Effect of Annealing Process on Mechanical Properties of Mild Steel

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Abstract -To control the mechanical/physical properties heat treatment is very significance for mild steel below the recrystallization temperature (<830 °C) which is carried out in annealing process as per required of mechanical properties this process is carried out in closed annealing cycle process below the recrystallization temperature as aforesaid. During processing in there are different heating and holding stage are carried out to maintaining properly physical/mechanical properties along with this cycle (total time period of heating and cooling) removal of surface carbon and coolant particles (carried out during rolling process) also take place which improve the surface finishing of metal. this process increases ductility and reduce the hardness to make it more workable and relieving the internal stresses that was built up during the cold rolling process.

Keyword: Mild steel Coils, furnace, RLNG, Hydrogen gas, Nitrogen gas, Automation for controlling process and cooling water.

1.Introduction

The challenges in heat treatment are maintaining good surface finishing and mechanical properties without material losses and decreasing cost value and very friendly with environment and also having less times consumption during process. Main function of annealing is to increase the ductilityand reduce the hardness.

In cold rolling industries, during rolling time high reduction is done up to 80% because of this high tension in both sides of sheet and high rolls force which increase the hardness and very low ductility so this material is not more workable in industries or in others applications. Second during high-speed rolling very high friction is generated by load and tension between rolls and running sheet during rolling so there is also used coolant for reduction of friction, this coolant mix with carbon contains generate during friction between rolls force and sheets make a layer on surface which can't be removed by normal rubbing this is can be done only in annealing process. So, this process is very significantly for the mechanical properties and surface finishing.

When a metal is plastically deformed, dislocation of atoms occurs within the material. Particularly, the dislocationsoccur across or with in the grains of metal. The dislocations over-lap each other and the dislocation density with in the material increases. The increase in over-lap dislocations makes the movement of further dislocation more difficult. Moreover, the metal's yield strength actually increases after the metal's yield strength actually increase after the material has been plastically deformed. Additionally, the elastic region increase as well and plastic deformation requires the new, increasing yield strength, the ductility of a metal decrease after strain hardening and the metal becomes stiffer. By virtue of the aforementioned strengthening, it's evident that the mechanical properties of a metal can be manipulated by means of strain hardening. A common method of strain hardening is known as cold working

The change made to a metal by cold working can be reversed by subjecting that metal to aparticular temperature for a particular number of times. This is known as annealing.

Cold working is plastic deformation a martials at a temperature below its recrystallization temperature. A material's recrystallization temperature is the temperature at which new grains with low dislocation density being to replace the high dislocation density grains.

Cold working is a strengthening mechanism by virtue of strain hardening, but cold working is also useful for shaping materials.

In this experiment metal specimens were cold rolled, a form of cold working in which metal specimen forced through two rolls that have a gap between each other. Cold rolling is often used commercially in order to produce sheet metal, plate and bars.

When metal is cold rolled, it is plastically deformed as it is forced between two rolls of rolling mill the metal is compressed by the rolls and the plastic deformation is along the rolling direction, unlike a tensile test, no necking occurs in the metal.

A measure of how much cold work a material received is needed if an investigation into mechanical property change is desire. the change in cross- section area of a metal specimen that underwent cold work is one means of measurement.

Metal is cold worked in order to change their shape. A martial loses ductility when it is cold worked or moreover, cold rolled. If one wishes to its partially or fully restore a cold worked material to its original properties, one can anneal the material to its original properties, one can anneal the material. Annealing is performed by heating a material; in this instance, the material is metal. There are three stages of annealing and each stage produces different results. The three stages of annealing are recovery, recrystallization, and grain growth.

2. Literature review

Brick, Robert Maynard (1977) [1] Metalsare made up of large number crystals and each crystal consist of large number of atoms. Crystal structure is atomic arrangement in solids. This arrangement of atoms changes as per temperature change and this change in material properties.

ISIJ international ,2013 [2]– jstage.jst.go.jp, Against this background, in this research the effect of initial cold- rolling reduction and anticritical annealing temperature on the final microstructure and retained austenite characteristics has been studied on a silicon – containing TRIP steel by election backscattered diffraction (EBSD) method. The result show that moderate percent of cold rolling followed by intermediate annealing temperature would provide optimum condition for desirable retained austenite characteristics with proper adjustment phase.

