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Study of Mechanical Properties of Stainless Steel (304) Bolts at Elevated and Sub-Zero Temperatures.

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Abstract –*Stainless steel is utilized in a huge variety of applications which include aircraft, mechanical gadget and railways. Stainless steel is best-made use in important enterprises but also can be used in non-predominant enterprises which includes watching production that includes the micro size of factors. Stainless is an iron alloy containing 0.02 to 2.14% of C, Cr content greater than 12%, and different alloying factors. Engineering materials, on the whole metallic, are heat treated underneath managed sequence of heating and cooling to regulate their bodily and mechanical residences to satisfy preferred engineering utility. In this look at, the effect of warmth remedy on the microstructures, some selected mechanical properties of stainless steel were studied. Heat remedy is the process of heating of metallic to the specified temperature and soaking it for steady time and cooled or quenched in one of a kind medium. The microstructure of the sample become examined using metallographic microscope. The steel samples have been heated handled in an electric powered tubular furnace at one-of-a-kind temperature tiers and constant soaking times after which cooled in air cooling. Rockwell hardness values of warmth dealt with and untreated samples were determined the usage of trendy strategies. The sub-zero treatment has been accomplished the use of a combination of dry ice and acetone up to -80 degrees Celsius for a soaking time of 60min.*

***Key Words*: Mechanical properties, Soaking, Microstructure, Heat treatment, Hardness, Quenching,….**

1.INTRODUCTION

The stainless steel is department of the family of ferrous alloys designed for extraordinarily high ranges of corrosion resistance. This effect is executed via alloying mainly with chromium but may additionally to be improved by way of the addition of elements together with molybdenum and nickel. Furthermore, these alloy elements can also extensively adjust the section relationships in the metal and method a wide spectrum of viable microstructures. The variety of microstructures serves to qualify a few stainless-steel for special types of carriers past their use in corrosion providers. 12wt% of chromium attention offers the stainless character to the metal. To make sure a robust metal, the higher chromium awareness, and other solute consisting of molybdenum, nickel and nitrogen is required. In metallurgy, chrome steel, also known as inox metal or inox from French "inoxydable", is a metallic alloy with not less than 10.5% chromium content by means of mass. Chrome steel does no longer without problems corrosion, rust or stain with water as ordinary steel does, but despite the name, it is not fully stain-evidence, maximum considerably below low-oxygen, excessive-salinity, or bad-movement environments. There are different grades and floor finishes of chrome steel to match the environment the alloy has to endure. Stainless steel is used wherein each house of metal and resistance to corrosion are required. Stainless steel differs from carbon metal via the amount of chromium gift. Unprotected carbon steel rusts comfortably whilst uncovered to air and moisture. This iron oxide film (the rust) is energetic and quickens corrosion by using forming iron oxide, and because of the more extent of the iron oxide, this has a tendency to flake and fall away. Stainless steel comprises sufficient chromium to shape a passive film of chromium oxide, which prevents similarly floor corrosion by blocking oxygen diffusion to the steel surface and blocks corrosion from spreading into the steel's inner structure, and because of the same size of the steel and oxide ions, they bond very strongly and stay connected to the surface. Passivation best takes place if the proportion of chromium is high enough and oxygen is present.

1.1 Heat Treatment

Maximum of the Engineering properties of metals and alloys are related to atomic structure, crystal structure, and microstructure. Mechanical houses are shape sensitive they depend upon the scale, shaped and distribution of diverse micro parts. Mechanical properties may be changed through a process called heat treatment. The method consists of heating a metallic or alloy to a specific predetermined temperature, conserving at this temperature for the required time, and finally cooling from this temperature. All these methods are carried in the solid countries. Usually, warmth treatment is executed for the subsequent cause.

- Improvement in ductility
- Relieving internal stresses
- Refinement of grain size
- Improving hardness or tensile strength and achieving changes in the chemical composition of metal surface as in the case of case-hardening.

- Improvement in machinability
- Alteration in magnetic properties
- Enhancement of electrical conductivity
- enhancement in toughness and development of recrystallized structures in cold working metal.

Fig -1: Heating of bolts in an electric furnace

1.1.1 Air cooling

It is a heat treatment process where a metal after heating to a required temperature is cooled at room temperature. The metal is left in an open area to cool it to room temperature.

1.1.2 Quenching

It is a heat treatment process where a metal after heating to the required temperature is suddenly cooled by dipping in a quenching medium. Quenching medium can be any liquid called water or oil. Due to the sudden quenching of metal, the arresting of crystallization structure takes place.

1.2 Sub-Zero Treatment

Sub-zero treatment is the manner of treating painting portions to underneath zero temperatures (i.e., as much as the temperature of -80 degrees Celsius). so that you can eliminate residual stresses and improve wear resistance in steel and other steel alloys, including aluminum. In addition to looking for more advantageous strain remedy and stabilization, or wear resistance, the cryogenic remedy is likewise hunted for its ability to enhance corrosion resistance by using precipitating micro-fine eta carbides, which may be measured before and after in an element.

