EXPERIMENTAL STUDY OF COPPER-NICKEL-CHROMIUM COATINGS ON SUBSEA PIPELINE MATERIAL

FINAL YEAR PROJECT REPORT

Submitted by

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Under the guidance of

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A thesis submitted in partial fulfillment of the requirements for the Degree of
Master of Technology
(Pipeline Engineering)

By
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Approved

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CERTIFICATE

This is to certify that the work contained in this thesis titled "**Experimental Study of Copper-Nickel-Chromium Coatings on Pipeline Material**" has been carried out by **Aquin Jose** under my supervision and has not been submitted elsewhere for a degree.

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Abstract

The offshore oil and gas industry is growing at an unprecedented rate as multinational companies scramble to explore new energy sources from deep sea. Offshore drilling platforms and subsea pipelines are often located in the world's harshest marine environments, where long term asset protection is essential to overall planning. The project is to select a suitable subsea material and improve its corrosion resistance, operating life and mechanical properties with the help of Copper- Nickel- Chromium metallic coating. From an innovative angle, the standards of stirring have remained unchanged since this coating came into use over two hundred years ago. On the other hand, on account of new applications in the automotive and construction industry, a considerable amount of research has recently occurred on all aspects of the galvanizing process and on new types of Zn coatings. The specimens are modelled as per ASTM E8 for tensile test and ASTM E23 for Impact test. The modelled specimen is then tested for its yield strength, percentage elongation, etc. The specimens are practically tested for mechanical properties. The last phase of the project involves, performing corrosion tests in artificial saltwater solution. . These tests will be conducted on bare metal and the coated metal and the results will be compared. Microstructure of the material will be examined by Scanning Electron Microscope (SEM) analysis. The effectiveness of the coating will be concluded accordingly.

Acknowledgement

Aside from our endeavors, the accomplishment of any project depends to a great extent on the consolation and rules of numerous others. I take this chance to express my appreciation to the individuals who have been instrumental in the effective culmination of this project.

I would like to show my greatest appreciation to Mr. RAMESH M, Assistant Professor Senior Scale, Department of Mechanical Engineering, University of Petroleum and Energy Studies, Dehradun. I can't thank him enough for his tremendous support and help. Without his encouragement and guidance this project would not have materialized.

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Nacl – SODIUM CHLORIDE

CR- CORROSION RATE

AISI –AMERICAN IRON AND STEEL INSTITUTE

ASTM – AMERICAN SOCIETY OF TESTING MATERIALS

ISO - INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ASME- AMERICAN SOCIETY OF MECHANICAL ENGINEERS

BS- BRITISH STANDARD

EN – ENGLISH NOMENCLATURE

Ni – NICKEL

Cr – CHROMIUM

Cu- COPPER

Chapter 1 – Introduction

1.1 General

Pipelines assume a to a great degree critical part all through the world for transporting gasses and fluids. Generally, these pipelines lay under covered situations over long separations from source to destination. In the United States, there are around 2 million km of covered characteristic gas pipelines and 280,000 km of petroleum items pipelines. In Canada, there is around 580,000 km of covered pipelines, which contributes billions of dollars to the economy. The developing interest and significance for pipelines in everywhere throughout the world warrant uncommon thoughtfulness regarding shielding it from the decaying impacts, for example, erosion, outer powers and others. Among these impacts, corrosion contributes most of the channel disappointment cases. For instance, a late survey demonstrates that the erosion of metals and compounds costs U.S organizations a sum of pretty nearly $300 billion every year. The researchers at Battelle Institute and the National Institute of Standards and Technology presumed that roughly 33% of the aggregate expenses ($ 100 billion every year) could be essentially decreased or killed by the utilization of best accessible erosion counteractive action systems and materials. Unprotected pipelines, whether covered in the ground, presented to the environment or submerged in water are powerless to corrosion. Without legitimate upkeep, each pipeline framework will inevitably break down. Corrosion can debilitate the basic trustworthiness of a pipeline and make it a dangerous vehicle for transporting conceivably perilous materials. In any case, innovation exists to develop pipeline auxiliary life inconclusively if connected effectively and looked after reliably. Assessing the earth in which a pipeline is or will be found is vital to corrosion control, regardless of which strategy or mix of systems is utilized. Adjusting the earth promptly encompassing a pipeline, for example, diminishing dampness or enhancing seepage, can be a basic and powerful approach to diminish the potential for corrosion.

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The two principle classes of funnel disappointment are outside strengths and corrosion. The outside strengths are because of pipeline administrators, mischances like tremor and others. The pipeline disappointment because of corrosion incorporates both inside and outer erosion. Outer powers and corrosion represent more than 60 percent of all pipeline disappointments. Erosion is delegated the real reason for pipeline disappointment with its both sorts (inward and outside). Erosion is the phenomena of electrochemical response between the material and its encompassing surroundings. In the vast majority of the cases, the funnel encompassing environment is soil under the covered conditions. For this situation, corrosion will be impacted by numerous components inside the dirt. Basically physical, compound and natural qualities of the dirt will assume the significant part in pipeline corrosion. Actually, temperature, pH, dampness substance, salts, and another concoction consider regularly impact the pipelines erosion under the dirt. For all intents and purposes all pipeline corrosion in soil is electrochemical in nature; that is, the erosion is an electrochemical response where electrons move from anode to cathode inside the consuming metal. The metal erodes at one spot at first glance while the dirt dampness is responding at a nearby site or even at some exceptionally separation site. Corrosion happens at the anode site where metal particles leave the surface to disintegrate in the dirt dampness. This electrochemical corrosion can be influenced by distinctive variables, for example, different soil, differential air circulation, divergent metals, new and old steel funnel, soil sort, dampness substance, and position of water table, soil resistivity, solvent particles substance, soil pH, oxidation-decrease potential and the vicinity of organisms in soil. Be that as it may, the erosion issue can be adequately overseen or averted by utilizing best accessible innovations of corrosion assurance. Covering of pipeline assumes a significant part in corrosion control of pipelines particularly in the dirt. Covering is connected to minimize the obliged force utilization in cathodic assurance frameworks. The key strategies used to avert outer corrosion of pipelines are coatings and cathodic insurance. Periodically, soil conditions can trade off the execution of cathodic security. For instance, the electrical conductivity of the dirt is a key calculate the outline of a proper cathodic assurance framework. Poor outline or an unforeseen increment in soil resistivity can bring about a loss of successful security at covered steel surfaces. High temperatures or extreme cathodic security possibilities can quicken covering disbandment. Covering materials including polyvinyl chloride, black-top or coal tar can endure a loss of honesty in administration through the evacuation of covering parts by water draining, oxidation, or biodegradation. High temperatures can again quicken covering disintegration. The subsequent increment in covering porousness permits water access to the hidden steel surfaces.

In this proposal AISI 1040 oil extinguished exposed steel covered with 20 microns unadulterated zinc (Zn) is changed over to UTM tractable example of 300mm length with 56 mm gage length (ASTM standard) to check for the yield quality distinction in the middle of covered and uncoated steel in an UTM machine. V-indent Charpy test examples with the same covering are tried to focus the distinction in the measure of vitality consumed by the material amid crack. The same material (exposed and covered with 20 microns zinc) is weighed for hardness contrast in Rockwell hardness scale in light of the space hardness of a material. The Rockwell test decides the hardness by measuring the profundity of the entrance of an indenter under an extensive burden contrasted with the infiltration made by a preload. The example of 20 microns of zinc covering of both UTM and Charpy V-score test are kept in 5% Nacl answer for 96 hours. After that, the eroded example are tried for coming about yield quality and the vitality retained. The contrast between the consumed zinc and non-eroded zinc example of both UTM and Charpy V-score test are plotted on charts. Filtering Electron Microscope (SEM) will be utilized to study the surface morphology, the geology and the surface disciple properties of the coatings. These tests will be directed on exposed metal and the covered metal and the outcomes will be analysed. The adequacy of the covering will be finished up appropriately.

1.2 Types of Corrosion

Corrosion is a characteristic procedure, which changes over refined metal to their more steady oxide. It is the progressive annihilation of materials (normally metals) by compound response with their surroundings. The major types of corrosion are :-

1.2.1Galvanic Corrosion

Galvanic erosion happens when two separate metals have physical or electrical contact with one another and are drenched in a typical electrolyte, or when the same metal is presented to electrolyte with distinctive focuses. In a galvanic couple, the more dynamic metal (the anode) consumes at a quickened rate and the more honourable metal (the cathode) erodes at a slower rate. At the point when submerged independently, every metal erodes at its own particular rate. Galvanic erosion is of significant enthusiasm to the marine business furthermore anyplace water (containing salts) contacts pipes or metal structures.

Variables, for example, relative size of the anode, sorts of metal, and working conditions (temperature, stickiness, saltiness, and so on.) influence galvanic corrosion. The surface range degree of the anode and cathode straightforwardly influences the erosion rates of the materials. Galvanic erosion is frequently averted by the utilization of conciliatory anodes.

1.2.2 Pitting corrosion

Low amassing of oxygen or high convergence of species, for example, chloride which finish as anions, can meddle with a given combination's capacity to re-frame a passivizing film. In the most pessimistic scenario, the majority of the surface will stay secure, however, little nearby changes will corrupt the oxide film in a couple of basic focuses. Corrosion at these focuses will be extraordinarily intensified, and can bring about corrosion pits of a few sorts, contingent on conditions. While the corrosion pits just nucleate under genuinely amazing circumstances, they can keep on growing notwithstanding when conditions come back to typical, since the inside of a pit is characteristically denied of oxygen and mainly the pH reductions to low values and the corrosion rate increments because of an autocatalytic procedure. In compelling cases, the sharp tips of to a great degree long and slender corrosion pits can bring about anxiety focus to the point that overall intense combinations can break; a meagre film penetrated by an imperceptibly little gap can conceal a thumb measured pit from perspective. These issues are particularly unsafe on the grounds that they are hard to distinguish from a part or structure comes up short. Setting stays among the most well-known and harming manifestations of corrosion in passivated combinations.

1.2.3 Crevice corrosion

Crevice corrosion is a restricted manifestation of corrosion happening inbound spaces (fissure), to which the entrance of the working liquid from nature is constrained. The arrangement of a differential air circulation cell prompts corrosion inside the cleft. Samples of the fissure are holes and contact zones between parts, under gaskets or seals, inside splits and creases, spaces loaded with stores and under ooze heaps.

Fissure corrosion is impacted by the cleft sort (metal-metal, metal-non-metal), hole geometry (size, surface completion), and metallurgical and natural elements. The defencelessness to fissure corrosion can be assessed with ASTM standard methods. A basic cleft corrosion temperature is usually used to rank a material's imperviousness to fissure corrosion.

1.2.4 Microbial corrosion

Microbial corrosion, or normally known as microbiologically impacted corrosion (MIC), is a corrosion brought about or advanced by microorganisms, for the most part chemoautotrophs. It can apply to both metallic and non-metallic materials, in the vicinity or nonappearance of oxygen. Sulphate-diminishing microbes are dynamic without oxygen (anaerobic); they create hydrogen sulphide, bringing on sulphide anxiety splitting. In the vicinity of oxygen (vigorous), some microbes might straightforwardly oxidize iron to iron oxides and hydroxides, other microscopic organisms oxidize sulphur and produce sulphuric corrosive bringing on biogenic sulphide corrosion. Fixation cells can shape in the stores of corrosion items, prompting restricted corrosion.

