENON

Blast resistant design technology in the petrochemical industry has evolved from equivalent static loads and conventional static design methods (Bradford and Culbertson), to simplified dynamic design methods that take into account dynamic characteristics and ductility of structural components, and based on TNT equivalent blast loading (Forbes 1982), and finally to more complex and rational methods involving vapor cloud explosion models to characterize the blast loading and nonlinear multi-degree of freedom dynamic models to analyze the building structure.

Blast resistant design technology is very much useful for design the buildings constructed for industries where chemical process is the main activity. An increasing number of research programs on the sources of these impact loads a dynamic analysis and preventive measures are being undertaken. Just in design some areas takes into account the effects of earthquakes, hurricanes, tornadoes and extremes snow loads, likewise even explosive or blast loads has to be taken into design consideration. This does not mean design and consideration of special shelter facilities but simply the application of appropriate design techniques to ordinary buildings, so that one can achieve some degree of safety from sudden attacks. The analysis and design of structures subjected to blast loads require a detailed understanding of blast phenomena and the dynamic response of various structural elements. This article presents the effects of explosion on structures and explanation of the nature of explosions and the mechanism of blast waves in free air is given.

An explosion is defined as a large-scale, rapid and sudden release of energy. Explosions can be categorized on the basis of their nature as physical, nuclear or chemical events. In physical explosions, energy may be released from the catastrophic failure of a cylinder of compressed gas, volcanic eruptions or even mixing of two liquids at different temperatures. In a nuclear explosion, energy is released from the formation of different atomic nuclei by the redistribution of the protons and neutrons within the interacting nuclei, whereas the rapid oxidation of fuel elements (carbon and hydrogen atoms) is the main source of energy in the case of chemical explosions.

Explosive materials can be classified according to their physical state as solids, liquids or gases. Solid explosives are mainly high explosives for which blast effects are best known. They can also be classified on the basis of their sensitivity to ignition as secondary or primary explosive. The latter is one that can be easily detonated by simple ignition from a spark, flame or impact. Materials such as mercury fulminate and lead azide are primary explosives. Secondary explosives when detonated create blast (shock) waves which can result in widespread damage to the surroundings. Examples include trinitrotoluene (TNT) and ANFO.

The detonation of a condensed high explosive generates hot gases under pressure up to 300 kilo bar and a temperature of about 3000-4000C°. The hot gas expands forcing out the volume it occupies. As a consequence, a layer of compressed air (blast wave) forms in front of this gas volume containing most of the energy released by the explosion. Blast wave instantaneously increases to a value of pressure above the ambient atmospheric pressure. This is referred to as the side-on overpressure that decays as the shock wave expands outward from the explosion source. After a short time, the pressure behind the front may drop below the ambient pressure (Figure 1). During such a negative phase, a partial vacuum is created, and air is sucked in. This is also accompanied by high suction winds that carry the debris for long distances away from the explosion source.

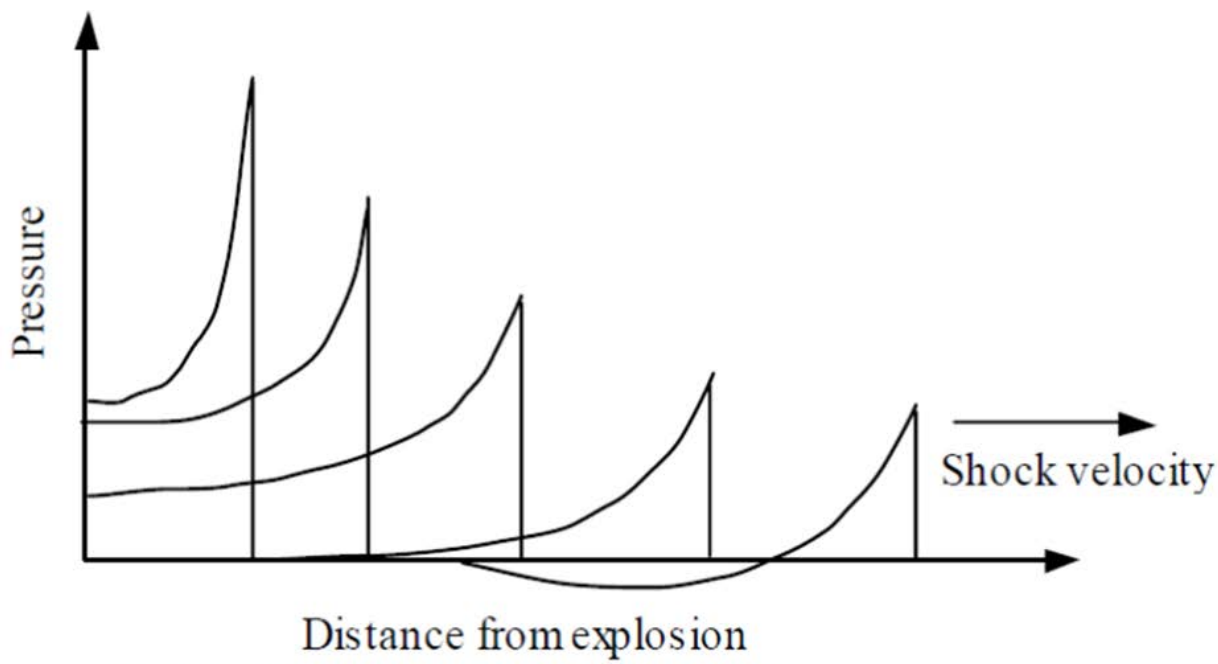


Figure 1: Blast wave propagation

BLAST LOADING ON AIR

The threat for a conventional bomb is defined by two equally important elements, the bomb size, or charge weight W, and the standoff distance R between the blast source and the target (Figure 3).

The observed characteristics of air blast waves are found to be affected by the physical properties of the explosion source. Figure 2 shows a typical blast pressure profile. At the arrival time tA, following the explosion, pressure at that position suddenly increases to a peak value of overpressure, Pso, over the ambient pressure, Po. The pressure then decays to ambient level at time td, then decays further to an under pressure Pso - (creating a partial vacumn) before eventually returning to ambient conditions at time td + td -. The quantity Pso is usually referred to as the peak side-on overpressure, incident peak overpressure or merely peak overpressure.