Fig -2: Bolts dipped in a mixture of Dry-ice and Acetone

2. MECHANICAL PROPERTIES

The Mechanical conduct of Metals and alloys is known as the relationship between the deformations to a carried-out load. Those mechanical residences are determined by means of appearing numerous laboratory exams by way of making use of the various loads like tensile, and compressive masses through continuously or fluctuating hundreds at various temperatures we get the various mechanical houses like hardness, tensile power and compressive electricity of the alloys. However, those temperatures carried out loads and varieties of hundreds are particularly based totally on the utility. By way of engaging in these take a look at we come to the concept that whether the alloy is appropriate to withstand at that particular application or not. Stainless steels are particularly used within corrosive environments. However, based on the software we use unique kinds of steel. Suppose if we require low corrosion resistance and excessive power use of austenitic stainless steel. Like this based totally at the programs, we use suitable chrome steel kind.

2.1 Hardness

The Rockwell hardness check is defined in ASTM E 18 and numerous other standards. Rockwell hardness checking out differs from Brinell trying out in that the Rockwell hardness number is based totally on the difference of indenter intensity from two load applications. To start with a minor load is applied, and a zero datum is mounted. The main load is then implemented for a distinctive period, causing an extra penetration intensity beyond the 0 datum factor previously established by way of the minor load. After the specified stay time for the primary load, it's far removed whilst nonetheless keeping the minor load carried out. The ensuing Rockwell number represents the distinction in depth from the 0 datum function because of the software of the foremost load. The whole procedure calls for the most effective 5 to tens. Right here C scale is used.

2.2 Yield Strength

Yield strength is the term used to refer to a measurement of the maximum stress that can be applied to a material without causing it to plastically deform. The yield strength of a material is the stress point at which it permanently deforms, serving as a good approximation of its elastic limit. The material will elastically deform before reaching the yield point, but it will always return to its initial shape once the applied stress is removed. A small portion of the deformation experienced will become permanent and irreversible once the yield point is exceeded.

2.3 Ultimate tensile Strength

The ultimate tensile strength is the maximum force or load on the stress-strain curve. This corresponds to the maximum strain that may be sustained through a structure in tension. Closing tensile energy is regularly shortened to "tensile power" or even to "the remaining." If this pressure is implemented and maintained, the fracture will result. Regularly, this fee is drastically extra than the yield stress (as tons as 50 to 60 percent more than the yield for a few types of metals).

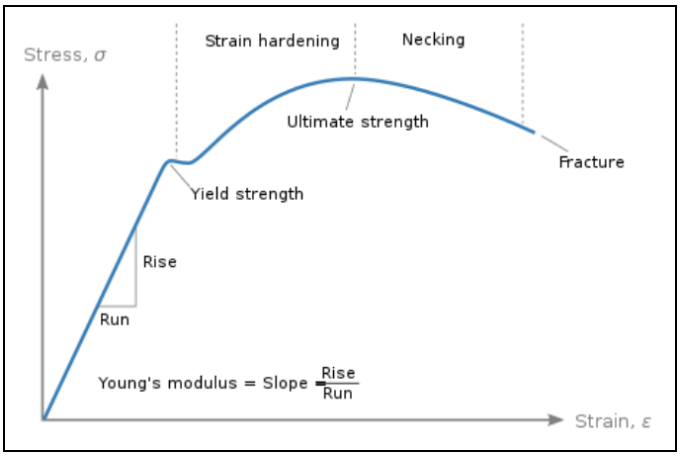

Fig -3: Stress-strain curve

3. MECHANICAL TESTING

- All the heat-treated samples are tested for mechanical properties using a universal testing machine and Rockwell hardness.
- The bolts are fixed in a UTM of the capacity of 600 tons and load increases gradually on the bolts.
- The bolts are tested for proof load by holding the bolt at a specific weight for 15 sec and further raising it for yield strength and ultimate tensile strength
- The bolts break at the ultimate tensile test.
- Once the test is done all the values are generated using the computer.

Fig -4: Universal testing machine (UTM)

- To measure the hardness of a bolt the bolts are placed on the Rockwell apparatus and for all the bolts hardness is measured.

Fig -5: Rockwell hardness

3. EXPERIMENTAL PROCEDURE

3.1 Heat Treatment

- The selected material for heat treatment and cryogenic treatment of bolts is stainless steel.

- One of the raw samples is tested for hardness, Yield strength, and ultimate tensile strength.
- The raw sample is tested to have a comparison that how the properties have altered after treatment.
- These bolts were placed in an electric furnace for heat treatment for different of 400°, 600°, 800°, and 1100°, These bolts were soaked to the required temperature for 30 min.
- Once the heating process is completed one sample is cooled in air and the other sample is quenched water.

3.2 Sub-Zero treatment

A sub-zero treatment is a process of treating workpieces to below zero temperatures (i.e., up to a temp of -80 degrees Celsius) in order to remove residual stresses and improve wear resistance in steel and other metal alloys, such as aluminum. Further to looking for more advantageous strain alleviation and stabilization, or wear resistance, cryogenic treatment is also hunted for its ability to enhance corrosion resistance by precipitating micro-quality eta carbides, which can be measured earlier than and after in an element. Bolts were placed in a beaker with a mixture of dry ice and acetone which can reach up to a temperature of -80° C and hold for 60 minutes.