1.2.5 High-Temperature Corrosion

High-temperature corrosion is compound crumbling of a material (commonly a metal) as a consequence of warming. This non-galvanic manifestation of corrosion can happen when a metal is subjected to a hot environment containing oxygen, sulphur or different mixes fit for oxidizing (or helping the oxidation of) the material concerned. Case in point, materials utilized as a part of aviation, force era and even in auto motors need to oppose supported periods at high temperature in which they may be presented to an environment containing possibly exceptionally destructive results of ignition.

The results of high-temperature corrosion can conceivably be swung to the preference of the specialist. The development of oxides on stainless steels, for instance, can give a defensive layer anticipating further environmental assault, taking into consideration a material to be utilized for managed periods at both room and high temperatures in threatening conditions. Such high-temperature corrosion items, as compacted oxide layer coatings, anticipate or diminish wear amid high-temperature sliding contact of metallic (or metallic and clay) surfaces.

1.2.6 Metal dusting

Metal dusting is a cataclysmic type of corrosion that happens when defenceless materials are presented to situations with high carbon exercises, for example, combination gas and other high-CO situations. The corrosion shows itself as a separation of mass metal to metal powder. The associated instrument is firstly the testimony with a graphite layer on the surface of the metal, normally from carbon monoxide (CO) in the vapour stage. This graphite layer is then thought to frame metastable M3C species (where M is the metal), which relocate far from the metal surface. Nonetheless, in a few administrations no M3C species is watched showing a direct exchange of metal iotas into the graphite layer.

1.3 Electroplating

Electroplating is the utilization of a metal covering to metallic or other directing surfaces by an electrochemical methodology. The article to be plated (the work) is made the cathode (negative anode) of an electrolysis cell through which a direct electric current is passed. The article is inundated in a watery arrangement (the shower) containing the obliged metal in an oxidized structure, either as an equated activity or as a complex particle. The anode is generally a bar of the metal being plated. Electroplating is generally utilized as a part of commercial ventures, for example, vehicles, planes, hardware, adornments, and toys. The general methodology of electroplating uses an electrolytic cell, which comprises of putting a negative charge on the metal and dunking it into an answer that contains metal salt (electrolytes) which contain decidedly charged metal particles. At that point, because of the negative and positive charges, the two metals are pulled in to one another.

1.3.1 Preparing the Surface

The reason for setting up the surface before starting to plate another metal onto it is to guarantee that it is clean and free of contaminants, which may meddle with the holding. Tainting frequently forestalls statement and absence of attachment. Typically this is done in three stages: cleaning, treatment and flushing. Cleaning generally comprises of utilizing certain solvents, for example, antacid cleaners, water, or corrosive cleaners so as to evacuate layers of oil at first glance. Treatment incorporates surface alteration which is the solidifying of the parts and applying metal layers. Washing prompts the last item and is the last touch to electroplating. Two certain techniques for setting up the surface are physical cleaning and synthetic cleaning. Concoction cleaning comprises of utilizing solvents that are either surface-dynamic chemicals or chemicals which respond with the metal/surface. In physical, cleaning there is mechanical vitality being connected so as to evacuate contaminants. Physical cleaning incorporates brush scraped area and ultrasonic fomentation.

1.3.2 Galvanic Series

The galvanic series is a diagram demonstrating the connections and an aide for selecting metals that can be joined, with a point of aiding in the choice making methodology. This is finished by showing which materials have a negligible inclination to a galvanic communication, or the need or even level of assurance that can be connected to lessen the normal plausible cooperation

The galvanic series characterizes the respectability of metals and in addition semi-metals. This procedure happens when two metals are submerged in an electrolyte when electronically associated, before letting the base experience galvanic consumption. The consumption rate will be impacted by the electrolyte and also the distinction in honorability. Batteries frame the essential rule of metal consumption potential in the galvanic response. Every combination or metal has a particular consumption potential. The more negative a metal or composite is in the galvanic series, the more probable it is to endure galvanic consumption while the positive shows resistivity to erosion when subjected to reasonable conditions to erosion. The closer a metal or a compound is in the series, the less are the impacts of galvanic consumption contrasted with those metals far separated in the series with more noteworthy erosion. Then again, the series can be controlled by the anode and cathode reactivity to the metals' electrons. Those metals with high quantities of electron responses at the anode are found lower in the galvanic series contrasted with those with higher responses, with the inverse valid in the cathode.

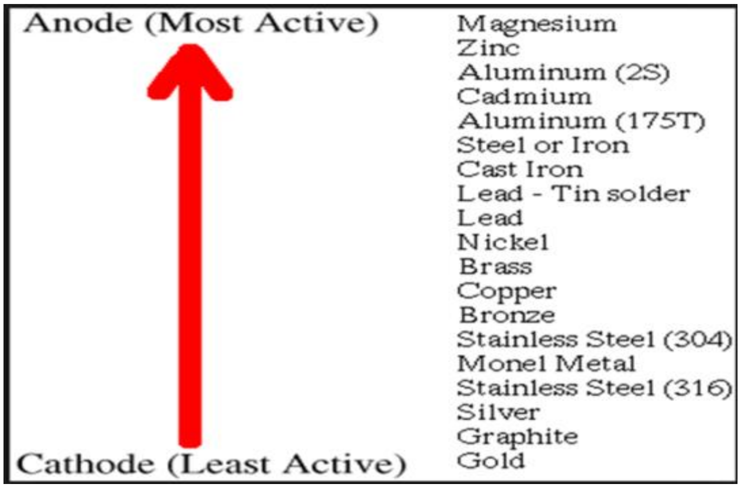


Figure 1 Galvanic Series

Chapter 2 – Literature Review

2.1 Copper Alloys for Marine Environments

'Copper Alloys for Marine Environments', the paper published by Carol Powell and Peter Webster, Copper Development Association builds an energy about copper amalgams usually utilized as a part of marine applications. It will give a review of the scope of amalgams and their properties and give references and hotspots for additional data. Every single copper compound can be machined precisely and expense adequately and to a decent standard of resistance and surface completion. Some copper compounds have phenomenal machinability as an essential property particularly leaded brasses, which set the standard by which every single other metal are judged. Other copper compounds are made with an assortment of mixes of properties, for example, quality, wear resistance, against rankling and frosty formability. These may be less effortlessly machined, however, are still simpler to machine than numerous different sorts of material. For seawater frameworks, copper-nickel and aluminium bronze are frequently favoured, albeit other copper compounds are utilized as a part of the marine administration and have their particular focal points. Copper combinations vary from different metals in that they have a characteristic high imperviousness to bio fouling, especially macro fouling, which can take out the requirement for antifouling coatings or water treatment. The copper-nickel alloying framework is moderately straightforward, upgrading the general properties of copper regarding quality and erosion resistance while keeping up a high innate imperviousness to bio fouling. The 90-10 copper-nickel compound (CW352H, C70600) is the most generally utilized fashioned copper amalgam for marine designing and can be found in seawater frameworks for maritime and business delivery and seaward oil and gas generation, and in desalination and aquaculture. Amalgams with higher nickel content, and those which are all the more very alloyed with chromium, aluminium and tin, are utilized where more noteworthy imperviousness to stream conditions, sand scraped spot, wear and rankling are needed, and also higher mechanical properties or cast ability. While the more conservative 90-10 copper-nickel combination (CW352H, C70600) is the most broadly utilized, the 70-30 copper-nickel composite (CW354H, C71500) is stronger and can withstand higher stream speeds, making it supported in the UK for submarine frameworks. Iron and manganese levels are vital in upgrading the erosion resistance of both combinations and it is essential these are inside the cut off points given in universal measures. Copper-nickels have high resistance to chloride pitting, crevice corrosion and stress corrosion cracking and do not have localized corrosion limitations caused by temperature, as do stainless steels. Piping is typically used up to 100oC. However, it is important to keep flow velocities below certain limits to avoid erosion corrosion. For tube and pipe, these limits depend on alloy, diameter, sand loadings and system design The CW353H (C71640) and C72200 alloys can be used at relatively higher flow velocities. Ammonia stress corrosion cracking in seawater or sulphide stress cracking/ hydrogen embrittlement is not the problem areas with these copper-nickels. However, ammonia can cause increased corrosion rates and can also cause low-temperature hotspot corrosion in heat exchanger tubes where there is little or low flow. Sulphites can cause pitting and increase corrosion rates, usually in situations when aerated water mixes with sulphide containing waters. An established oxide film offers a good degree of resistance to such corrosion, as does ferrous sulphate dosing. The 90-10 and 70-30 copper-nickel alloys are essentially ductile and available in all product forms. Their strength is increased by cold work but not age hardening. They can be joined by brazing and welding.

2.2 Materials for seawater pipeline systems

‘Materials for seawater pipeline systems’, the paper published by ‘Copper Development Association’ in1986, describes the purpose to review the technical and economic advantages and disadvantages of the different types of materials for the various applications concerned[3]. The principle applications to be considered are seawater admissions and circulation frameworks for maritime and beachfront vessels of various types, offshore oil and gas stage establishments, desalination plants creating new water from seawater, coastal petroleum and petrochemical transforming plants, coastal power producing stations. The variables that are applicable in picking a material for such applications are, resistance to consumption via seawater over an extensive variety of working conditions, resistance to erosion by the outer environment, resistance to marine bio fouling, permissible water velocities, the physical and mechanical properties of the material, ability to cut, machine, twist and perform other creating operations, availability of suitable jointing strategies and of NDT techniques to affirm the quality and serviceability of joints, availability of thorough scopes of segments to empower complete frameworks to be gathered, including perfect pumps, valves, heat exchangers, etc, existence of satisfactory and dependable supplies of funnels and parts and free accessibility of crude materials for their creation, initial expense of funnel and parts and expenses of manufacturing and introducing frameworks, life hope and the estimation of scrap when the framework is disassembled, demonstrable dependability in light of sufficient administration experience, ability to withstand dangers amid development and administration, eg. Mechanical damage, fire.