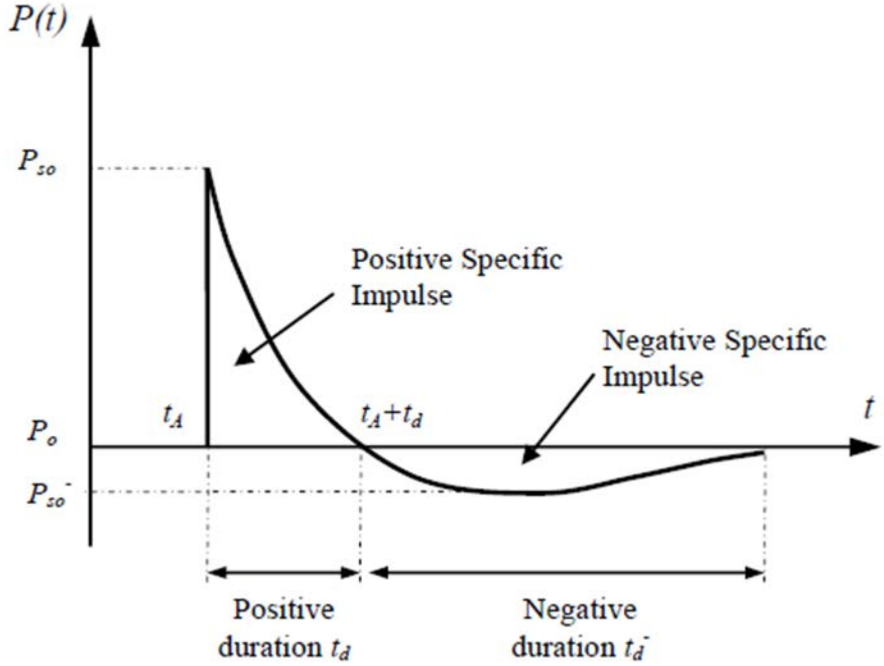
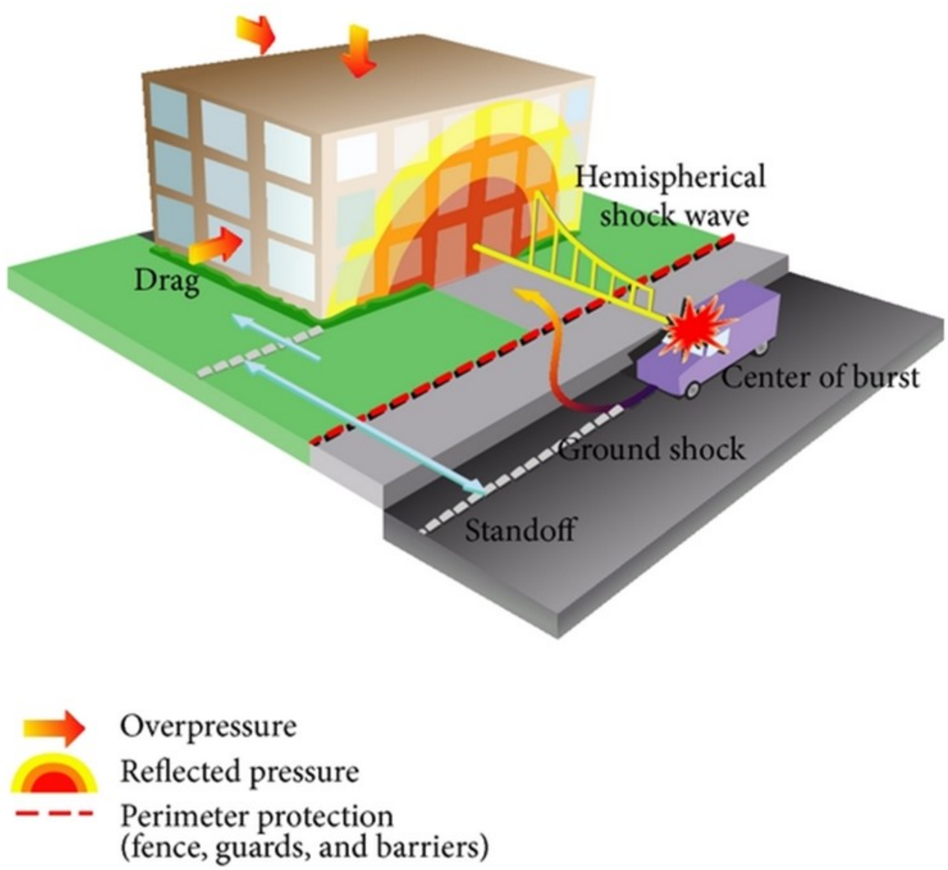


Figure 2: Blast wave pressure - time history

The incident peak over pressures Pso are amplified by a reflection factor as the shock wave encounters an object or structure in its path. Except for specific focusing of high intensity shock waves at near 45° incidence, these reflection factors are typically greatest for normal incidence (a surface adjacent and perpendicular to the source) and diminish with the angle of obliquity or angular position relative to the source. Reflection factors depend on the intensity of the shock wave, and for large explosives at normal incidence these reflection factors may enhance the incident pressures by as much as an order of magnitude.



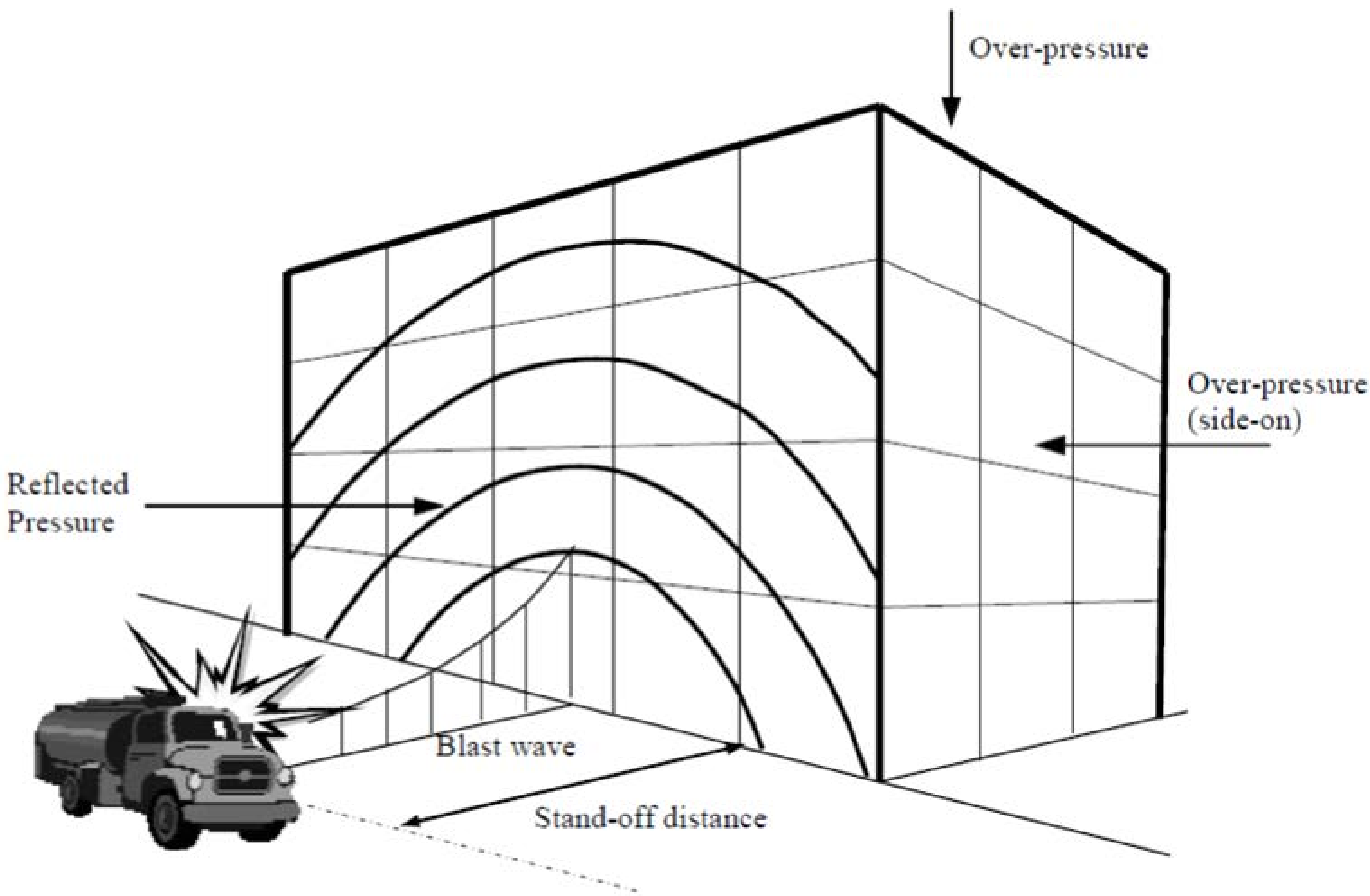


Figure 3: Blast loads on a building

Throughout the pressure-time profile, two main phases can be observed; portion above ambient is called positive phase of duration td, while that below ambient is called negative phase of duration, td -. The negative phase is of a longer duration and a lower intensity than the positive duration. As the stand-off distance increases, the duration of the positive-phase blast wave increases resulting in a lower-amplitude, longer-duration shock pulse. Charges situated extremely close to a target structure impose a highly impulsive, high intensity pressure load over a localized region of the structure; charges situated further away produce a lower-intensity, longer-duration uniform pressure distribution over the entire structure. Eventually, the entire structure is engulfed in the shock wave, with reflection and diffraction effects creating focusing and shadow zones in a complex pattern around the structure. During the negative phase, the weakened structure may be subjected to impact by debris that may cause additional damage.

