

Tribological Properties on P91 Alloy Steel Treated With Normalizing & Carburizing Process

Md.Rahel, Lakshmi Deepak Tadepalli, M.Balubai, K.Sunil Kumar Reddy, Ram Subbiah

Abstract: An Experimental analysis was undertaken to analyze the changes in the Mechanical Properties and Microstructure of P91 steel, subjected to Normalizing and Carburizing heat treatment Processes keeping in mind the potential capabilities of P91 steel as the base metal due to its wide applications in Boilers manufacturing. P91 is a type of alloy steels having high hardness and wear resistance surface. The heat treatment processes were carried out in the present experimental procedure at constant temperature and for different timings like 60 minutes, 90 minutes and 120 minutes. Hardness of the specimen was tested by using Rockwell Hardness test. A pin on disc machine was used to conduct the wear test. Wear test was carried out on treated P91 steel on various parameters like variable load and constant speed. The Microstructural results are concluded with SEM (Scanning Electron Microscope) and XRD (X-Ray diffraction) techniques.

Keywords: P91 steel, Normalizing, Carburizing, Hardness, Pin-on-Disc wear test.

I. INTRODUCTION

Alloying components are added to accomplish certain properties in the material. As a rule, alloying components are included lower rates (under 5%) to build quality or hardenability, or in bigger rates (over 5%) to accomplish exceptional properties, for example, erosion opposition or extraordinary temperature solidness. Manganese, silicon, or aluminum are added during the steelmaking procedure to expel broke up oxygen, sulfur and phosphorus from the dissolve. Manganese, silicon, nickel, and copper are added to expand quality by shaping strong arrangements in ferrite. Chromium, vanadium, molybdenum, and tungsten increment quality by framing second-stage carbides. Nickel and copper improve consumption opposition in little amounts. Molybdenum opposes embrittlement. Zirconium, cerium, and calcium increment sturdiness by controlling the state of incorporations. Sulfur (as manganese sulfide) lead, bismuth, selenium, and tellurium increment machinability. The alloying components will in general structure either strong arrangements or mixes or carbides. Nickel is extremely solvent in ferrite; in this manner, it structures mixes, generally Ni₃Al. Aluminum breaks down in the ferrite and structures the mixes Al₂O₃ and AlN. Silicon is likewise dissolvable and for the most part frames the compound SiO₂•MxO_y.

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Manganese generally breaks up in ferrite framing the mixes MnS, MnO•SiO₂, yet will likewise shape carbides as (Fe,Mn)₃C. Chromium structures parcels between the ferrite and carbide stages in steel, shaping (Fe,Cr)₃C, Cr₇C₃, and Cr₂₃C₆. The kind of carbide that chromium structures relies upon the measure of carbon and different sorts of alloying components present. Tungsten and molybdenum structure carbides if there is sufficient carbon and a nonattendance of more grounded carbide framing components (i.e., titanium and niobium), they structure the carbides W₂C and Mo₂C, individually. Vanadium, titanium, and niobium are solid carbide framing components, shaping vanadium carbide, titanium carbide, and niobium carbide individually. Alloying components likewise affect the eutectoid temperature of the steel. Manganese and nickel bring down the eutectoid temperature and are known as austenite balancing out components. With enough of these components the austenitic structure might be gotten at room temperature. Carbide-shaping components raise the eutectoid temperature; these components are known as ferrite balancing out components.

Amalgam steel is a kind of steel that has experienced alloying utilizing various components in levels somewhere in the range of 1% and half in weight so as to improve mechanical properties. It tends to be grouped further into two kinds: high-combination and low-composite steels. Steel is a sort of metal composite that contains generally iron with moment carbon levels, contingent upon the quality or evaluation of steel. Notwithstanding, amalgam steel is any steel where at least one of its components beside carbon have been added purposefully to accomplish progressively alluring qualities. The thing that matters is to some degree uniform, yet to make it recognizable, all steel alloyed with higher than 8% of its weight of components other than carbon and combination is viewed as high-composite steel. Alloyed steels are more diligently, progressively strong and increasingly impervious to consumption. Composite steels with carbon levels of medium to raised rates are hard to weld. In any case, if the carbon levels are decreased to 1% to 3%, such composite metals can accomplish more noteworthy formability and weldability, in this manner, improved quality.