In considering conduct in seawater, record must be taken of numerous components including the rate of general and/or limited consumption under relentless state stream conditions, possibility of fissure erosion and of store assault or setting, especially under stagnant or gradually moving conditions, imperviousness to stretch erosion cracking, effect of varieties in creation of seawater including saltiness, oxygen content, suspended material, poisons, etc. Speed limitations, effect of variety of temperature, conceivable circles of operation being anyplace from ice to tropical districts. In a few applications hot brackish water must be handled. Possible galvanic impacts between distinctive materials. It should likewise be borne as a top priority that in the marine environment outer consumption of channelling frameworks can be a danger, e.g. event of fissure consumption because of entrance of chloride underneath sheathings, laggings, sections, and so on. There have been numerous recorded instances of funnelling frameworks coming up short rashly all things considered. To make a complete financial evaluation of the differently focused materials considering all the variables listed above is a matter of amazing many-sided quality, skirting on the impossible. Adequate information on administration conditions may not be accessible and regardless of the fact that the beginning conditions can be indicated decently exactly, they might in this manner change in an erratic manner. Estimates of the likelihood of tasteful conduct for the different materials will need to be made. To begin with expenses must be adjusted against resulting expenses of support, repair and replacement and loss of income because of the blackout. The counts need to incorporate assumptions about varieties in material expenses, work expenses, interest rates, expansion, levy policies, product costs etc. In a few circumstances, the expenses of breakdown are much higher than in others. In seaward establishments, loss of generation could rapidly invalidate any funds made in the first cost of the establishment and the completing of repairs could be a matter of extensive trouble and cost. As a result of these complexities, substantial dependence must be put on genuine or related knowledge. A change from a made material won't be viewed as unless there are a sufficiently awesome financial impetus and a sufficient collection of confirmation of the dependability of the new material. Adequate proof could take the type of long and acceptable administration in related applications. A decent case is the boundless change from carbon steel to 90/10 copper nickel composite for seawater pipelines on seaward stages, taking into account the demonstrated acceptable administration conduct of copper-nickel pipelines in boats and other marine establishments.

2.3 Bimetallic Consumption

DR. R. Francis of Weir Materials and Foundries under contract from NPL for the Department of Trade and Industry discusses that, 'the reason for this aide is to give general data about bimetallic consumption.' More point by point data can be acquired from English Gauges Foundation Distributed Record PD6484: 1979 (1). Further exhortation on particular issues can be gotten from the associations recorded toward the end of this aide. At the point when a metal is drenched in a directing fluid, it takes up a cathode potential (otherwise called the consumption potential). This is controlled by the harmony between the anodic and cathodic responses happening at first glance and it is normally measured with reference to a standard anode, for example, the immersed calomel terminal (SCE). Bimetallic erosion happens when two metals, with diverse possibilities, are in electrical contact while inundated in an electrically directing destructive fluid, In light of the fact that the metals have distinctive common possibilities in the fluid, a current will spill out of the anode (more electronegative) metal to the cathode (more electropositive), which will build the consumption on the anode.

Other Cathodic responses can happen in deaerated situations and one sample is fluids containing hydrogen sulfide. There is a scope of incompletely oxidized sulfur species (e.g. thiosulphate, dithionate and so forth.) and lessening of one or a greater amount of these species can be the rule cathodic response in consumption e.g. in acrid methodology salt waters in the oil and gas industry. Under uncoupled erosion, the anodic and cathodic responses happen at little, neighborhoods the metal. In a bimetallic couple, the cathodic response is more, or absolutely, on the electropositive individual from the couple and the anodic response is generally, or absolutely, on the electronegative part of the couple. In this aide reference is made to various normal amalgams for general designing utilization. For those new to these, the compounds are recorded in Table 1 by amalgam bunch, normal name and ostensible structure.

2.4 Application of copper-nickel alloy UNS C70600 for seawater service

'Application of copper-nickel alloy UNS C70600 for seawater service', Wilhelm Schleich, Germany. In this paper he states about the application of Copper- Nickel alloy for seawater services. More than a very long while, numerous thousands of huge amounts of the copper-nickel composite UNS C70600 have been utilized as a seawater channeling material in marine building. Keeping in mind the end goal to give solid administration execution of the material, this paper examines its metallurgical properties, the important components of general, confined and disintegration erosion, the one of a kind bio fouling resistance, and the execution in the contaminated water. The rules for the generation of UNS C70600 items, the configuration of pipework, the cutoff points of the combination and valuable administration proposals are delineated.

The decision of a fitting material for seawater administration is a troublesome choice that must be made by a fashioner preceding detail of the framework. Since a wide scope of conditions will more often than not be forced on the funneling material, the effect of seawater on material execution is controlled by various variables, for example, state of the material, framework outline, manufacture method, different seawater temperatures and stream administrations, natural action, and vicinity of oxidizing mixes. Further figures that are pertinent picking a material for a seawater funneling framework are: physical and mechanical properties, accessibility, material expenses, simplicity of creation and support, expected configuration life and past outline experience. More than a very long while, numerous thousands of huge amounts of the copper-nickel compounds UNS C71500 and UNS C70600 have been introduced in diverse marine building structures for the shipbuilding, seaward, power and desalination commercial enterprises. These compounds, which have been requested seawater funneling and warmth exchangers, are embraced by different gauges. UNS C71500 is overwhelmingly utilized for military submarine administration because of its higher quality and greatest reasonable stream rate, and in addition low attractive penetrability. Be that as it may, the more extensive business utilization of this compound is constrained to a certain degree in light of its higher material expense. The work-horse, consequently, is the UNS C70600 (CuNi 90/10, cupronickel). This combination uncovers a very much adjusted mix of attributes permitting its far reaching and temperate utilization. To guarantee the further dependable utilization of the material, there is a requirement for an itemized dialog on its properties. Specifically, consideration ought to be attracted to the nature of Cu-Ni 90/10 items, the performance in waters containing hydrogen sulfide and the aversion of disintegration and in addition galvanic erosion. At all temperatures, Cu-Ni compounds are spoken to by a solitary stage face focused cubic structure. The unlucky deficiency of stage change amid warm cycles diminishes the impact of welding on mechanical qualities and the erosion resistance of the material. This crystallographic structure uncovers great malleability and effect quality even at temperatures well underneath the point of solidification. The moderate dispersion rate for nickel in copper prompts focus slopes in the melt and, therefore, builds an isolation propensity in the cast structure at typical cooling rates. Thus, to give a uniform foundation defensive oxide layers, the homogenization of the isolated structure is needed for hot manufacturing or chilly living up to expectations with an ensuing recrystallization toughen.

The erosion conduct of copper-nickel relies on upon the vicinity of oxygen and different oxidizers be-cause it is cathodic to the hydrogen anode. Amid the essential consumption response, a cuprous oxide film is delivered that is predominately in charge of the erosion assurance. The results of consumption responses can respond with mixes in seawater and in this manner form a multi-layered oxide structure. The erosion rate rapidly diminishes altogether over a couple of days, with one study demonstrating that the related release of copper particles was decreased tenfold amid 10 min and

100-fold in the first hour.5 The long haul general consumption rates of UNS C70600 have been found to persistently diminish with time of presentation to underneath 2.5 μm/yr. However, foundation of an adult film takes from 27 to 35 months at temperatures of 15-17°C. At 27°C, normal channel temperature for the Middle East, the foundation of the defensive film inside a couple of hours was reported. regardless of a wide usage of cupronickel, the beneficial outcome of the seawater temperature is still not well comprehended and more research is needed on this area.

In clean natural seawater or in seawater chlorinated to levels sufficient to control the biological metabolism, UNS C70600 is resistant to localized attack. Due to its bio fouling resistance, the number of potential sites for pitting attack is limited, even in slowly moving seawater. However, in polluted water containing hydrogen sulfide, pitting usually takes place in the form of wide and shallow pits. The undercut type of pitting attack normally associated with stainless steel is not common for Cu-Ni 90/10.

Only a limited amount of information is available on failures of copper-nickel due to crevice corrosion. Theoretically, the crevice corrosion behavior of the alloy is generally controlled by an ion concentration cell mechanism where the accumulation of copper ions in the crevice leads to ennoblement. Thus, if encountered, the corrosion attack would tend to take place in the region adjacent to the crevice, which is exposed to the bulk water.

Under-deposit corrosion is really crevice corrosion beneath deposits. There is a tendency for deposition of suspended matter at flow rates below 0.5-1 m/s. Cupronickel performs well as a material for firefighting systems with predominantly quiet conditions. However, if the region under deposits become anaerobic, contributing to the establishment of sulfate-reducing bacteria, the situation can become critical.

Since, stagnating conditions should be avoided in seawater containing high levels of suspended particles or biological matter; it is advisable to use the water from the open sea in stand-by systems.

In addition, the frequent refreshment of seawater is preferable at least once every 4-5 days. The chlorination of seawater could improve the water quality by control of microbiological activity. During prolonged shut-down periods of the plant, it is recommended to rinse the system with clean seawater and keep it dry.

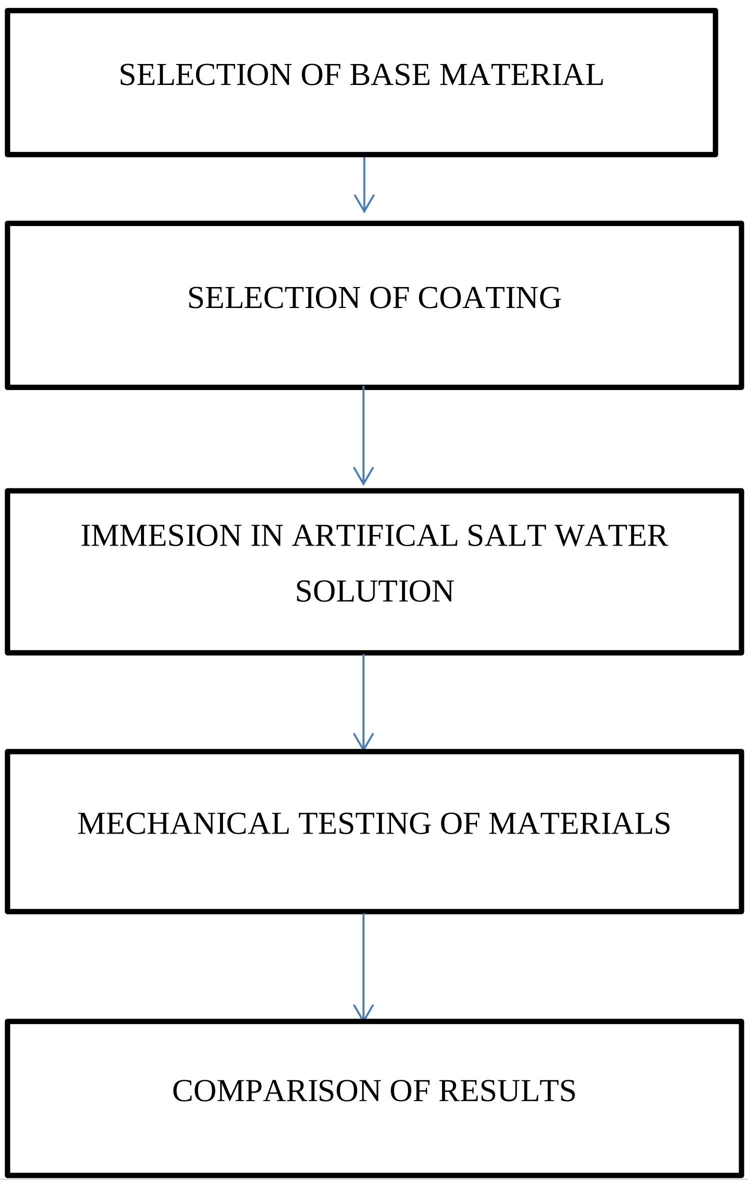
The benefits of the Copper-Nickel as a fitting composite for seawater pipework can be credited to different viewpoints. Above all else, it is a basic alloying framework with a solitary stage face focused cubic structure giving magnificent hot and chilly workability. The unlucky deficiency of stage changes amid welding adds to its simple weldability with no requirement for far reaching post-weld medications. Nonetheless, the synthetic creation and the assembling of cupronickel items must agree to universal measures.