If the exterior building walls are capable of resisting the blast load, the shock front penetrates through window and door openings, subjecting the floors, ceilings, walls, contents, and people to sudden pressures and fragments from shattered windows, doors, etc. Building components not capable of resisting the blast wave will fracture and be further fragmented and moved by the dynamic pressure that immediately follows the shock front.

Building contents and people will be displaced and tumbled in the direction of blast wave propagation. In this manner the blast will propagate through the building (Figure 4).

Effects on Structures

Blast effects on building structures can be classified as primary effects and secondary effects. Primary effects include:

1. **Air blast:** the blast wave causes a pressure increase of the air surrounding a building structure and also a blast wind.
2. **Direct ground shock:** an explosive which is buried completely or partly below the ground surface will cause a ground shock. This is a horizontal (and vertical, depending on the location of the explosion with regard to the structural foundation) vibration of the ground, similar to an earthquake but with a different frequency.
3. **Heat:** a part of the explosive energy is converted to heat. Building materials are weakened at increased temperature. Heat can cause fire if the temperature is high enough.
4. **Primary fragments:** fragments from the explosive source which are thrown into the air at high velocity (for example wall fragments of an exploded gas tank). Secondary effects can be fragments hitting people or buildings near the explosion. They are not a direct threat to the bearing structure of the building, which is usually covered by a facade. However, they may destroy windows and glass facades and cause victims among inhabitants and passers-by.

Blast loading on structures can be explained by three main loading conditions (figure4)

- In the first type a relatively large shock wave reaches a structure relatively small enough that the blast wave encloses the entire structure. The shock wave effectively acts on the entire structure simultaneously. Additionally, there is a drag force from the rapidly moving wind behind the blast wave. The structure is, however, massive enough to resist translation.
- The second condition also involves a relatively large shock wave and a target much smaller than the previous case. The same phenomena happen during this case, but the target is sufficiently small enough to be moved by the dynamic, drag pressure.
- In the final case, the shock burst is too small to surround the structure simultaneously and the structure is too large to be shifted. Instead of simultaneous loading, each component is affected in succession. For a typical building, the front face is loaded with a reflected overpressure.

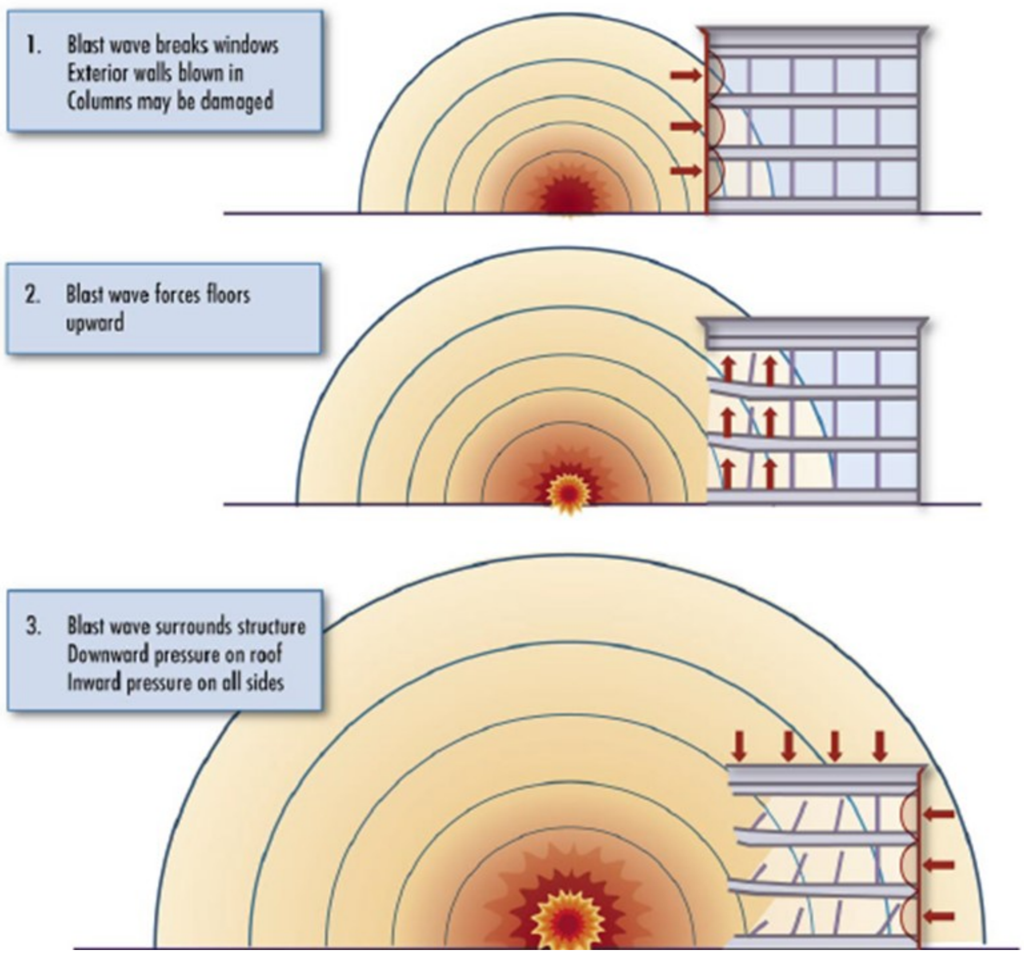


Figure 4: Blast pressure effects on a structure

CONCLUSION

The explosion near to structure can cause hazard damage on the building, analysis and design the building to resist blast load should take into account recently. Blast resistant design refers to improving structural integrity of structure instead of complete collapse of building. A blast wave is a high intensity wave with a very short duration. As the intensity of blast increases the positive phase duration goes on reducing. Peak static pressure Pso is found to be increasing as the weight of blast increases. Peak static pressure Pso is decreasing as the stand-off distance increases. Blast waves take milliseconds to reach the building from site of explosion and affect the building.