Evaluation T/P91 is a ferritic-martensitic (9 % chromium, 1 % molybdenum) steel miniaturized scale alloyed with vanadium and niobium, and has a controlled nitrogen substance as indicated by ASTM A 335, A 213. On fossil-fuelled power plants, this evaluation is principally utilized for high-temperature applications in superheater and reheater cylinders, headers and steam funneling (fundamental steam and hot warm). Evaluation T/P91 displays astounding raised temperature quality and creep conduct up to 580 °C - 600 °C. Its 9 % chromium substance offers preferable erosion and oxidation obstruction over evaluation 22. What's more, the decreased load of kettle

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and channeling segments coming about because of the steel's predominant presentation contrasted and other standard steels enables higher protection from warm weakness. Contrasted and austenitic steels, grade T/P91 has higher warmth move and lower warm extension coefficients. There are specific strategies for welding it appropriately to protect it will hold up. Welding A335 P91 for the most part requires preheating the joint, keeping up interpass temperatures, hydrogen prepares, and postweld heat treatment (PWHT). Preheating, ordinarily to 400 to 500⁰F, drives off dampness and subsequently diminishes hydrogen. Welding is one procedure that is broadly utilized during the development. This influences the microstructure. Preheating, keeping up between pass temperatures, and post-weld heat treatment techniques are exceptionally basic for P91 grade. For thick walle d pipes, the utilization of an enlistment warming framework is the best strategy. Welding P91 for the most part requires preheating the joint, keeping up interpass temperatures, hydrogen prepares, and postweld heat treatment (PWHT). Preheating, regularly to 400 to 500⁰F, drives off dampness and in this way lessens hydrogen. Hydrogen embrittlement can prompt virus breaking of the completed weld. For this equivalent reason, hydrogen prepares are prescribed for P91 if a weld cools to encompassing temperature before PWHT. The presentation of Grade 91 welds depends altogether on having the right concoction investigation in the weld metal; thusly, it is profoundly suggested that filler metals be acquired with test reports indicating genuine synthetic examination for the particular warmth/parcel mix that one has bought.

Table 1.1 Chemical Composition of P91 Steel

C	Si	Mn	K	S	Mo	Cr	Fe
0.08	0.20	0.30	0.0	0.0	0.85	8.0	Balan
-	-	-	2	1	-	0-	ce
0.12	0.50	0.60			1.05	9.5	

II. EXPERIMENT DETAILS

Passivation is a procedure performed to make a surface detached, a surface film is made that makes the surface lose its compound reactivity. Passivation unipotentializes the tempered steel with the oxygen consumed by the 18 metal surface, making a monomolecular oxide film. Passivation can bring about the especially wanted low erosion pace of the metal. Passivation is performed when free iron, oxide scale, rust, iron particles, metal chips or other nonvolatile stores may unfavorably influence the metallurgical or sterile condition or dependability of the surface, the mechanical activity of a section, segment or framework, or defile the procedure liquid. Hardened steels owe to wear and consumption protection from the nearness of a „passive“ chromium rich, oxide film that structures normally superficially. Albeit amazingly slender, 1-15 nanometers and undetectable, this defensive film follows solidly and is synthetically steady under conditions which give adequate oxygen to the surface. Moreover, the defensive oxide film, is self mending given, there is adequate oxygen accessible. In this way, notwithstanding when the steel is damaged, scratched or cut, oxygen from the air promptly joins with chromium to change the defensive layer. Passivation is performed on the completely cleaned and descaled surface.