Generic MMPDS [3] mechanical properties table, the material will consider is aluminum alloy 2024- T351.

"Low-carbon steels" (AISI 1005-1026, 1108-1119, 1211-1215, and 1513-1527)[4], by definition, contains less carbon than other steels and are inherently easier to cold-form due to their soft and ductile nature.When strength is not a major concern, low-carbon steels are good choices because they are easy to handle (draw, bend, punch, swage, etc.) and fairly inexpensive. Surface hardness can be improved by a process called carburizing which involves heating the alloys in a carbon-rich atmosphere. Low-carbon steels that are usually carburized are AISI 1015, 1018, 1020, and 1117.

Archived from the original (PDF) on 28 June 2007. Retrieved 11 May 2007.[5] The tensile and creep properties of PE fibre have been studied. The tests have shown the importance of the molecular chains' alignment which is characteristic of the fibre microstructure. Indeed, the mechanical performance and more particularly the fibre stiffness has been found to be about 20 times higher than that of non-oriented PE, and barely depend on the strain rate. Furthermore, the way in which the tensile properties drop near the melting temperature has been defined precisely, allowing the corresponding characteristics of the PE Dyneema SK 75 fibre to be used for the numerical simulation of a thermally activated failure related to PE fibre reinforced structures. The identification of an exponential law through creep tests has enlarged the validity domain of the constitutive representation established in previous papers.

Gerdau AmeriSteel. [6] Steel products in the solid state do not present any known health hazards. However, some users' processes such as welding, burning, sawing, grinding, or cutting may produce fume or dusts. Health hazard data is given for fume or dusts.

[7] Modulus of Elasticity, Strength Properties of Metals – Iron and Steel give all details of properties with explanations of all chemical and mechanical properties of metal.

Medium-carbon steels (AISI 1029-1053, 1137-1151, and 1541-1552)[8] can be heat treated to have a good balance of ductility and strength. These steels are typically used in large parts, forgings, and machined components.

Bolts, rods, crankshafts, and turbine in the automotive industry are generally made of AISI 1040 and its modifications. Axles, gears, and components that require higher hardness and wear resistance are frequently made of AISI 1050.

[9] Silver is another unique member of the metal's family -the "whitest" of all metals. In its pure form this moon-coloured metal is highly lustrous, and can be polished to a mirror finish. Silver was known and used by primitive man. The ancient Hebrews called it by a name meaning pale. The Greeks knew it by a name meaning *shining*. American Indians called it "tears of the moon" The chemical symbol for silver, Ag, comes from its Latin name, argent.

Like gold, silver is considered a precious metal, and is extremely malleable and ductile. It is harder than gold, but softer than copper. Silver can be hammered into sheets so thin that it would take 100,000 of them to make a stack an inch high. Silver has a specific gravity of 10.5, and a melting point of 1760ºF (960ºC.)- almost 200ºF below that of gold.

Averill, Bruce A.; Eldredge, Patricia (2012). [10] The state exhibited by a given sample of matter depends on the identity, temperature, and pressure of the sample. A phase diagram is a graphic summary of the physical state of a substance as a function of temperature and pressure in a closed system.

[11]When solid state physics emerged in the 1940s its name was controversial. By the 1970s, some physicists came to prefer “condensed matter” as a way to identify the discipline of physics examining complex matter. Physicists and historians often gloss this transition as a simple rebranding of a problematically named field, but attention to the motives behind these names reveals telling nuances. “Solid state physics” and “condensed matter physics”— along with “materials science,” which also emerged during the Cold War—were named in accordance with ideological commitments about the identity of physics. Historians, therefore, can profitably understand solid state and condensed matter physics as distinct disciplines. Condensed matter, rather than being continuous with solid state physics, should be considered alongside materials science as an outlet for specific frustrations with the way solid state was organized.

BBC News. 5 March 2007[12] Levitating high-speed trains, super-efficient power generators and ultra-powerful supercomputers would become commonplace thanks to a new breed of materials known as high temperature superconductors (HTSC).