The low uniform consumption rates of the composite permit the particular of more slender walled funneling and, in this way, give weight sparing. Cathodic insurance is not normal for UNS C70600 channeling. The combination is impervious to bio fouling and does not uncover delicate consumption potential varieties under diverse seawater conditions. Such a blend of highlights prompts the enhanced imperviousness to confined consumption and the disposal of far reaching observing systems connected with chlorination and higher seawater temperatures which other composite frameworks may require. The compound has high imperviousness to hole consumption and is impervious to stretch erosion splitting under marine conditions.

For lower seawater temperatures, defensive surface movies may take up to 3 months to completely develop. Consequently, hydro testing and appointing proposals have been given. What's more, to keep away from untimely disappointments in the vicinity of hydrogen sulfide, preparatory measures are required. The given reasonable proposals ought to be taken after to stay away from erosion issues. The defenselessness to disintegration consumption and galvanic erosion can be wiped out by suggested configuration contemplations.

Chapter 3 – Theoretical Development

3.0 PROCESS FLOW DIAGRAM



3.1 Tensile test

A tensile test is most likely the most major kind of mechanical test you can perform on material. Tensile tests are straightforward, moderately reasonable, and completely institutionalized. By pulling on something, you will rapidly decide how the material will respond to powers being connected in strain. As the material is being pulled, you will think that its quality alongside the amount it will stretch.

The tensile test or strain test includes applying a continually expanding burden to a test example up to the point of disappointment. The procedure makes an anxiety/strain bend indicating how the material responds all through the tensile test. The information created amid tensile testing is utilized to focus mechanical properties of materials and gives the accompanying quantitative estimations:

Tensile strength, otherwise called Ultimate Tensile Strength (UTS), is the greatest tensile anxiety conveyed by the example, characterized as the most extreme burden isolated by the first cross-sectional territory of the test specimen.

Yield strength is the stress at which time permanent (plastic) deformation or yielding is observed to begin.

Ductility measurements are typically elongation, defined as the strain at, or after, the point of fracture and reduction of area of the fracture of the test sample.

The test specimen is safely held by top and base holds joined to the tensile or widespread testing machine. Amid the strain test, the holds are moved separated at a consistent rate to extend the example. The power on the example and its relocation is constantly observed and plotted on an anxiety strain bend until disappointment. The estimations, tensile quality, yield quality and flexibility. are computed by the professional after the test example has broken. The test example is assembled back to gauge the last length, then this estimation is contrasted and the pre-test or unique length to acquire stretching. The first cross area estimation is likewise contrasted with the last cross segment to get the diminishment in region.

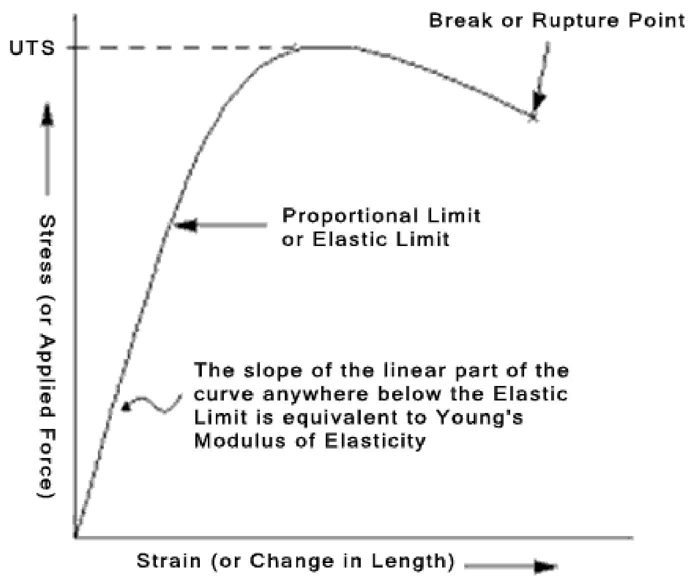


Figure 2 Stress Strain Graph

3.1.2 Modulus of Elasticity

The modulus of elasticity is a measure of the firmness of the material; however it just applies to the straight locale of the bend. On the off chance that an example is stacked inside this direct district, the material will come back to its literally the same condition if the heap is uprooted. At the point that the bend is no straighter and digresses from the straight-line relationship, Hooke's Law no more applies and some changeless twisting happens in the example. This point is known as the "versatile or relative utmost". Starting here on in the tensile test, the material responds plastically to any further increment in burden or anxiety. It won't come back to its unique, unstressed condition if the heap were uprooted.

3.1.3 Yield Strength

"Yield strength" of a material is characterized as the anxiety connected to the material at which plastic disfigurement begins to happen while the material is stacked.

3.1.4 Strain

A strain is a standardized measure of disfigurement speaking to the uprooting between particles in the body in respect to a reference length. The condition of strain at a material purpose of a continuum body is characterized as the totality of every last one of changes long of material lines or strands, the ordinary strain, which go through that point furthermore the totality of every last one of changes in the edge between sets of lines at first opposite to one another, the shear strain, emanating starting here. Nonetheless, it is sufficient to know the ordinary and shear segments of strain on an arrangement of three commonly opposite bearings.

3.1.5 Stress

Stress is a physical amount that communicates the inside powers that neighboring particles of a ceaseless material apply on one another, while strain is the measure of the distortion of the material. Strain inside a material may emerge by different systems, for example, stress as connected by outer strengths to the mass material (like gravity) or to its surface (like contact powers, outside weight, or grating). Any strain (distortion) of a strong material produces an inward flexible stress, closely resembling the response power of a spring that has a tendency to restore the material to its unique non-twisted state. In fluids and gasses, just misshapenness that changes the volume produce persevering flexible stress. In any case, if the distortion is progressively changing with time, even in liquids there will ordinarily be a few gooey stresses, contradicting that change. Versatile and thick stresses are typically joined with the name mechanical stress.

3.1.6 Ultimate Tensile Strength

One of the properties you can focus on a material is its ultimate tensile strength (UTS). This is the greatest burden the example supports amid the test. The UTS might compare to the strength at break. This all relies on upon what sort of material you are trying. . .fragile, malleable or a substance that even shows both properties. Furthermore, here and there a material may be flexible when tried in a lab, be that as it may, when set in administration and presented to amazing icy temperatures, it may move to fragile conduct

3.2 Impact Charpy Testing

The Charpy impact test is an institutionalized high strain-rate test which decides the measure of vitality consumed by a material amid break. This ingested vitality is a measure of a given material's indent strength and goes about as a device to study temperature-subordinate bendable fragile move. The mechanical assembly comprises of a pendulum of known mass and length that is dropped from a known stature to impact an indented example of material. The vitality exchanged to the material can be surmised by contrasting the distinction in the stature of the mallet prior and then afterward the break (vitality consumed by the crack occasion). The score in the example influences the consequences of the impact test; hence it is important for the intent to be of consistent measurements and geometry. The span of the example can likewise influence results following the measurements figure out if or not the material are in plane strain. This distinction can incredibly influence conclusions made.

The Charpy Impact Test is ordinarily utilized on metals but, on the other hand, is connected to composites, earthenware production, and polymers. With the Charpy impact test one most regularly assesses the relative durability of a material, in that capacity, it is utilized as a fast and temperate quality control gadget. The Charpy Impact Test comprise of hitting a suitable example with a mallet on a pendulum arm while the example is held safely at every end. The sled strikes inverse the score. The vitality consumed by the example is dictated by definitely measuring the decline in the movement of the pendulum arm.

Vital variables that include the strength of a material incorporate low temperatures, high strain rates (by impact or pressurization), and anxiety concentrators, for example, indents breaks and voids. By applying the Charpy Impact Test to indistinguishable examples at distinctive temperatures, and after that plotting the impact vitality as a component of temperature, the bendable weak move gets to be evident. This is fundamental data to acquire when deciding the base administration temperature for a material.

Impact testing decides a material's strength or impact quality in the vicinity of a blemish or score and quick stacking conditions. This damaging test includes cracking an indented example and measuring the measure of vitality consumed by the material amid break.

This impact test demonstrates the relationship of flexible to weak move in consumed vitality at a progression of temperatures. Since iron and all other body-focused cubic metals experience a move from bendable conduct at higher temperatures to fragile conduct at lower temperatures, this test is obliged today for various imperative steel items including steel structure plate for boats, atomic plant weight vessels, forgings for electric force plant generator rotors, and so forth. The test is performed utilizing a few machined bar examples 1cm x 1cm x 5.5cm with a 2mm profound indent at the center of a predetermined level surface – normally a "V" score. The examples are tested at a progression of indicated temperatures (e.g. -20ºC, -10ºC, 0ºC, +10ºC, +20ºC). When an example achieves the exact temperature, it is immediately set into a unique holder with the score arranged vertically and toward the birthplace of impact. The example is struck by a "tup" appended to a swinging pendulum of particular outline and weight. The example breaks at its scored cross-segment upon impact, and the upward swing of the pendulum is utilized to focus the measure of vitality consumed (indent sturdiness) simultaneously. It is still an inquiry if Charpy and others thought about the flexible to fragile move that happens with temperature in steel amid these early years of impact tests. The extent that it is known, the majority of Charpy's tests were led at room temperature.

Charpy test specimens normally measure 55x10x10mm and have a notch machined across one of the larger faces. The notches may be:

- V-notch – A V-shaped notch, 2mm deep, with 45° angle and 0.25mm radius along the base
- U-notch or keyhole notch – A 5mm deep notch with 1mm radius at the base of the notch.

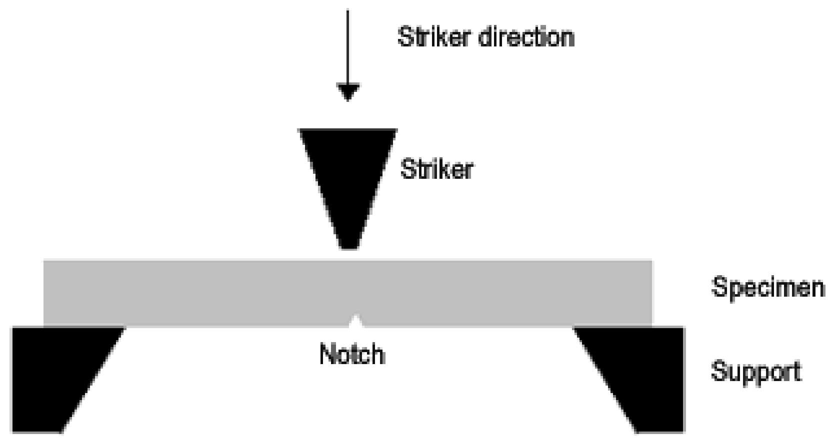


Figure 3 Impact Charpy concept

3.2.1 Toughness

Toughness is the capacity of a material to ingest vitality and plastically misshape without fracturing. One meaning of material toughness is the measure of vitality every unit volume that a material can assimilate before bursting. It is additionally characterized as a material's imperviousness to break when focused.