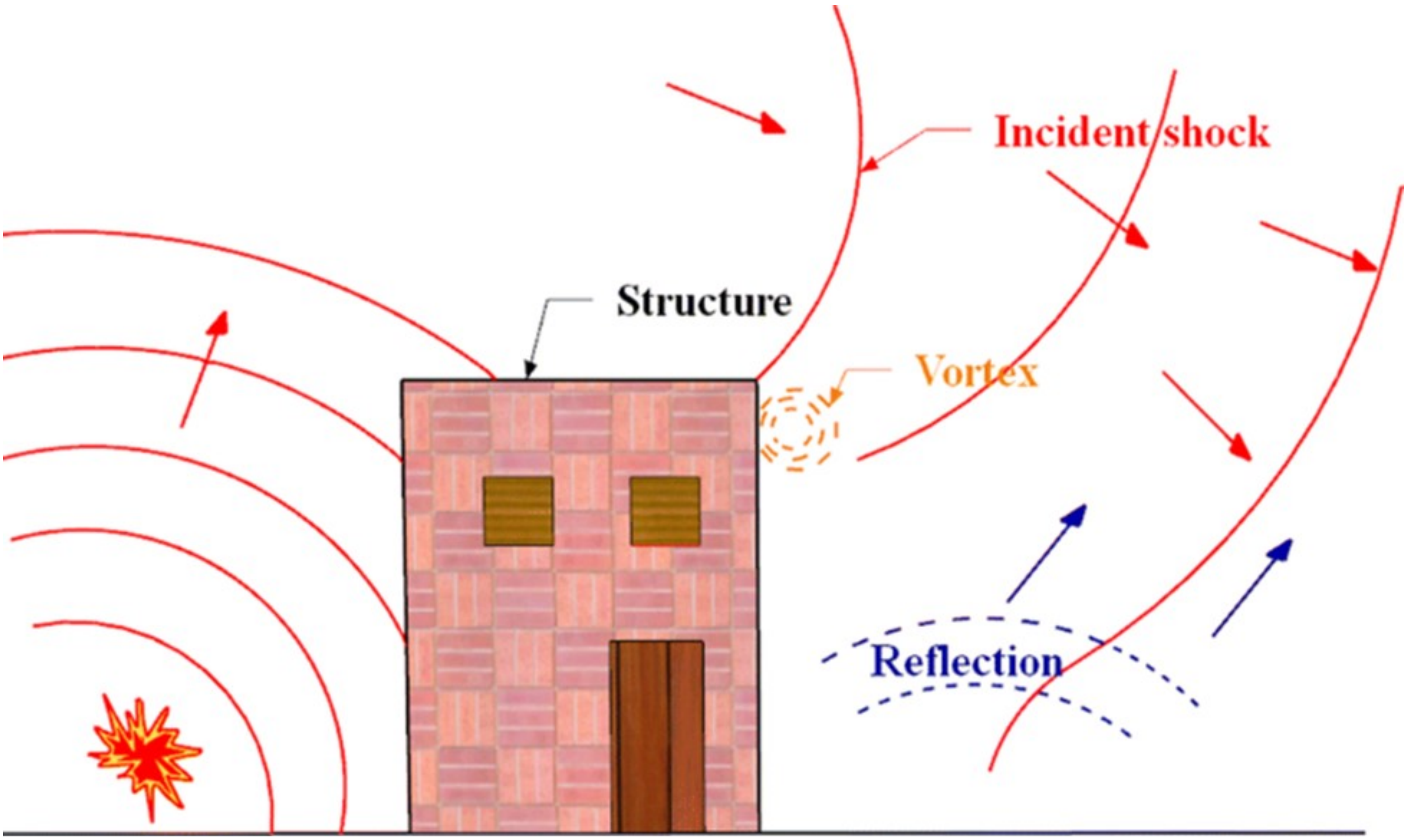


Figure 5: A Critical Review of Blast Wave Parameters and Approaches for Blast Load Mitigation

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GENERIC CORROSION AND CORROSION CONTROL

Article By: Dr. Adel Eid

Summary

Corrosion affects our society on a daily basis, causing deterioration and damage to every industry and infrastructure in our society. These damages affect energy and power production and distribution systems, manufacturing and transport operations, roadway and bridge networks, as well as airplanes, automobiles and even household items.

In the following we will concentrated briefly on the corrosion theories, types of corrosion, factors affecting on the rate of corrosion, methods for the Prevention of Corrosion, and finally the corrosion cost.

in the next series we will deeply study the effect of protective coating system or other protection system for depress the corrosion effect and the effect of the corrosion cost on the global economical, especially for Egypt.

1. Introduction

The corrosion is a real fact and everywhere you can find the corrosion. See figure 1

Figure 1

We live in an industrialized country contains of many different industries like Power plants, water/ waste water plants, oil and gas, petrochemicals industrials, agriculture industry, Iron industry and etc. We all used parts which are extensions of us, and those parts periodically wear out, break and malfunction. Much of that is due to corrosion. See Figure 2

Figure 2

There are four main reasons to study corrosion. Three of these reasons are based on societal issues regarding (i) human life and safety, (ii) the cost of corrosion, and (iii) conservation of materials. The fourth reason is that corrosion is inherently a difficult phenomenon to understand.

Corrosion is one of the most common phenomena that we observe in our daily lives. You must have noticed that some objects made of iron are covered with an orange or reddish-brown colored layer at some point in time. The formation of this layer is the result of a chemical process known as rusting, which is a form of corrosion.

2. Corrosion Definition

Corrosion is defined as the deterioration of a material and/or its properties caused by a chemical reaction or physical reaction with its surrounding environment either liquid or gas. Both the type of metal and the environmental conditions, particularly
gasses that are in contact with the metal, determine the form and rate of deterioration. See figure 3

Figure 3

Corrosion is a spontaneous/ irreversible process wherein the metals turn into a much stable chemical compound like oxides, sulphides, hydroxides, etc. in general, is a process through which refined metals are converted into more stable compounds such as metal oxides, metal sulfides, or metal hydroxides.

In industries most metals corrode on contact with water (and moisture in the air), acids, bases, salts, oils, aggressive metal polishes, and other solid and liquid chemicals. Metals will also corrode when exposed to gaseous materials like acid vapors, formaldehyde gas, ammonia gas, and sulfur containing gases.
Some, like pure iron, corrode quickly. Stainless steel, however, which combines iron and other alloys, is slower to corrode and is therefore used more frequently.

3. Corrosion Theories

There are many theories of corrosion were detected and the various theories of corrosion have been developed. The factors needed to occur corrosion are Anode, a positive charged area, Cathode, a negative charged area and Electrolyte, substance which will conduct a current and be broken down by it. The following major theories are.

a) Chemical (acid) action theory

This theory is the simplest corrosion produced by means of a chemical attack as a metal (iron) in the presence of acids surrounding it. Iron is corroded by atmospheric Carbo Di-Oxide and Oxygen. The corrosion products are the mixture of $Fe(HCO_3)_2$, $Fe(OH)CO_3$ and $Fe(OH)_3$.

b) Electro-chemical corrosion theory.

The corrosion takes place due to direct chemical reaction of atmospheric gases like oxygen, halogens, oxides of Sulphur, oxides of nitrogen, hydrogen sulphides and fumes of chemicals with metal in combination with electrolysis. The extent of corrosion depends on the chemical affinity of the metal towards reactive gas. It takes place at or near room temperature when the metal comes into contact with moisture or with aqueous solutions of salts, acids or bases.

c) Galvanic action theory

The galvanic corrosion occurs when two dissimilar metals are in electrical contact with each other and are exposed to an electrolyte. For instance, a less noble metal like zinc will dissolve and form the anode whereas the more noble metal such as copper will act as the cathode.
Thus the anode metal is made to corrode or dissolve continuously by the galvanic action. It is therefore necessary to observe that the direct contact between dissimilar metals is avoided in the fabrication work to prevent the corrosion of the anodic metal.

d) High-temperature oxidation theory

The rusting of ferrous alloys at high temperatures forms scales and oxides. It indicates the high-temperature dry corrosion. The other form of the high -temperature corrosion occurs when the liquid metals flow through other metals. The corrosion is due to the tendency of the solid to dissolve in the liquid metal up to the solubility limit at the given temperature.