4. RESULT

4.1 Mechanical Test Result

The mechanical properties of stainless steel mainly depend on the microstructure and heat treatment. The tensile strength, Yield strength, and Hardness of stainless steel depend on microstructure, heat treatment and Quenching medium. After conducting the test, it was identified that the mechanical properties of stainless steel decreased when the temperature increased. All the mechanical values were obtained after the conducting of the test on stainless steel material.

Table -1: Results of bolts cooled at room temperature

Temperature	Rockwell Hardness	Load at yield (KN)	Load at Break (KN)	Tensile Strength (N/MM2)
Raw bolt	106	47.43	51.39	749.81
-40°C	103	43.17	51.93	758.97
-80°C	110	55.23	59.43	766.61
400°C	109	41.37	50.26	641.94
600°C	108	35.73	47.64	634.18
800°C	86	30.27	42.30	599.31
1100°C	78	32.95	39.45	586.41

Table -2: Result of bolts Quenched in water

Temperature	Rockwell Hardness	Load at yield (KN)	Load at Break (KN)	Tensile Strength (N/MM2)
Raw bolt	106	47.43	51.39	749.81
-40°C	103	43.17	51.93	758.97
-80°C	110	55.23	59.43	766.61
400°C	108	41.06	52.73	661.83
600°C	108	38.91	51.56	658.91
800°C	98	34.05	49.14	626.81
1100°C	78	33.06	44.32	614.29

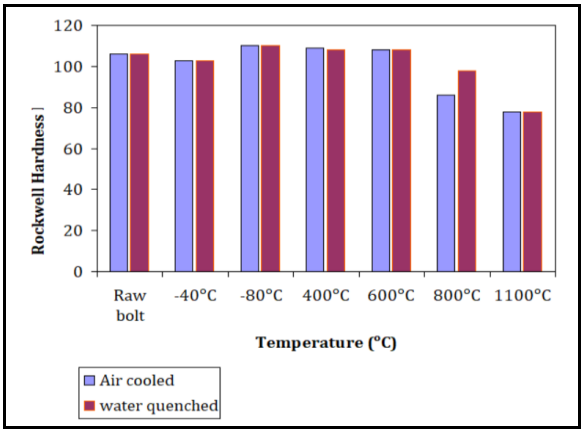

Chart-1 : Temperature vs Rockwell hardness

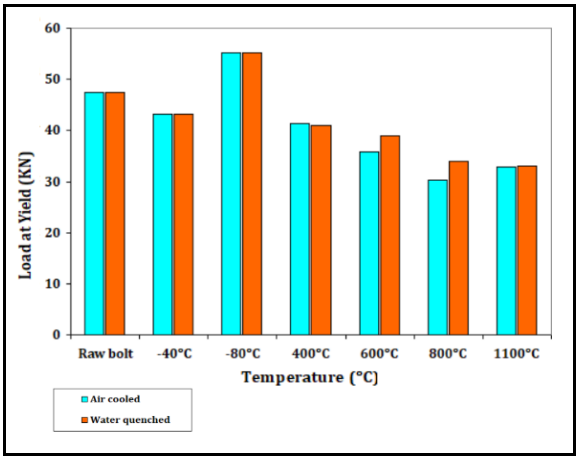

Chart-2 : Temperature vs Load at Yield

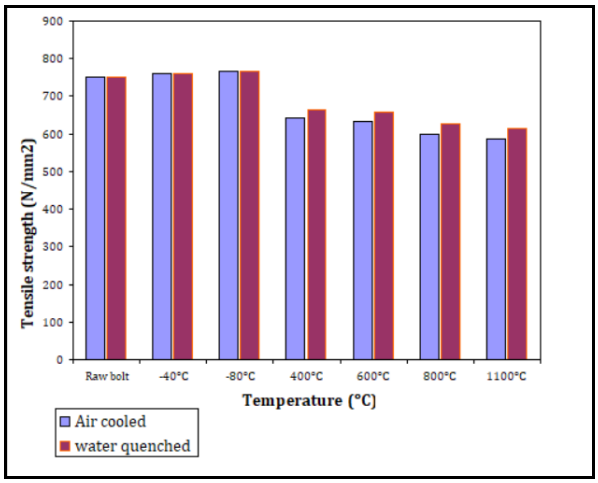

Chart-3 : Temperature vs Tensile strength

5. CONCLUSION

- All the samples were heat treated in an electric furnace and quenched in a different medium.
- The behavior of high-strength and stainless steel bolt assemblies at elevated temperatures has been reviewed and presented.
- It was found that heat treatment does not give any positive result for stainless bolts and mechanical properties were decreased.
- The temperature is indirectly proportional to the mechanical properties of stainless steel bolts.
- Due to sub-zero treatment, the mechanical properties of stainless steel increased.
- Tensile strength is increased with a decrease in temperature, and strain rate due to increased percentage of strain-induced martensite.
- The predominant deformation mechanism is phase transformation, rather than slipping and twinning.
- The hardness and yield strength of stainless steel increase due to decrease in temperature.

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