3.2.2 Fracture

A fracture is the detachment of an item or material into two or more pieces under the activity of anxiety. The fracture of a strong as a rule happens because of the improvement of certain relocation intermittence surfaces inside the strong. On the off chance that a dislodging creates opposite to the surface of relocation, it is known as a typical elastic split or essentially a break; if an uprooting grows tangentially to the surface of removal, it is known as a shear break, slip band, or dislocation, rapture quality or breaking quality is the anxiety when an example comes up short or fractures.

3.3 Coating Specifications and Properties

Cupronickel is exceptionally impervious to erosion in seawater, in light of the fact that its terminal potential is conformed to be impartial with respect to seawater. On account of this, it is utilized for funneling, warmth exchangers and condensers in seawater frameworks, and marine equipment, and some of the time for the propellers, crankshafts and structures of premium tugboats, angling watercrafts and other working vessels. The expansion of nickel to copper enhances quality and consumption resistance without decreasing the great flexibility. Copper-nickel compounds have phenomenal imperviousness to marine erosion and bio fouling.

The two primary composites are 90/10 (90% copper, 10% nickel) and 70/30 (70% copper, 30% nickel). The 70/30 is the stronger and has more prominent imperviousness to seawater stream, however the 90/10 will give great support of most applications and, being less costly, has a tendency to be all the more generally utilized. Both composites contain little, however, vital augmentations of iron and manganese which have been decided to give the best blend of imperviousness to streaming seawater and to general corrosion. Copper-nickel amalgams are generally utilized as a part of marine applications because of their fantastic imperviousness to seawater corrosion, high inalienable imperviousness to bio fouling and simplicity of manufacture. They have given solid support of quite a few years whilst offering compelling answers throughout today's mechanical difficulties.

The copper- nickel composites are singled staged all through the full scope of arrangements and numerous principles amalgams exist inside this extent, more often than not with little increases of different components for exceptional purposes. The two most famous of the copper- rich compounds contain 10 or 30% of nickel. Some manganese is perpetually shown in the business composites as a deoxidant and desulphurize, it enhances working qualities and moreover adds to corrosion resistance in seawater. Chromium can be utilized to supplant a portion of the iron substance and at one every penny or more gives higher quality.

The corrosion resistance of the combinations is because of the defensive surface film shaped when in contact with water. On beginning submersion cuprous oxide is shaped, however, complex changes happen in seawater which research work is just now being to explain. The fouling resistance is because of the copper particles at the surface, making it ungracious to most marine living beings in gradually moving water. In static conditions there may be some statement of substance salts and organic oozes, conceivably prompting some feebly follower fouling, however such deposits are effortlessly disconnected from the metal's corrosion safe surface, uncovering a new, biocidally dynamic surface. The sorts of issues experienced in pipeline materials incorporate general corrosion in new water, impingement assault because of turbulent stream round curves or deterrents, setting corrosion brought about by collaboration with other material, hole corrosion, in areas kept from oxygen and disintegration created by suspended solids.

90/10 copper-nickel, equal to CuNi10Fe1Mn (according to DIN 17670) or CN 102 (according to BS

2870), involves an exceptional spot among the scope of copper-base composites containing nickel. Aside from showing high imperviousness to uniform and nearby corrosion when subjected to seawater, this material additionally introduces similar great imperviousness to disintegration. A third preference is this current amalgam's remarkable imperviousness to fouling in seawater. Recognizable fields of utilization in which CuNi10Fe1Mn has been effectively utilized for a long time incorporate seawater-conveying device and pipelines. Where, notwithstanding exceedingly destructive conditions, a lot of mechanical anxiety must be withstood, with respect to sample in admission containers of seawater desalination plants, steels clad with CuNi10Fe1Mn can be utilized as conservative constructional materials. Due to their corrosion, disintegration and antifouling properties, CuNi10Fe1Mn and the steels clad with it are thus additionally utilized as materials as a part of boat and pontoon structures. This subject is managed in the accompanying, with a rundown above all else being given the learning picked up as such.

By the 1920s, a 70–30 copper-nickel evaluation was produced for maritime condensers. Before long a while later, a 2% manganese and 2% iron composite now known as amalgam C71640 was presented for a UK force station which required better disintegration resistance on the grounds that the levels of entrained sand in the seawater. A 90–10 compound first got to be accessible in the 1950s, at first for seawater channeling and is presently the all the more generally utilized amalgam.

In seawater, the amalgams have astounding corrosion rates which stay low the length of the most extreme configuration stream speed is not surpassed. This speed relies on upon geometry and channel measurement. They have high imperviousness to cleft corrosion, stress corrosion breaking and hydrogen embrittlement that can be troublesome to other amalgam frameworks. Copper-nickels characteristically frame a slim defensive surface layer over the initial a few weeks of introduction to seawater and this gives its progressing resistance. Furthermore, they have a high intrinsic bio fouling imperviousness to connection by macro foulers (e.g. sea grasses and molluscs) living in the seawater. To utilize this property to its maximum capacity, the combination needs to be free of the impacts of, or protected from, any type of cathodic insured.

Table 3. 1 Properties of Copper Nickel

Alloy	Density g/cm^3	Thermal conductivity W/(m·K)	TEC µm/(m·K)	Electrical resistivity µOhm·cm	Elastic modulus GPa	Yield strength MPa	Tensile strength MPa
90-10	8.9	50	17	19	135	105	275
70-30	8.95	29	16	34	152	125	360
66-30-2-2	8.86	25	15.5	50	156	170	435

Carlson Alloy 90 10 Cu-Ni is a copper-based compound grew as a financially savvy substitute for 70 30 Cu-Ni. An expansion of roughly 1.4% iron was made to build its imperviousness to general corrosion, disintegration and impingement corrosion coming about structure the turbulent stream of water containing air pockets and sediment streaming at a high speed. 90 10 Cu-Ni has great quality at moderate temperatures. It can be manufactured by both hot and cool working methods, and is promptly weld able. 90 10 Cu-Ni has phenomenal imperviousness to corrosion by freshwater, bitter water, and ocean water. It is not suggested for use in intensely dirtied water containing sewage and modern squanders. 90 10 Cu-Ni opposes assault by phosphoric, sulfuric, and gentle natural acids. It is assaulted by chromic, hydrochloric and nitric acids. 90 10 Cu-Ni is likewise impervious to the soluble base chlorides, nitrates, sulfates and to smelling salts and ammonium mixes.

3.4 Properties of AISI 1040 oil quench steel

Table 3. 2 AISI 1040 Mechanical Properties

Hardness (Brinell)	170
Ultimate Tensile Strength	571MPa
Yield Tensile Strength	360MPa
Modules Of Elasticity	200GPa
Bulk Modulus	160GPa

3.5 ASTM E8 Metal Tensile Strength Testing

ASTM E8 depicts tractable testing of metals, for example, steel or metal compounds. This test decides critical mechanical properties, for example, yield quality, extreme elasticity, stretching, and diminishment of the zone. E8 ductile tests focus the malleability and quality of different metals when the materials experience uniaxial pliable burdens. Such data is essential to compound improvement, outline, quality control, and correlation of diverse arrangements of metals.

3.5.1 Tensile specimen

Table 3. 3 Tensile Specimen Dimensions

Length	300mm
Gauge length	56mm
Radius	10mm
Diameter of hole in gauge length	1mm
Depth of hole in gauge length	0.5mm

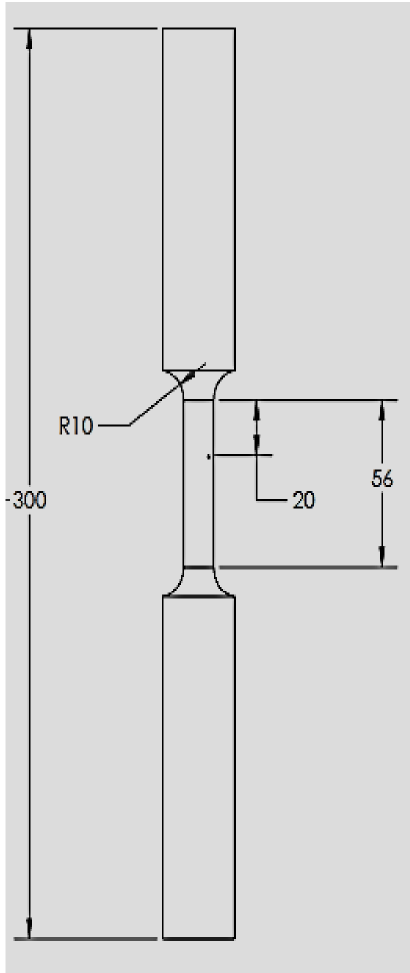


Figure 4 Tensile Specimen Dimensions

3.5.2 Impact Charpy Test Specimens

The standard Charpy Impact Test specimen comprise of a bar of metal or other material, 55x10x10mm having a score machined over one of the bigger measurements.

Table 3. 4 Impact Specimen Dimensions

Length of specimen	55mm
Angle of V-notch	90°
Width of specimen	10mm

Height of specimen	10mm

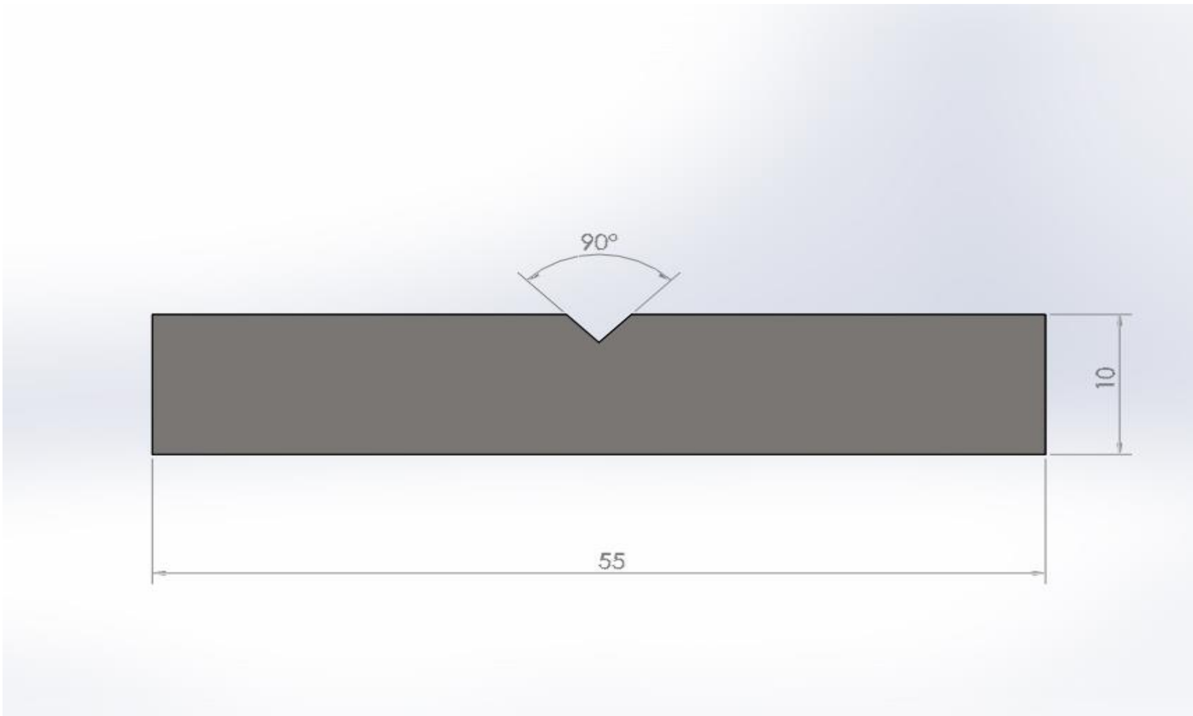


Figure 5 Charpy Test Specimen

Chapter 4 – Experimental Development

4.1 Formulas Used

4.1.1 Formulas Used for Tensile Test

$$ultimate\ tensile\ strength = \frac{ultimate\ load}{orginal\ cross\ sectional\ area}$$

$$percentage\ elongation = \frac{extended\ gauge\ length - orginal\ gauge\ length}{orginal\ gauge\ length} \times 100$$

$$yeild\ stength = \frac{load\ on\ yeild\ point}{orginal\ cross\ sectional\ area} \quad (N/mm^2)$$