Passivation by which treated steel will precipitously frame a synthetically inert surface when presented to air or other oxygen-containing situations. Passivation is the expulsion of exogenous iron or iron mixes from the outside of hardened steel by methods for a concoction disintegration, most regularly by a treatment with a citrus extract arrangement that will evacuate the surface tainting however won't essentially influence the tempered steel itself. The aloof film framed on the outside of treated steel gives a powerful obstruction to consumption under ordinary conditions. The latent film, a couple millimeter thick frames precipitously when comes to contact with air and comprises of complex synthesis of iron oxides, chromium oxides and chromium hydroxides. This film development is the aftereffect of hydrated edifices that are quickly assimilated superficially pursued by the arrangement of hydroxide film within the sight of water. The arrangement of an insoluble surface film is formed because of deprotonation of the hydroxide film. Whenever harmed, the aloof film quickly changes quickly itself affected by oxygen from water, by keeping the material ensured.

The study details with an experimental work on changes in properties of P91 steel after Heat Treatment. The desired Heat Treatment parameters are determined based on the standard practice as obtained from literature review. Initially, the material was ordered in form of rods and turning and facing operations were performed on it, till desired specimen diameter 12mm was reached. Later, the rod was cut into small specimen of size 40mm total of 8 specimens were prepared, of which 3 specimens were considered for Normalizing and 3 specimens for Carburizing Process and 2 specimens is considered as Un-treated for both processes. Normalizing Process was performed at 1000°C with 3 specimens for 60 minutes, 90 minutes and 120 minutes respectively and were air cooled, the Carburizing was performed at 950°C for same set of timings for next 3 specimens. After Heat treatment the cooled specimens were tested for Hardness test, Wear test and for microstructural study Scanning Electron Microscope and X-Ray Diffraction techniques were used. Hardness test was done using Rockwell Hardness test, for both Normalized and Carburized specimens as well as untreated specimen.

III. WEAR TESTS

A major challenge in technological development has been the need to continuously meet the stringent materials requirements for the use in progressively demanding conditions. Exposure to increasingly aggressive environments has made modern engineering components more susceptible to rapid degradation due to interactions between the component surface and the environment. In the material environment configuration, the surface of a component serves as the first line defence against the attack by an adverse environment. Therefore, the component surface is always of vital importance in determining its performance and durability. This has formed the basis for improving the material properties by adopting the surface modification approach. This approach involves the formation of an appropriate protective coating on the surface t impart the desired property of combating premature degradation of the component. Generally the surface modification approach, which



is also referred to as “surface engineering”, enables the achievement of properties that neither the bulk nor the coating is capable of imparting on its own.

A protective coating deposited to act as a barrier between the surface of the component and the aggressive environment that it is exposed during routine operation is now globally acknowledged to be an attractive means to significantly reduce and suppress damage to the actual component by acting as the first line of defence. The increasing utility and the industrial adoption of surface engineering is a consequence of the recent advances in the field. The design of surface and substrate together as a system to give a cost effective performance enhancement of which neither is capable on its own is the best definition of surface engineering.

The pin on disc wear test is conducted with two specimens, a pin and a disc Fig 3.2. The disc is rotated against sliding pin acting with a constant load. Here untreated with 6 treated samples are to be replaced immediately for wear test. Wear results are reported as volume loss in millimeters for the pin and the disk separately. The wear loss and volume wear loss are determined. The following Fig 3.1 shows a schematic drawing of a typical pin-on-disk wear test system, showing wear track. Here the system consists of a driven spindle and chuck for holding the revolving disk, a lever-arm device to hold the pin and attachments to allow the pin specimen to be forced against the revolving disk specimen with a controlled load, shown in the Fig3.3. The wear track on the disk is a circle, involving multiple wear passes on the same track is obtained.