Martin, Joseph D. (2015). [13] Finally, in my experience, the more popular (to the steel yard) sizes of mild steel usually come in both cold and hot rolled, I buy hot rolled whenever I can for blacksmithing, except if I’ am going to put a LOT of work into piece. Then I buy cold rolled steel to minimize the possibility of having a crack appear in the shaft of my fancy flesh fork after about an hour of forging and an hour of filing and chasing. But in some sizes, for instance 1/4" square, the steel yards in our area only carry it in cold rolled, at twice the price of hot rolled so if I want any of that for S- hook and for nails, etc I’m stuck with the higher priced stuff- unless I want any order a ton or two to get it in hot rolled form.

Todd, Robert H.; Allen, Dell K.; Alting, Leo (1994[14] written by a team of educators with unmatched experience, in collaboration with a consortium of industrial representatives from Black and Decker, Boeing, Caterpillar, General Motors, Grumman, Tektronix, Texas Instruments, Westinghouse, and Xerox, Manufacturing Processes Reference Guide provides thorough descriptions of over 125 of the most important processes available to industry today. This important resource encompasses the entire spectrum of manufacturing, from "Abrasive Jet Machining" to "Wire Drawing." Used with Fundamental Principles of Manufacturing Processes, the two books provide all the information needed to identify the ideal process for a specific manufacturing requirement.

IS 1608 :2005[15] give all detail on operation on UTM and also measuring procedure of material sample.

IS 10175(Part1): 1993[16] Identification of cupping value as per required in auto industries and give method or all observations details.

3. METHODOLOGY

After cold rolling, the strips coming out of the rolling mill would have been stretched and hardened, making it unsuitable for any forming or drawing.

These coils (Metal used in roll formation) must be heated at certain temperature to get proper characteristics of ductility, yield, elongation, softness, and drawability. The cold rolling coils are generally annealed in single stack bell type annealing furnace. In your case of ferritic steel maximum annealing temperature is 710 °C.

Following sequential operation are adopted for annealing.

Charging, → Clamping → Tightness test → Purging → Heating and socking → cooling → Post Anneal purging → Unclamping.

As shown in fig1: as processs as shown in different colour code as per standerd colour code.

In circle overview of the base is shown in the computer screen which show the base details

Fig1:(Base waise parameters overview)

Including heating temperature increasing or decreasing with set point, time taken to complete the total cycle and hydrogen flow rate in m3/hr. inside the inner cover.

Charging: - The coils should be stacked with the center of the coils in line with the axis of the furnace i.e., staking should be absolutely concentric so that uniform gap is obtained between the coils and inner cover, intermediate convector place such that the orientation of the vanes on the upper side is counter to the direction of rotation of the base fan. As shown in fig 1 which charge is ready for clamping.

Clamping: - After stacking coils on the base with necessary intermediate convector the inner cover is positioned and clamped against the base by hydraulic swing clamp cylinders. The charge space now become gas tight because of solid silicon seal between the inner cover flange and base.

Note: –

- Ensure all the cylinders are clamped properly.
- Ensure that water supply to the base fan motor and base is open.
- Ensure that colling water to the decantation is open.
- Connect the water supply hoses for inner cover water jacket inlet form base seal circuit and inner water jacket outlet to discharge funnel for return of water to sump.
- Ensure water flow switch is working properly.

As shown in fig 1 bottom black colorhydraulic will hold the inner cover for safe and properly heating of inside coil stack in hydrogen environment

Tightness test: - After clamping nitrogen gas outlet line are closed first and nitrogen inlet line is opened for three minutes to achieve uniform pressure 250- 400 mmWc inside the inner cover. After that inlet valve is closed and the fall in base pressure is monitored up to three minutes in case the fall in base pressure exceed 50mmWc in three minutes. The cycle will abort and not process to the next sequence check the base assembly connecting points or joints sealing between inner cover and base and check physically if any outlet valves are open, rectify the same before restarting the tightness test.

- Ensure Nitrogen pressure is sufficient.
- Ensure pressure drop of the base is with in specific limit.

Purging: - After the completion of tightness test both the nitrogen gas inlet and nitrogen outlet are open for purging of the base for safety reasons purging is carried out to remove oxygen content inside the inner, preventing air mixture with flammable process atmosphere in the charge space

During purging the nitrogen flow will be 60-90 Nm3/hr. purging is terminated when the calculated time is over the oxygen content measure inside the inner cover is less than 0.50%.