4.1.2 Formulas Used For Impact Charpy Test

$$Impact\ Energy, U = initial\ reading - final\ reading \ \ (Joules)$$

$$Notch\ impact\ strength\ I = \frac{impact\ energy}{effective\ area\ of\ specimen} \ \ (N/m)$$

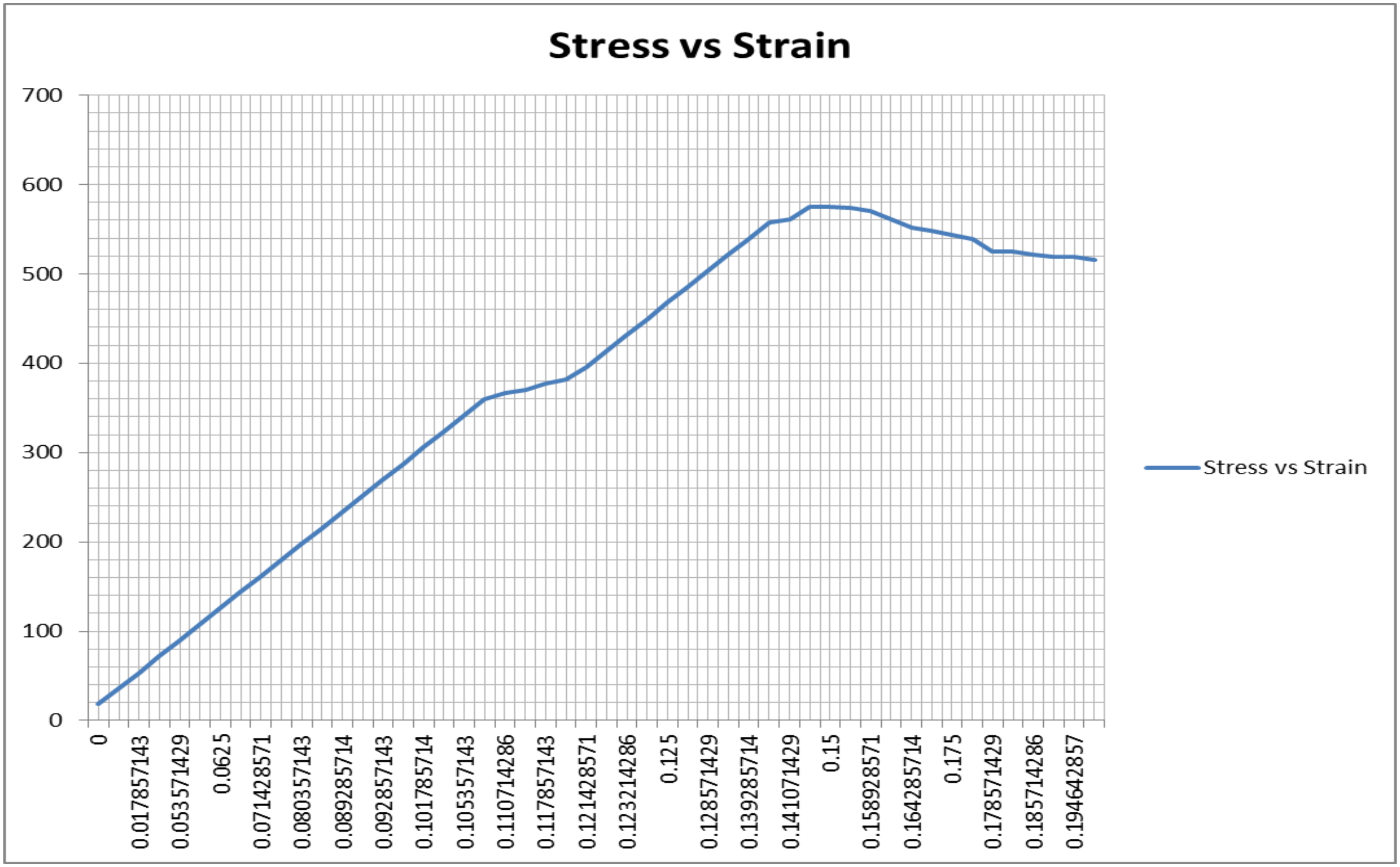
$$Modulus\ of\ rupture = \frac{impact\ energy}{effective\ volume} \ \ (Joule/mm^3)$$

4.2 Stress and strain values of bare material

Table 4. 1 Stress And Strain Values Of Bare Material

STRESS	***STRAIN***
17.98238	0
35.96475	0
53.94713	0.017857
71.92951	0.035714
89.91189	0.053571
107.8943	0.0625
125.8766	0.0625
143.859	0.071429
161.8414	0.071429
179.8238	0.075
197.8061	0.080357
215.7885	0.085714
233.7709	0.089286
251.7533	0.089286
269.7357	0.092857
287.718	0.098214
305.7004	0.101786
323.6828	0.101786
341.6652	0.105357
359.6475	0.107143
366.8405	0.110714
370.437	0.114286
377.6299	0.117857
381.2264	0.121429
395.6123	0.121429
413.5947	0.123214
431.5771	0.123214
449.5594	0.124107
467.5418	0.125
485.5242	0.125
503.5066	0.128571
521.4889	0.132143
539.4713	0.139286
557.4537	0.140179

561.0502	0.141071
575.4361	0.142857
575.4361	0.15
573.6378	0.157143
570.0414	0.158929
561.0502	0.160714
552.059	0.164286
548.4625	0.167857
543.0678	0.175
539.4713	0.176786
525.0854	0.178571
525.0854	0.182143
521.4889	0.185714
519.6907	0.19375
519.6907	0.194643
516.0942	0.196429



Graph 1 Stress Vs Strain of Bare Material

4.3 Load and Elongation Values of Coated Specimen

Table 4. 2 Load And Elongation Values Of Coated Specimen

LOAD	***ELONGATION***
0	0
1	0
2	0
3	0
4	0
5	0.2
6	0.6
7	0.85
8	1
9	1.3
9.6	1.5
10	1.8
11	2
12	2.2
13	2.4
14	2.6
15	2.8
16	3
17	3
18	3.2
19	3.4
20	3.6
21	3.7
22	3.9
23	3.9
24	4
25	4.05
26	4.1
27	4.3
28	4.4
29	4.5
30	4.7
31	4.7
32	4.8
33	4.9
34	5
35	5.05
36	5.1
37	5.1
38	5.1
39	5.2
40	5.2
41	5.3

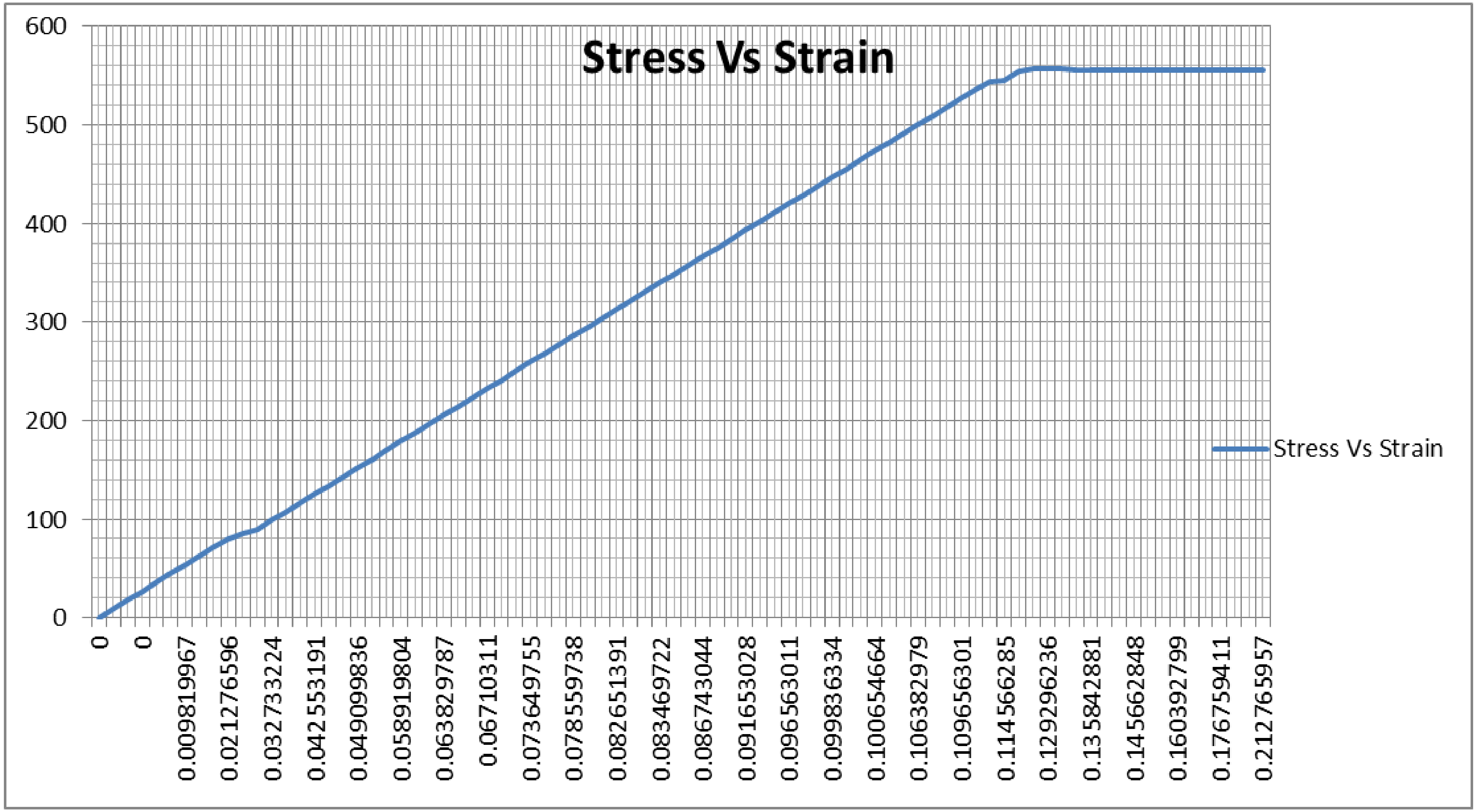
42	5.3
43	5.5
44	5.6
45	5.8
46	5.9
47	5.9
48	6
49	6
50	6.1
51	6.1
52	6.1
53	6.15
54	6.2
55	6.4
56	6.5
57	6.5
58	6.6
59	6.7
60	6.8
60.8	6.9
61	7
62	7.3
62.4	7.7
62.4	7.9
62.3	8
62.2	8.1
62.2	8.3
62.2	8.5
62.2	8.75
62.2	8.9
62.2	9
62.2	9.3
62.2	9.8
62.2	10
62.2	10.3
62.2	10.8
62.2	11
62.2	11.5
62.2	13