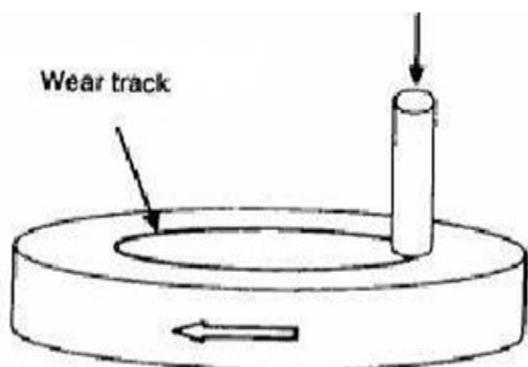
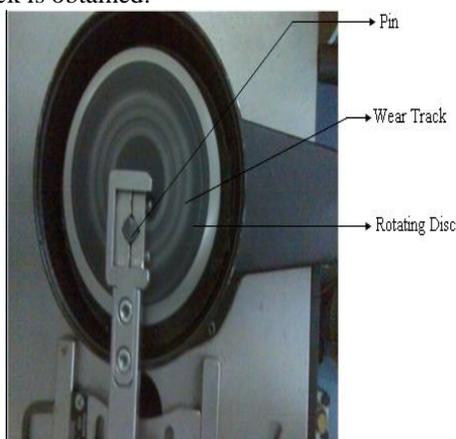


Fig 3.1 Wear Track obtained

Fig 3.2 Outline of a Pin on Disc Machine



Fig 3.3 - Pin on Disc Apparatus

From the wear tests, it was noted that a huge amount of loss of material was found to be in untreated specimen. Whereas in treated specimens, less amount of loss of material were obtained. During pin on disc test, the following were noted down. For a load of 30 N, the following values were obtained for specimens treated under normalized condition. The weight loss in an untreated specimen was found to be as 0.072 grams, the weight loss for the P91 steel that was treated to 60 minutes was found to be 0.044 grams, the weight loss for the P91 steel that was treated to 90 minutes was found to be 0.018 grams, the weight loss for the P91 steel that was treated to 120 minutes was found to be 0.013 grams. The volume wear loss was found to be 9.278 mm³, 5.670 mm³, 2.319 mm³, 1.675 mm³ respectively. For a load of 50 N, the following values were obtained for specimens treated under normalized condition. The weight loss in an untreated specimen was found to be as 0.098 grams, the weight loss for the P91 steel that was treated to 60 minutes was found to be 0.062 grams, the weight loss for the P91 steel that was treated to 90 minutes was found to be 0.040 grams, the weight loss for the P91 steel that was treated to 120 minutes was found to be 0.012 grams. The volume wear loss was found to be 12.628 mm³, 7.98 mm³, 5.15 mm³, 1.54 mm³ respectively.

For a load of 30 N, the following values were obtained for specimens treated under carburized condition. The weight loss in an untreated specimen was found to be as 0.086 grams, the weight loss for the P91 steel that was treated to 60 minutes was found to be 0.078 grams, the weight loss for the P91 steel that was treated to 90 minutes was found to be 0.019 grams, the weight loss for the P91 steel that was treated to 120 minutes was found to be 0.011 grams. The volume wear loss was found to be 11.08 mm³, 10.05 mm³, 2.345 mm³, 1.417 mm³ respectively. For a load of 50 N, the following values were obtained for specimens treated under carburized condition. The weight loss in an untreated specimen was found to be as 0.084 grams, the weight loss for the P91 steel that was treated to 60 minutes was found to be 0.038 grams, the weight loss for the P91 steel that was treated to 90 minutes was found to be 0.037 grams, the weight loss for the P91 steel that was treated to 120 minutes was found to be 0.024 grams. The volume wear loss was found to be 10.82 mm³, 4.89 mm³, 4.76 mm³, 3.09 mm³ respectively.

IV. RESULTS & DISCUSSION

The moulded specimens were polished with a series of emery sheets of different grades of 100, 200, 400, 800 and 1000 sizes. The polishing through a series of emery sheets was accomplished in order to obtain the scratch free specimen surface for the scanning 80 electron microscope analysis for better results. After polishing, the specimens were etched with oxalic acid for 15 seconds. Then the specimens were gold plated before placed into the chamber of scanning electron microscope machine.