4. Types of Corrosion

a) Uniform Corrosion

The surface effect produced by most direct chemical attacks (e.g., as by an acid) is a uniform etching of the metal. This type of corrosion develops as pits of very small diameter. See figure 4.

Figure 4

The rate of uniform corrosion can be determined by measuring the mass loss or the quantity of released hydrogen. This type of corrosion is generally of little engineering significance, because structures will normally become unsightly and attract maintenance long before they become structurally affected.

b) Pitting Corrosion

Pitting corrosion can lead to unexpected catastrophic system failure due to the localized form of corrosion. This localized form of corrosion characterized by the formation of irregularly shaped cavities on the surface of the metal. Their diameter and depth depend on the medium and service conditions. See figure 5

Figure 5

The initiation of a pit can be the result of any of the chemical attack, such as ferrous chloride or aerated seawater on stainless steel or mechanical attack such as an impact or scratching that removes small areas of the protective film

c) Intergranular Corrosion

Intergranular corrosion is an attack on or adjacent to the grain boundaries of a metal or alloy which results in the loss of strength and ductility and lead to dislodgment of the grain. Heat treatment and welding can lead to changes metal composition which may incite intergranular corrosion. See figure 6.

Figure 6

In severe cases, intergranular corrosion can lead to a marked decrease in mechanical properties and can, in extreme cases, turn the metal into a pile of individual grains. One of the most common examples of intergranular corrosion occurs in stainless steels. During welding of the alloy, or heating in the temperature range of 950°F to 1450°F, the alloy becomes sensitized or susceptible to intergranular corrosion.

d) Stress Corrosion Cracking (SCC)

It is a catastrophic type of failure results from the simultaneous presence of combine action of a mechanical stress (bending and tension), a corrosive environment and it is characterized by cracks propagating either transgranular and intergranular (along grain boundaries). See figure 7

Figure 7

During stress corrosion, the metal is essentially untacked over most of its surface area, but fine cracks progress through parts of it. This kind of cracking has serious consequences because it can occur at stresses within the range of typical design stress.

e) Crevice Corrosion

It refers to the localized attack on a metal surface at, or immediately adjacent to, the gap or crevice between two joining surfaces. The major factors influencing crevice corrosion are, firstly is the crevice type either metal to metal or metal to non-metal, secondly is the crevice geometry which depends on the gap size, depth and the surface roughness, thirdly the type of martial either alloy composition (e.g. Cr, Mo) or structure, fourth one is the environmental surrounding as the effect of PH, temperature halides ions and oxygen. This type of corrosion is also known as deposit attack. See figure 8.

Figure 8

f) Galvanic Corrosion

Galvanic corrosion is an electrochemical action of two dissimilar metals in the presence of an electrolyte and an electron conductive path. It occurs when dissimilar metals are in contact. See figure 9

Figure 9

For example, when aluminum alloys or magnesium alloys are in contact with steel (carbon steel or stainless steel), galvanic corrosion can occur and accelerate the corrosion of the aluminum or magnesium, due to the natural differences in metal potentials produce galvanic differences, the current must flow between them.

The farther apart the metals are in the galvanic series, the greater the galvanic corrosion effect or rate will be. Metals or alloys at the upper end (Titanium or Gold) are noble while those at the lower end (Zinc or Magnesium) are active. The more active metal is the anode or the one that will corrode. The Zone affected by galvanic corrosion has a shinier aspect than the rest of the surface.

Not all galvanic corrosion is detrimental. Zinc coated steel, or galvanizing, is used to protect steel, not because the steel is resistant to corrosion, but because the zine, being anodic to the steel, corrodes preferentially. Hence, the steel is protected cathodically by making any exposed areas of steel into cathodes.

g) Erosion Corrosion

Erosion corrosion is a material degradation process due to the combined effect of corrosion and wear. Nearly all flowing or turbulent corrosive media can cause erosion corrosion. See figure 10

Figure 10

A combination of erosion and corrosion can lead to extremely high pitting rates. It is an acceleration in the rate of corrosion attack in metal due to the relative motion of a corrosive fluid and a metal surface and the increased turbulence caused by pitting on the internal surfaces of a tube can result in rapidly increasing erosion rates and eventually a leak. For example, burrs left at cut tube ends can upset smooth water flow, because localized turbulence and high flow velocities, resulting in erosion corrosion. Erosion-corrosion is most prevalent in soft alloys (i.e. copper, aluminum and lead alloys).

h) Exfoliations Corrosion

Exfoliation corrosion is known as layer corrosion or lamellar corrosion and it is a form of intergranular corrosion which involves selective attack of a metal at or adjacent to grain boundaries. See figure 11

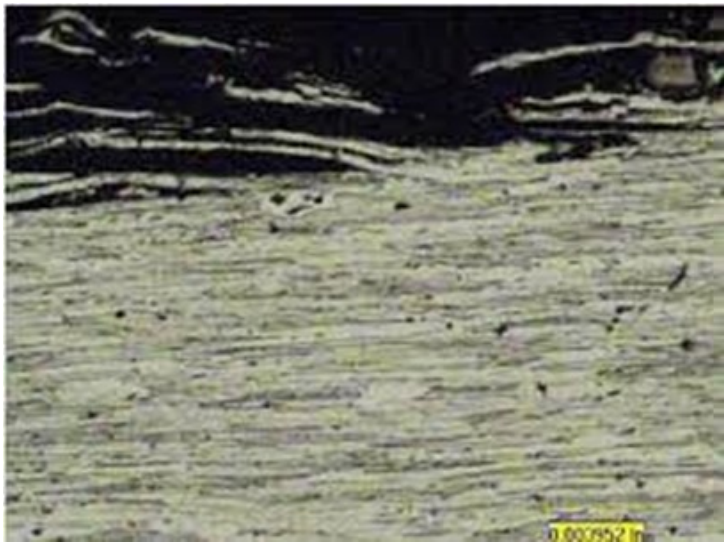


Figure 11

This type of corrosion occurs on the extended grain boundaries. The products of corrosion force the material to move away from the body, so these products occupy a greater volume than the volume of the parent metal, thus causing the metal to exfoliate or delaminate. E.g. Aluminum alloys, especially those containing copper or zinc-magnesium-copper as alloying constituents are susceptible to this type of corrosion.

i) Corrosion Fatigue

The fatigue process is thought to cause rupture of the protective passive film, upon which corrosion is accelerated or when a metal mechanically degrades faster than expected under the combined action of cycling loading and corrosion. If the metal is simultaneously exposed to a corrosive environment, the failure can take place at even lower loads and after shorter time. In a corrosive environment the stress level at which it could be assumed a material has infinite life is lowered or removed completely. Contrary to a pure mechanical fatigue, there is no fatigue limit load in corrosion-assisted fatigue. Finally the Corrosion-fatigue is the result of the combined action of an alternating or cycling stresses and a corrosive environment. See figure 12

Figure 12

j) Fretting Corrosion

Fretting corrosion can be defined as an irreversible transformation of a material resulting from simultaneous physicochemical and mechanical surface interaction occurring in a tribological contact and also it refers to corrosion damage at the asperities of contact surfaces. See figure 13

Figure 13

This damage is induced under load and in the presence of repeated relative surface motion, as induced for example by vibration. Pits or grooves and oxide debris characterize this damage, typically found in machinery, bolted assemblies and ball or roller bearings. Contact surfaces exposed to vibration during transportation are exposed to the risk of fretting corrosion. The protective film on the metal surfaces is removed by the rubbing action and exposes fresh, active metal to the corrosive action of the atmosphere. Filiform Corrosion.

k) Concentration Cell Corrosion

Concentration cell corrosion occurs when two or more areas of a metal surface are in contact with different concentrations of the same solution or may occur in soils when a metal is exposed to an environment containing varying levels of electrolytes either of different substances or of the same substance in different amounts. See figure 14.