4.4 Stress And Strain Values of Coated Specimens

Table 4. 3 Stress And Strain Values Of Coated Specimens

STRESS	***STRAIN***
0	0
0.008932	0
0.017864	0
0.026795	0
0.035727	0
0.044659	0.003273
0.053591	0.00982
0.062522	0.013912
0.071454	0.016367
0.080386	0.021277
0.085745	0.02455
0.089318	0.02946
0.098249	0.032733
0.107181	0.036007
0.116113	0.03928
0.125045	0.042553
0.133976	0.045827
0.142908	0.0491
0.15184	0.0491
0.160772	0.052373
0.169703	0.055646
0.178635	0.05892
0.187567	0.060556
0.196499	0.06383
0.205431	0.06383
0.214362	0.065466
0.223294	0.066285
0.232226	0.067103
0.241158	0.070376
0.250089	0.072013
0.259021	0.07365
0.267953	0.076923
0.276885	0.076923
0.285816	0.07856
0.294748	0.080196
0.30368	0.081833
0.312612	0.082651
0.321543	0.08347
0.330475	0.08347
0.339407	0.08347

0.348339	0.085106
0.35727	0.085106
0.366202	0.086743
0.375134	0.086743
0.384066	0.090016
0.392997	0.091653
0.401929	0.094926
0.410861	0.096563
0.419793	0.096563
0.428725	0.0982
0.437656	0.0982
0.446588	0.099836
0.45552	0.099836
0.464452	0.099836
0.473383	0.100655
0.482315	0.101473
0.491247	0.104746
0.500179	0.106383
0.50911	0.106383
0.518042	0.10802
0.526974	0.109656
0.535906	0.111293
0.543051	0.11293
0.544837	0.114566
0.553769	0.119476
0.557342	0.126023
0.557342	0.129296
0.556449	0.130933
0.555556	0.13257
0.555556	0.135843
0.555556	0.139116
0.555556	0.143208
0.555556	0.145663
0.555556	0.1473
0.555556	0.152209
0.555556	0.160393
0.555556	0.163666
0.555556	0.168576
0.555556	0.176759
0.555556	0.180033
0.555556	0.188216
0.555556	0.212766



Graph 2 Stress Vs Strain of Coated Specimen

4.5 Load and elongation of Corroded Coated Specimens

Table 4. 4 Load and elongation Values of Corroded Coated Specimens

LOAD	***ELONGATION***
0	0
1	0
2	0
3	0
4	0
5	0.1
6	0.4
7	0.8
8	1
9	1.4
10	1.7
11	1.9
12	2
13	2.1
14	2.4
15	2.7
16	2.9
17	3
18	3.1
19	3.2
20	3.3
21	3.6
22	3.7
23	3.8
24	3.9
25	3.9
26	4
27	4.1
28	4.1
29	4.1
30	4.2
31	4.4
32	4.5
33	4.6
34	4.6

35	4.6
36	4.7
37	4.9
37.5	5
38	5
39	5.05
40	5.1
41	5.1
42	5.1
43	5.1
44	5.2
45	5.3
46	5.5
47	5.5
48	5.6
49	5.8
50	5.9
51	5.95
52	6
53	6
54	6.1
55	6.1
56	6.1
57	6.1
58	6.2
59	6.3
60	6.4
61	6.5
62	6.6
62.6	6.8
62.8	6.9
62.9	6.9
63	7
63.8	7.2
63.9	7.5
64	7.7
64	7.9
64	8
63.8	8.4
63.7	8.4
63.2	8.7
63.1	8.9
63.1	9
63.1	9.3
63.1	9.7

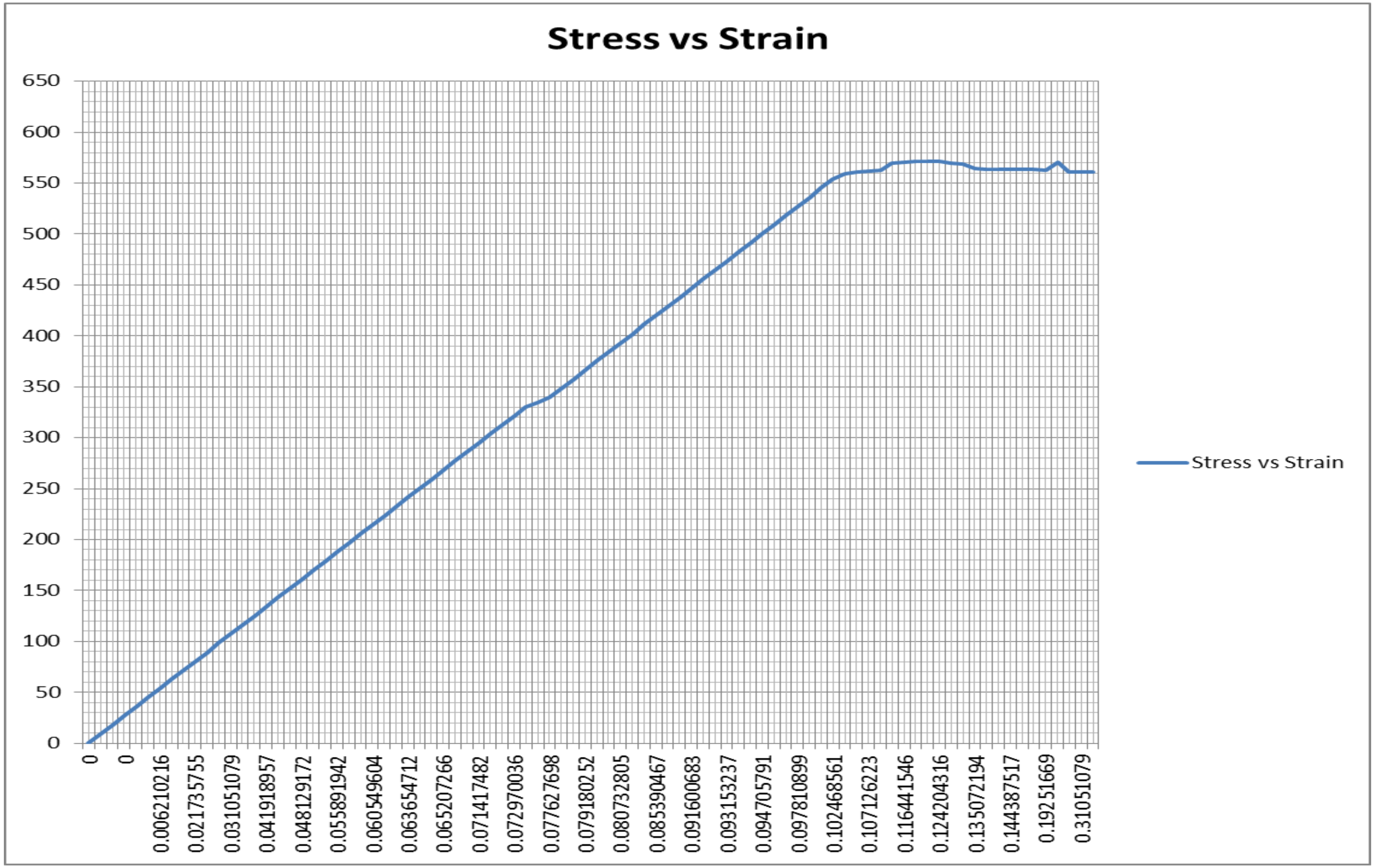
63.1	10
63	12.4
63.9	17
62.8	19
62.8	20
62.8	24

4.6 Stress And Strain Vales of Corroded Coated Specimens

Table 4. 5 Stress And Strain Vales of Corroded Coated Specimens

STRESS	***STRAIN***
0	0
8.931043	0
17.86209	0
26.79313	0
35.72417	0
44.65522	0.001553
53.58626	0.00621
62.5173	0.01242
71.44835	0.015526
80.37939	0.021736
89.31043	0.026393
98.24148	0.029499
107.1725	0.031051
116.1036	0.032604
125.0346	0.037261
133.9657	0.041919
142.8967	0.045024
151.8277	0.046577
160.7588	0.048129
169.6898	0.049682
178.6209	0.051234
187.5519	0.055892
196.483	0.057444
205.414	0.058997
214.345	0.06055
223.2761	0.06055
232.2071	0.062102
241.1382	0.063655
250.0692	0.063655
259.0003	0.063655
267.9313	0.065207
276.8623	0.068312
285.7934	0.069865
294.7244	0.071417
303.6555	0.071417
312.5865	0.071417
321.5176	0.07297
330.4486	0.076075
334.9141	0.077628
339.3796	0.077628
348.3107	0.078404

357.2417	0.07918
366.1728	0.07918
375.1038	0.07918
384.0349	0.07918
392.9659	0.080733
401.897	0.082285
410.828	0.08539
419.759	0.08539
428.6901	0.086943
437.6211	0.090048
446.5522	0.091601
455.4832	0.092377
464.4143	0.093153
473.3453	0.093153
482.2763	0.094706
491.2074	0.094706
500.1384	0.094706
509.0695	0.094706
518.0005	0.096258
526.9316	0.097811
535.8626	0.099363
544.7936	0.100916
553.7247	0.102469
559.0833	0.105574
560.8695	0.107126
561.7626	0.107126
562.6557	0.108679
569.8006	0.111784
570.6937	0.116442
571.5868	0.119547
571.5868	0.122652
571.5868	0.124204
569.8006	0.130415
568.9075	0.130415
564.4419	0.135072
563.5488	0.138177
563.5488	0.13973
563.5488	0.144388
563.5488	0.150598
563.5488	0.155255
562.6557	0.192517
570.6937	0.263934
560.8695	0.294985
560.8695	0.310511
560.8695	0.372613