4.1 Scanning Electron Microscope Results for normalized specimens:

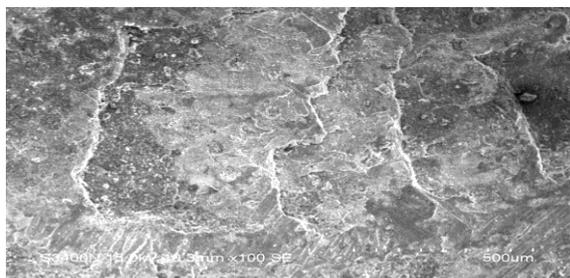
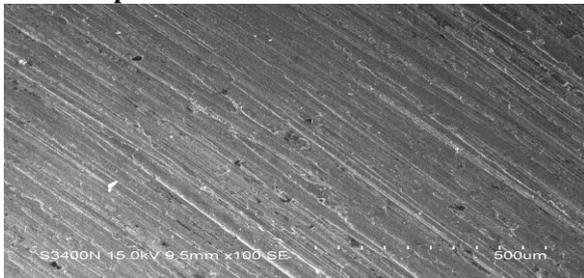


Fig 4.1: Microstructure for Untreated specimen and Normalized specimen 60 minutes at 100X



Fig 4.2: Microstructure for Normalized Specimen for 90 mins and 120 mins at 100X

From the above scanning electron microscope results, for an untreated specimen there were more wear obtained on P91 graded steel material. Under normalized condition treated at 60 minutes, the ductility was slightly promoted on P91 graded steel material. The hardness and brittleness were slightly reduced. When the specimens were further treated to 90 and 120 minutes, the ductility and machinability was promoted heavier when compared to specimen treated at 60 minutes. It was noted that medium strength and brittleness were maintained on the specimen. Thereby P91 graded type steel is applicable for commercial applications improving wear resistance.

4.2 Scanning Electron Microscope Images for Carburized Specimens

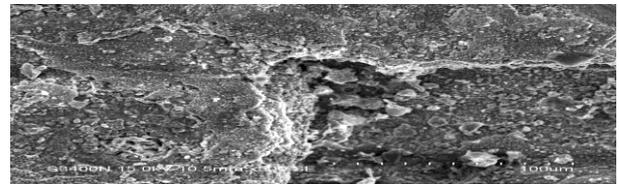
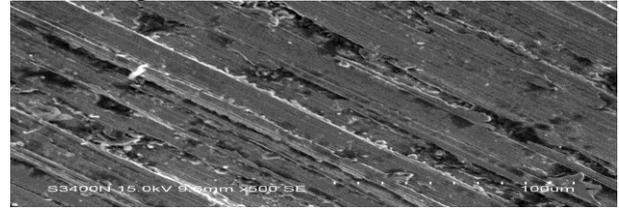


Fig 4.3: Microstructure for Carburized Specimens for 60 mins and 90 mins at 100x

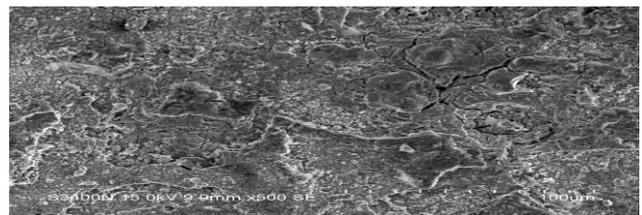


Fig 4.4: Microstructure for Carburized Specimens for 120 mins

From the above scanning electron microscope results, it was notes that P91 steel has enhanced with carbon content by carburizing process, improving its strength and wear resistance. The specimens which were carburized at 60 minutes has less carbon content, whereas the specimens treated at 90 minutes and 120 minutes has more carbon content. Formation of iron and carbon were identified in the treated specimens when compared to untreated specimens. The wear loss occurred was found to be less compared to normalized specimen.

V. CONCLUSIONS

The results of the present investigation indicate that the hardness of the P91 steel increases with both Normalizing and Carburizing but in Normalizing we can see hardness stabilizes with time whereas in Carburizing it seem to increase gradually with time of heat treatment.

Wear results comparison conclude that in both the processes the volume loss or wear percentage decreases with time of exposure which is a desirable property but the frictional loss seems to increase for 120 minutes of exposure to processes which id decreased at 60minutes and 90 minutes of exposure.

With the increase of Normalizing time of exposure the size of particles of precipitates present at prior - austenite grain boundary and within grain increased up to Normalization period of 120 minutes beyond which huge reduction in size of precipitate occurred.

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