When the purging starts the base fan motor will start automatically after that base fan motor start as temperature of annealingatmosphere increase during process with replacement of the cleaner nitrogen gas with hydrogen gas and stopped after past purging a current limit is set in VVVF drive which control the base fan speed.

After purging is completed the nitrogen atmosphere inside the inner cover is replaced by hydrogen atmosphere.

Note; -

- Before purging sequence, the base fan motor will be purged with nitrogen for three minutes.
- Ensure that oxygen prob provided in the outlet line of the gas is working properly.

Heating and socking

After the charge space is filled with nitrogen gas and nitrogen mixture the heating hood is placed on the annealing base as shown in fig

The heating and socking of the coils are performed as per present data the specific condition.

Note: -

- Connect the plug of power and control supply of heating hood to the respective socket on the base panel.
- Connect the RLNG gas pipe line couplet to the adopter provided on coming line near the base and ensure that couplet is seated properly with adopter.

Heating hood is made up 10Nos of burners with properly fitted spark plug and RLNG gas pipes line arrangement to give properly fuel supply from the supply source this arrangement is in very safe environment.

There are two pipes line with yellow color pipes give the supply of RLNG and second blue pipes line give the circulation of air flow with help blower fan shown in right side of the furnace.

This combination of air supply and gas supply give the properly air fuel ratio for properly heating efficiency.

Cooling

After heating and socking the heating hood is removed from the base for natural cooling, when the gas temperature reaches below 600°C the cooling starts. Water spraying is started when the temperature drops down to 350°C till the end of cooling cycle.

When the temperature has dropped to the present discharging temperature the nitrogen inlet valve is opened and charge space is purged again, after this cooling hood is removed from the base.

The cooling sequence is carried out in the cooling hood which is placed after removing the heating hood or furnace.

In this arrangement there are two types of cooling take place 1^{st} one air cooling which is done with the help of two side blower fan from the normal air. And 2^{nd} water cooling is done at last when temperature remain nearly 300°C. With the flow rate of water 80m3/hr. approximant time take by cooling is 16 to 20 hours but mostly depend of the cycle higher temperature and capacity of material.

Unclamping: -

After the cooling hood is removed from the base, the hydraulic swing clamp cylinders are released to remove the inner cover the coils are then discharge from the base and the base is now ready for the next charge.

All the sequence of all running basis are shown in a single computer screen which shows all parameter related to temperature, pressure time taken by charge, flow of hydrogen nitrogen and RLNG, water and others all parameters. As shown in the computer screen in fig 2:

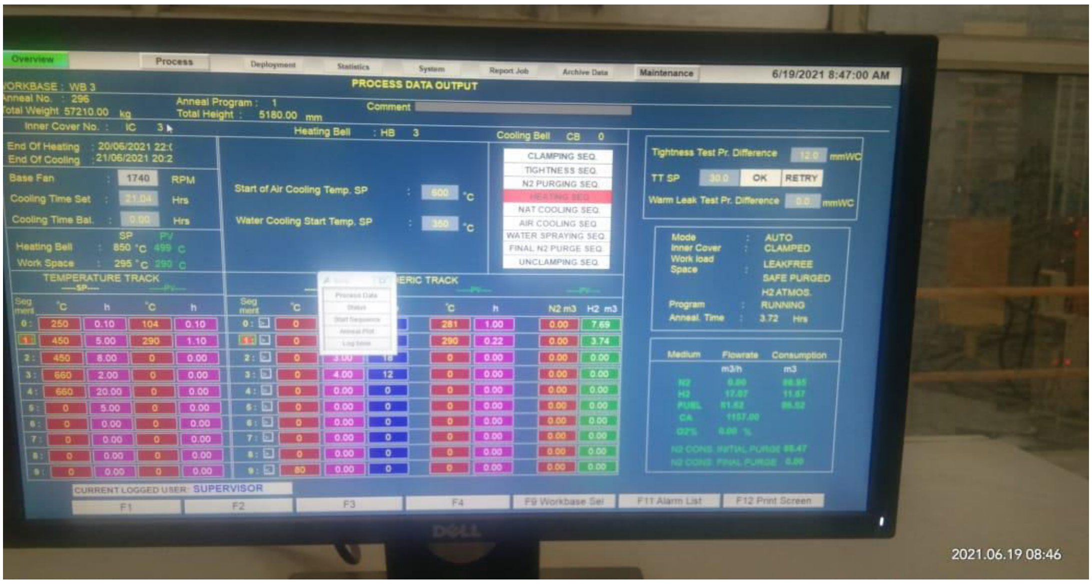

Fig 2: (All technical parameter base wise)