Figure 14

There are three general types of concentration cell corrosion, metal ion concentration cells, oxygen concentration cells, and active-passive cells. For example, if one electrolyte is a dilute salt solution and the other a concentrated salt solution, a concentration cell may be formed. This takes place because one of the factors that determine an electrode potential is the electrolyte concentration. Other example is the chloride ions can be quite aggressive towards steel and sulfate ions can serve as nutrients to sulfate reducing bacteria (SRB) which themselves can be extremely damaging to most buried metals.

l) Hydrogen Grooving

This is a corrosion of the piping by grooves that are formed due to the interaction of a corrosive agent, corroded pipe constituents, and hydrogen gas bubbles. The bubbles usually remove the protective coating once it comes in contact with the material.

m) Metal Dusting

Metal dusting is a damaging form of corrosion that occurs when vulnerable materials are exposed to certain environments with high carbon activities including synthesis gas. The corrosion results in the break-up of bulk metal to metal powder. Corrosion occurs as a graphite layer is deposited on the surface of the metals from carbon monoxide (CO) in the vapor phase. This graphite layer then goes on to form metastable M3C species (where M is the metal) that usually moves away from the metal surface. In some cases, no M3C species may be observed. This means that the metal atoms have been directly transferred into the graphite layer.

n) Microbial Corrosion

Microbial corrosion which is also known as microbiologically influenced corrosion (MIC), is a type of corrosion that is caused by microorganisms. The most common one is chemoautotrophs. Both metallic and non-metallic materials either in the presence or absence of oxygen can be affected by this corrosion.
High-temperature Corrosion
High-temperature corrosion as the name suggests is a type of corrosion of materials (mostly metals) due to heating. Chemical deterioration of metal can occur due to a hot atmosphere that contains gases such as oxygen, sulfur, or other compounds. These compounds are capable of oxidizing the materials (metals in this case) easily. For example, materials used in car engines have to resist sustained periods at high temperatures during which they can be affected by an atmosphere containing corrosive products of combustion.

5. Factors Influencing the Rate of Corrosion

The rate of corrosion could be predicted with the following methods one of this method is the Deal–Grove model which often mathematically describes the growth of an oxide layer on the surface of a material and it helps in predicting and controlling oxide layer formation in a lot of diverse situations. In addition other method is use the weight loss method is also used to measure corrosion. In this method, a clean weighed piece of the metal or alloy is exposed to the corrosive environment for a certain duration. This is followed by a cleaning process that removes the corrosion products. The piece is then weighed in to determine the loss of weight.
The rate of corrosion (R) is calculated as;

$R = kW/\rho At$

Where,

k = constant,

W = weight loss of the metal in time t,

A = surface area of the metal exposed,

ρ is the density of the metal (in g/cm³).

There are several factors influencing the rate of corrosion including diffusion, water velocity, temperature, conductivity, type of ions, Oxygen content, pH value

(Acidity and Alkalinity), Moisture, electrochemical potential and exposure of the metals to air containing gases like CO2, SO2, SO3 etc.

a) Diffusion Effect

In areas where oxygen diffusion is prevalent, corrosion appears to occur at faster rates. High flow areas, such as in the vicinity of bell mouths, will tend to exhibit higher corrosion rates because of the increased oxygen levels.
Freshly exposed bare steel surfaces will corrode at a greater rate than those covered with a compact layer of rust. The corrosion rate is also heavily controlled by the diffusion of oxygen through the water to the steel surface.

b) Temperature Effect
Temperature affects atmospheric corrosion. Essentially, every 50°F (10°C) increase in the temperature can double corrosion activity. When ambient temperature falls in the evening, the surfaces of metal objects or structures become warmer compared to the humid air that surrounds them. Thus, condensation will not begin until the dew peak has been attained. Cyclic temperature can result in severe metal corrosion in tropical areas, especially in unheated warehouses, objects in plastic bags, metal tools and more. See figure 15

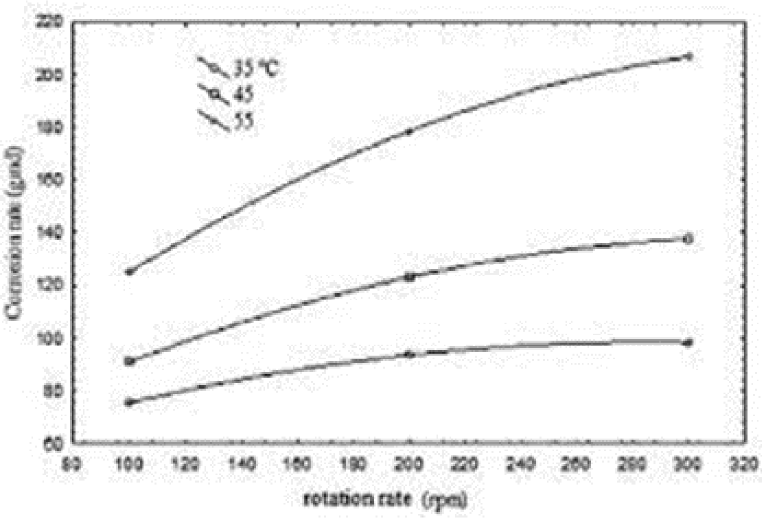


Figure 15

c) Relative Humidity Effect

Relative humidity is defined as the water vapor quantity that can be found in the atmosphere relative to the quantity of saturation in a certain temperature. See figure 16

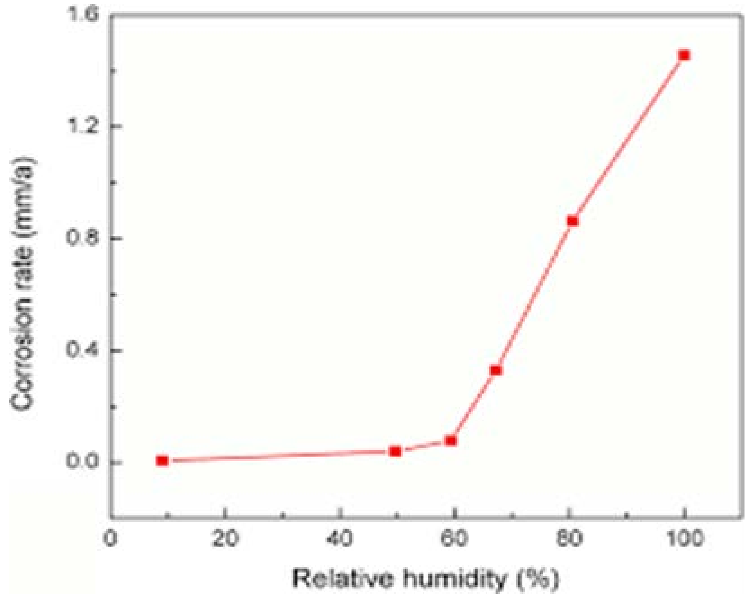


Figure 16

Among the essential requirements in the process of atmospheric corrosion is the existence of an electrolyte in the form of a thin film that can develop on steel or metal surfaces that are exposed to critical humidity levels. Although the film is invisible, it can contain corrosive contaminants at high concentrations, particularly in situations where there is alternate drying and wetting. The critical level of humidity is considered a variable that depends on the material undergoing corrosion. It also depends on the product's tendency to corrode and the absorption of moisture by surface deposits as well as the existence of pollutants.