Graph 3 Stress Vs Strain Of Corroded Coated Specimen

Chapter 5 – Results and Discussion

5.1 Corrosion Rate

5.1.1 Corrosion rate for bare metal

$$CR(mm/year) = \frac{weight\ loss\ in\ grams \times 8.74 \times 10^4}{density \times cross\ sectionl\ area \times time}$$

$$CR(miles/year) = \frac{weight\ loss\ in\ grams \times 3.45 \times 10^6}{density \times cross\ sectionl\ area \times time}$$

$$CR(mm/year) = \frac{4 \times 8.74 \times 10^4}{7.845 \times 180.57 \times 96} = \mathbf{2.5707\ mm/year}$$

$$CR(mm/year) = \frac{4 \times 3.45 \times 10^6}{7.845 \times 180.57 \times 96} = \mathbf{101.477\ mm/year}$$

Density – density of the bare metal (gram/cc)

Cross sectional area – cross sectional area of the gauge (mm^2)

Time – Duration immersed in saltwater solution (hours)

Weight loss – weight of specimen before immersed in saltwater − weight of specimen after immersed in water

5.1.2 Corrosion rate for copper- nickel-chromium

$$CR(mm/year) = \frac{weight\ loss\ in\ grams \times 8.74 \times 10^4}{density \times cross\ sectionl\ area \times time}$$

$$CR(miles/year) = \frac{weight\ loss\ in\ grams \times 3.45 \times 10^6}{density \times cross\ sectionl\ area \times time}$$

$$CR(mm/year) = \frac{2 \times 8.74 \times 10^4}{8.94 \times 180.57 \times 4 \times 96} = \mathbf{0.281\ mm/year}$$

$$CR(miles/year) = \frac{2 \times 3.45 \times 10^6}{8.94 \times 180.57 \times 4 \times 96} = \mathbf{11.13\ miles/year}$$

Density – density of the bare metal (gram/cc)

Cross sectional area – cross sectional area of the gauge (mm^2)

Time – Duration immersed in saltwater solution (hours)

Weight loss – weight of specimen before immersed in saltwater **–** weight of specimen after immersed in water.

5.1.3 Percent decrease in corrosion

$$\% \, decrease \; in \; corrosion = \frac{CR \; of \; coated \; specimen - CR \; of \; base \; metal}{CR \; of \; bare \; metal} \times 100$$

$$\% \, decrease \; in \; corrosion = \frac{0.281 - 2.570}{2.570} \times 100 = \mathbf{-89.3}\%$$

5.2 Results of Mechanical Testing

Table 5. 1 Results OF Mechanical Testing

	Tensile strength(N/mm^2)	Yield strength (N/mm^2)	Impact strength (KN)	Hardness
Bare material	574.01	360.49	400.912	33.166
Corroded bare material	568.01	352	357.605	29.667
Coated material	571.58	374.59	254.84	32.83
Corroded coated material	586	369.46	282.33	31.4

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Appendix

A1. Artificial Salt Water Solution

This substitute sea water may be utilized for research center testing where a reproducible arrangement reenacting ocean water is needed. Cases are for tests for oil sullying, detergency assessment, and erosion testing. The need natural matter, suspended matter, and marine life in this arrangement does not allow unfit acknowledgement of test results as speaking to execution in genuine sea water. Where erosion is included, the outcomes got from research facility tests may not estimate those secured under regular testing conditions that contrast extraordinarily from those of the lab, and particularly where impacts of speed, salt environments, or natural constituents are included. Additionally, the fast exhaustion of responding components introduce in low fixations recommends alert in the direct utilization of results.

A1.1 "The corrosion behavior of low carbon steel in natural and synthetic seawaters" By H. Moller, E.T. Boshoff, and H. Froneman.

Drenching tests were performed in consistently circulated air through arrangements utilizing two examples every arrangement. The volume of the arrangement was 1000 ml. Air circulation was attained to by utilizing a little vacuum apparatus, which additionally added to uniform test conditions by blending. All trials were directed at room temperature (25°C). The specimens were drenched in the different answers for 3, 10 or 21 days. The water in the test cells was invigorated at regular intervals for the most extended introduction times. Before examination in an examining electron magnifying lens (SEM), the examples were covered with a sputtered layer of gold keeping in mind the end goal to lessen charging impacts. erosion items in the examples utilized for the weight reduction investigations were uprooted with Clarke's answer preceding weighing. A without scale test was additionally tried in Clarke's answer for confirm that negligible metal misfortune happened amid this treatment.

A2. Universal Testing Machine

Operation of the machine is by pressure driven transmission of burden from the test example to an independently housed burden pointer. The framework is perfect since it replaces the transmission of burden: through levers and blade edges, which are inclined to wear and harm because of stun on burst of test pieces. The heap is connected by a hydrostatically greased up ram. Primary chamber weight is transmitted to the barrel of the pendulum dynamometer framework housed in the control board. The barrel of the dynamometer is additionally of self - greasing up outline. The heap transmitted to the barrel of the dynamometer is exchanged through an influence to the pendulum. Removal of the pendulum impels the rack and pinion instrument which works the heap marker pointer and the autographic recorder. The avoidance of the pendulum speaks to irrefutably the heap connected on the test example. Return development of the pendulum is viably damped to assimilate vitality in the occasion of sudden breakage of the example.

A2.2 Universal Testing Machine Components

Machine comprises of:

- Straining Unit
- Control Panel Power Pack
- Hydraulic Controls
- Load Indicator System

- Automatic Continuous Roll Load - Elongation Recorder

Tensile testing machines are accessible in mechanical, electronic & mechanized configuration and are suited for concentrating on the mechanical conduct of distinctive material, for example, metals, polymers, and elastomers. The tensile testing machine can be profited in variable velocity drives and tow alternatives. The model most favored by our customers is the summit strung screw with DC engine drive and ball lead screw with servo commute.

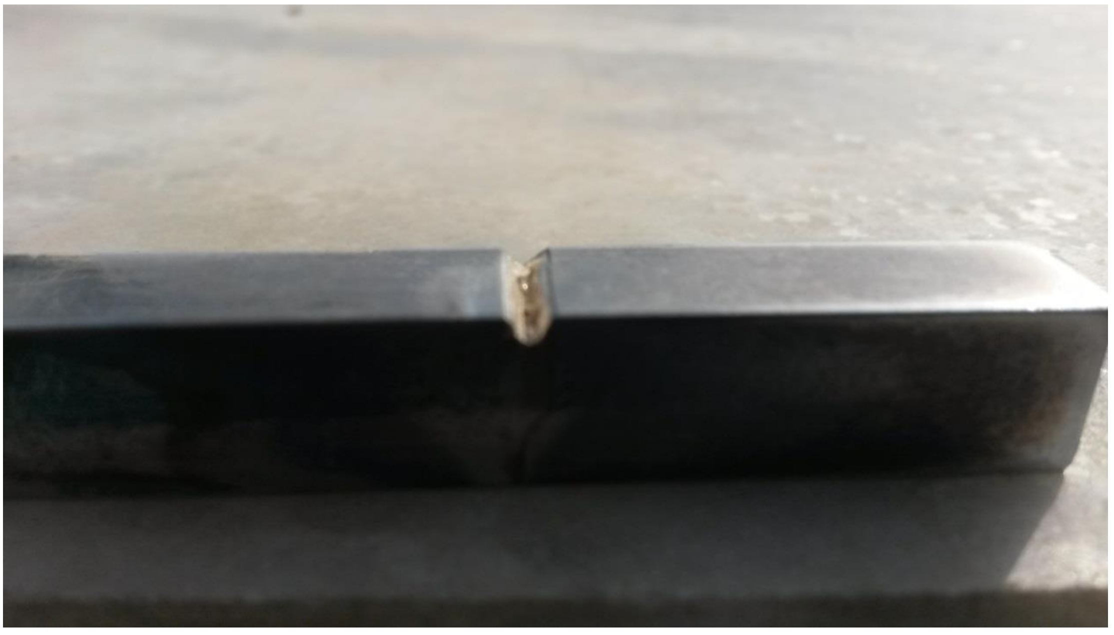
Appendix figure1. 1 UTM used for testing materials.

Appendix figure1. 2 Cu-Ni-Cr Coated Tensile Test Specimen

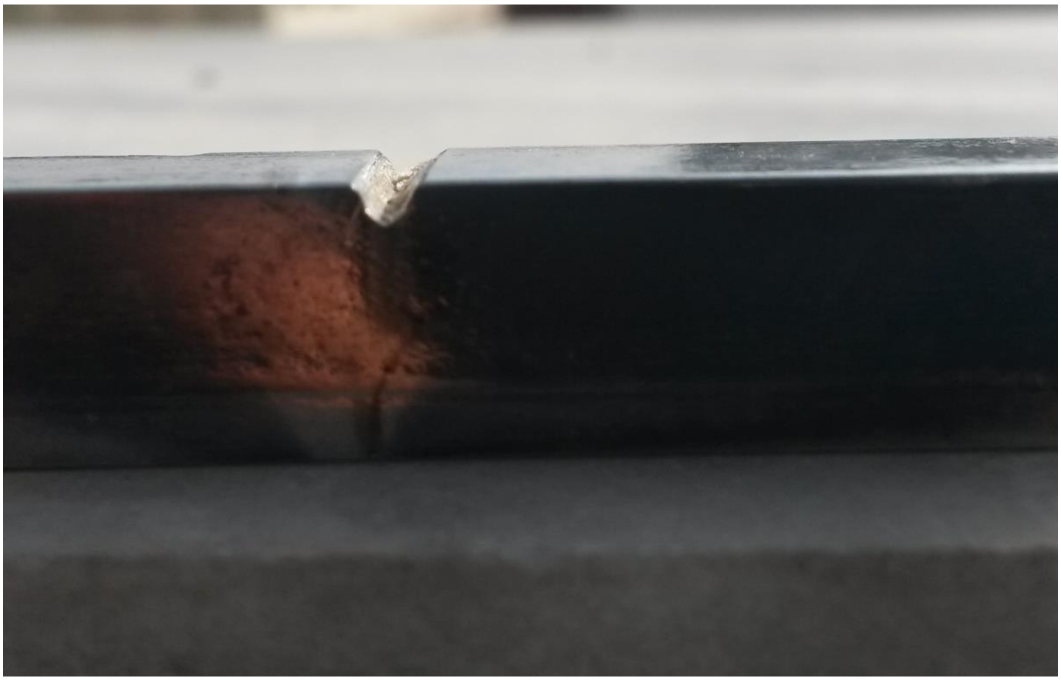
appendix figure1. 3 Bare Material Tensile Test Specimen

A3 Impact Testing Machine

Izod impact test system for metallic materials is indicated by ASTM E23 standard. This detail characterizes terms, measurement and resiliencies of test pieces, sort of the score (U or V), test power, confirmation of impact testing machines, and so on. The test comprises of breaking by one blow from a swinging pendulum, under conditions characterized by the standard, a test piece scored in the center and upheld at every end. The vitality consumed is dead set in joules. This assimilated vitality is a measure of the impact quality of the material.



Appendix Figure1. 4 Bare Material Impact Test Specimen



Appendix figure1. 5 Cu-Ni-Cr Coated Material Impact Test Specimen