In this fig all parameter issettledwith the help system operation data which give the automation operation of all valve motors and others movements of running instruments through the electrical signal and software.

By feeding all entry as per required temperature pressure and volume of gases this screen is also known as the process data output.

Time and temperature graph.For properly maintaining all the flow rate graph is shown on the screen which give all details of flow rate in annealing base process

Technical specification: - this annealing installation using hydrogen as a proactive gas is supplied with following technical specification.

Charge details-

- Coil OD ------- 2000mm
- Coil ID -------- 500/610mm
- Coil width ------- 12500mm max
- Maximum coil weight ------ 24.1 MT
- Stack height -------- 5300mm
- Maximum charge weight -------108 MT

Utility and storge requirements: -

1. Hydrogen: -
- Hydrogen purity ………. 99.99%
- Oxygen ………………… 3ppm max
- Dew Point ………………. Better than -70°C
- Flow rate ………………... 40Nm3/hr. avg.
- Pressure recommended …………... 4 kg /cm2
- Storge …………………... 80Nm3

2. Nitrogen: -
   - Nitrogen purity …………99%
   - Hydrogen ……………….1 %
   - Oxygen …………………10ppm max.
   - Dew points ……………… better than -60°C
   - Flow rate ……………….…100Nm3/hr. avg.

Experimental analysis

Fig3: full assembly of Vickers hardness testing machine

Table 1: Observation table of temperature grade wise

S.No	Base no	Material Grade	Thickness of coils(mm)	Maximum Temp (℃)	Total time taken (hours)	Socking time (hours)
1	5	DD	1.20	610	49	10
2	2	D	1.00	600	47.5	8
3	3	EDD	1.55	640	55	11
4	6	D	1.10	590	46	8
5	1	DD	1.18	600	48	8
6						
.						

Table 2: Observation of hardness before Annealing

Coil No	Thickness(mm)	Width (mm)	Minimum Hardness (VPN)	Maximum Hardness (VPN)
2515	0.80	650	250	260
2055	0.80	680	270	285
2889	1.10	712	280	282
2269	1.20	590	282	290
2125	1.00	600	289	289

Table 3:observations of hardness after annealing

Coil No	Thickness (mm)	Width (mm)	Minimum Hardness (VPN)	Maximum Hardness (VPN)
2515	0.80	650	95	102
2055	0.80	680	90	99
2889	1.10	712	70	82
2269	1.20	590	79	86
2125	1.00	600	88	92

S.No	Size (mm)	T.S (MPA)	Y.S (MPA)	EL% (G.L 50mm)
1	**1.20 X 487**	**294**	**188**	**46.8 %**
2	**1.20 X 558**	**285**	**175**	**57.98%**
3	**1.00 X 755**	**290**	**180**	**49.45%**

Ultimate tensile strength (UTS):

ECV (Erichsen Cupping Value): -

S.no	Size	Grade	ECV(mm)	Before Annealing ECV
1	1.20 x 487	EDD	11.35mm	8.50 mm
2	1.20 x588	EDD	11.10mm	7.80 mm
3	1.00 x 755	DD	10.25mm	6.00 mm

Result and Conclusion: -

From above experiment value it is justified that there are increases in ductility of material after annealing process because in all mechanical and physical properties change takes place and material become workable after annealing process that is result in only possible after mechanical properties changes take place after doing annealing. There are changes that take places in: -

Hardness 282 VPN to 102 VPN, Elongation changes nil to 57.98%, ECV 7.80mm to 11.10mm

Hence, result in formation of material after annealing process become more workable,machinable and more drawability as per required in industries.

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