d) Conductivity

For corrosion to occur there must be a conductive medium between the two parts of the corrosion reaction. Corrosion will not occur in distilled water and the rate of corrosion will increase as the conductivity increases due to the presence of more ions in the solution. The corrosion rate of steel reaches a maximum close to the normal ionic content of sea water. Fresh water corrodes steel to a lesser extent than brackish or estuarine water, with sea water usually being the most corrosive to steel. See figure 17

Figure 17

e) Acidity and alkalinity (pH) Effect

In neutral water, the pH is around 7.5 which mean that the hydrogen ions (acid) and hydroxyl ions (alkali) are almost in balance. Under such circumstances, the reaction that balances the iron dissolution is the reduction of dissolved oxygen to form hydroxyl ions. If however the environment becomes more acidic and the pH falls closer to 1, then there is a greater quantity of hydrogen ions than hydroxyl ions present in the solution. See figure 18

Figure 18

The excess hydrogen ions can become involved in the balancing (cathodic) reaction which results in the evolution of hydrogen gas. As both the hydrogen ions and the hydrogen gas can diffuse very rapidly, the steel can corrode faster.

Under alkaline conditions, where there is an excess of hydroxyl ions and the pH levels tend towards 14, steel cannot corrode and remains unaffected.

f) Electrochemical potential Effect

Every metal takes up a specific electrochemical potential when immersed in a conducting liquid. Common reference electrodes are the Saturated Calomel Electrode (SCE), silver/silver chloride and copper/copper sulfate reference electrodes. The potential that a metal takes up in a solution can determine if and how fast it will corrode. The potential can be changed by connecting it to another dissimilar metal or by applying an external potential, as occurs with an active cathodic protection system of the type employed on the external hull.

g) Water velocity Effect

The corrosion rate increased with the increasing liquid flow velocity at any different corrosion time. The corrosion rate decreased with the extension of corrosion time at the same liquid flow velocity. There was no continuous corrosion products film on the whole pipe wall at any different corrosion time. See figure 19

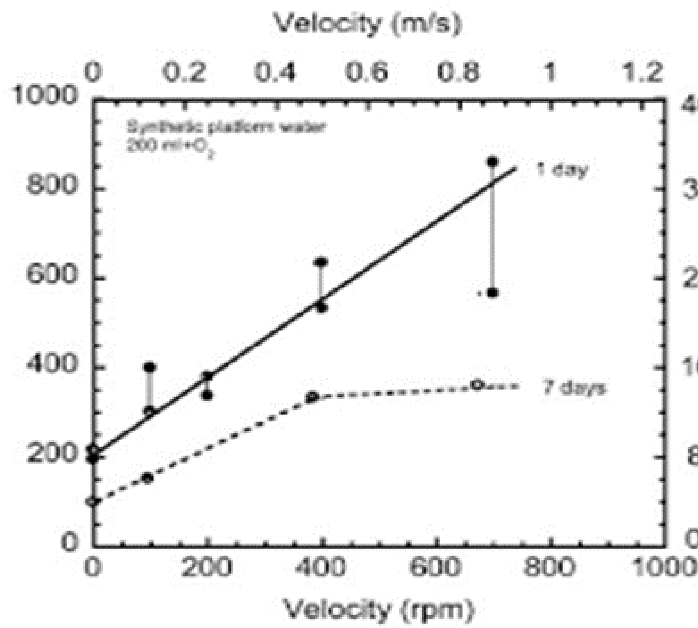


Figure 19

The macroscopic brown-yellow corrosion products on the pipe wall surface decreased with the increasing liquid flow velocity and the loose floccus corrosion products decreased gradually until these products were transformed into un-continuous needle-like dense products with the increasing liquid velocity.

h) Presence of impurities

Atmosphere is contaminated with gases like CO2, SO2, H2S; fumes of H2SO4, HCl etc. and other suspended particles in the vicinity of industrial areas. They are responsible for electrical conductivity, thereby increasing corrosion.

6. Methods for the Prevention of Corrosion

There are many methods of corrosion prevention or control the corrosion to prevent huge damage that are generally used. The famous methods are: (a) Material Selection, (b) Environmental Change, (c) Cathodic and Anodic Protection, (d) Coatings, and (e) Design consideration.

a) Material Selection

Material selection consists of obtaining a material which will do the job that we want done which should comply with the code and standards, temperature limitation, availability, cost, lead time and constructability. But corrosion control is almost always an economic situation. We select the material which is best for the job. This includes cost and strength as well as corrosion resistance considerations.

b) Environmental Change

Sometimes we can change the environment in which the corroding material is enclosed. When we think of environment, we might think of temperature and the possibility that we can control it. We might consider the concentration of solutions and the ions in the solution. Or we might think of our ability to add inhibitors to provide some control over the corrosion. An everyday example of a corrosion inhibitor of which almost everyone is aware is the inhibitor put into automobile-engine cooling radiator.

c) Cathodic and Anodic Control

Cathodic protection is used extensively worldwide as a corrosion control method. Anodic protection is used to a lesser extent, but nevertheless has some very interesting possibilities with respect providing corrosion protection. Cathodic protection results when we impress a negative potential onto the material we want to protect. Anodic protection is possible in very specific cases when we impress a positive potential. There are two types of cathodic protection either sacrificial anodic method or impressed current cathodic method

d) Protective Coatings

The coating is used to protect the metal from corrosion, there are many types of coating such as metallic coatings, tinning, electro-plating, galvanizing, organic coating, etc.

e) Design Consideration

The design should base on the right selection of the materials which belongs to the characteristics of the fluid and operating conditions including maximum pressures and temperatures and also taking into consideration the performing fatigue failure, stress level concern, stress analysis taking into account the potential upset conditions and an allowance for those upset conditions in the design of piping systems, in addition finding economical pipe diameter and wall thickness, and Installation cost.

7. Corrosion cost

Many studies of the Cost of Corrosion have been undertaken in several countries, including Japan, UK, USA, and have estimated losses to the national economy due to corrosion of up to 5% of Gross Domestic Product (GDP). This high cost stems directly from a general lack of awareness of the economic impact of corrosion, and the poor selection of protection measures. Although a definitive method to determine corrosion costs has not been established, the main methods that have been applied are the Uhlig method, which calculates corrosion related costs based on corrosion prevention methods; the Hoar method, which makes estimates in various industrial sectors, and the Input/output method, based on an Input/output matrix.

Corrosion costs could be divided into direct costs and indirect costs.

a) Direct Cost or Direct Losses

- Replacement of Corroded Parts

e.g., automobile mufflers, water lines, hot water heaters, sheet metal roofs, condenser tubes, mufflers, pipelines, and metal roofing, including necessary labor. Other examples are (a) repainting structures where prevention of rusting is the prime objective and (b) the capital costs plus maintenance of cathodic protection systems for underground pipelines.

Design costs

Extra cost of using corrosion-resistant alloys, protective coatings, corrosion inhibitors and alloys instead of carbon steel.

b) Indirect Cost or Indirect Losses

- Shutdown.

The replacement of a corroded tube in an oil refinery may cost a few hundred dollars, but shutdown of the unit while repairs are underway may cost $ 50,000 or more per hour in lost production. Similarly replacement of corroded boiler or condenser tubes in a large power plant may require $ 1,000,000 or more per day for power purchased from inter connected electric systems to supply customers while the boiler is down.

- Loss of Product.

  Losses of oil, gas, or water occur through a corroded -pipe system until repairs are made. Antifreeze may be lost through a corroded auto radiator; or gas leaking from a corroded pipe may enter the.

Direct and indirect costs of corrosion for an industrialized country rise up to the 6% of the GDP; 60% of all maintenance costs for North Sea production platforms are related to corrosion; The North America gas pipeline industry spends 80 million $ each year for coating new pipelines and recoating existing pipelines; 5 metric tons of steel are corroded worldwide every second; 40% off all produced steel is used to replace corroded structures;

At least 30% of all these costs could be saved with an efficient corrosion management.

Facts (ref. https: // energyskeptic.com/)

In the following we will review the cost of corrosion in many countries related to the GBD

◊ Cost of corrosion in the USA (Figure 20)

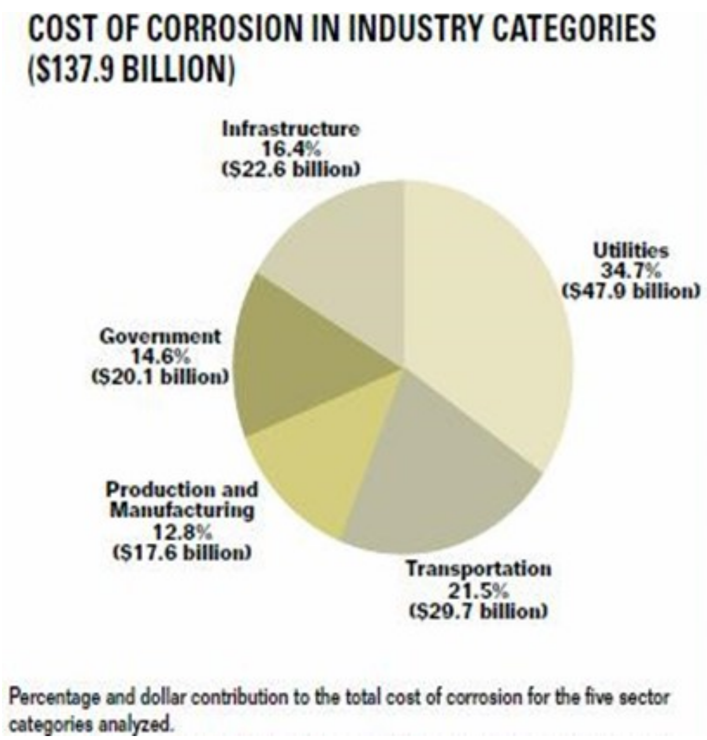


Figure 20

- Cost of corrosion in the China (Figure 21)

in China in 2014

Sector	Cost (billion RMB)	Percentage (%)
Infrastructure	74.91	6.68
Energy	229.33	20.45
Transportation	268.72	23.97
Water	9.69	0.86
Manufacturing and public services	538.57	48.03
Summation	1121.22	100

Figure 21

- Cost of corrosion in Australia (Figure 22)

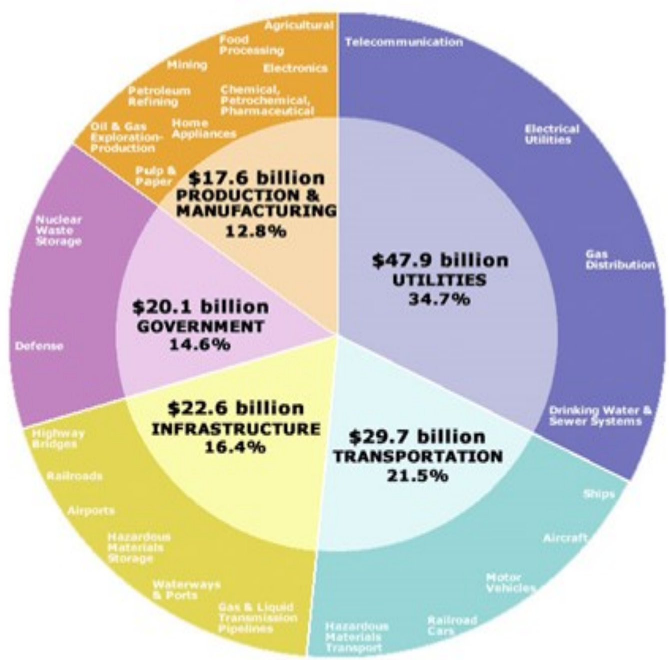
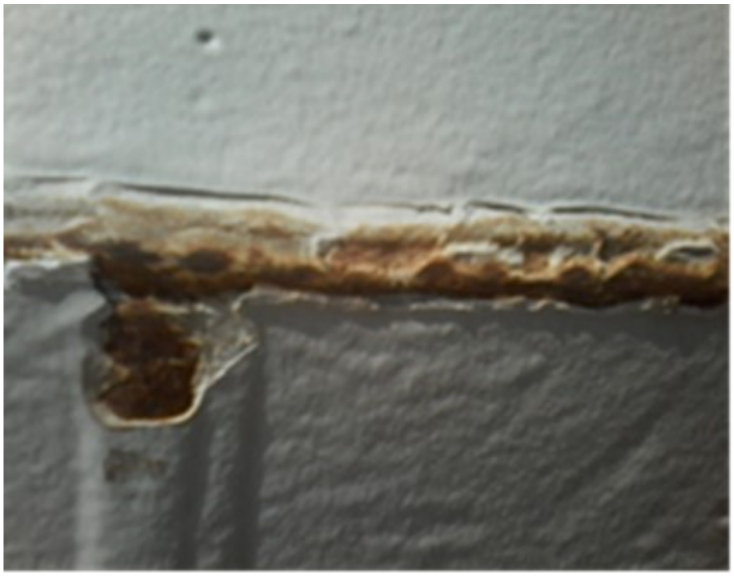


Figure 22

8. Case Study

We will review some case studies in the power plant and water treatment area.

a) Bad Transportation



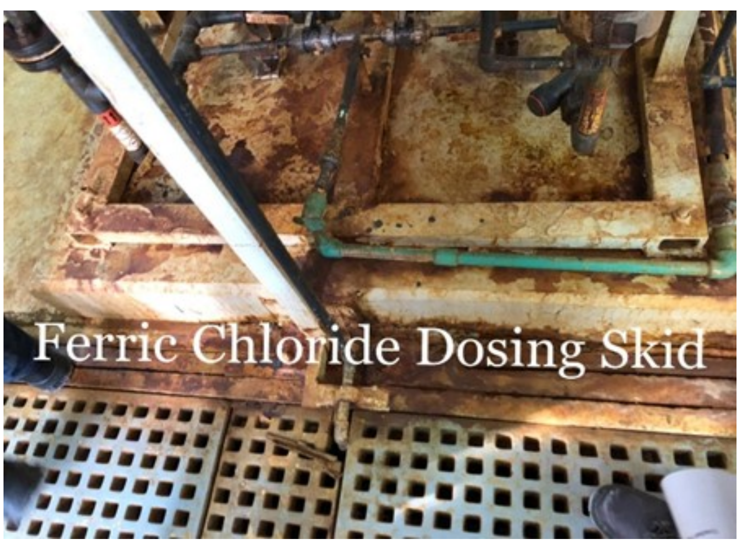
b) Material Defects

c) Bad Application

d) Environmental Defects

e) Bad material selection

f) Bad Coating Material Selection



9. Conclusion

By increasing the corrosion awareness for the people who are directly related or indirect related to the equipment and explain to them the economic impact of corrosion, and the poor selection of protection measures so we are working and always looking for a good cooperation between the researches centers and the latest technology that leads us to update the technical specifications in order to keep pace with the rapid developments and we looking for a good solutions with high efficiency, high quality with appropriate prices.

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