Material Characterization of Galvanized Steel Wire Rope Used In Oil Drilling.

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Abstract--The study is focused on the material characterization of a drilling wire rope composed of different wires. The wire rope basically consists of a copper wire in the core(used in wire logging for providing the electrical signal) which is supported by steel wire rope from the outside .The paper aims at basically characterizing this steel used. For this purpose laboratory testing (Elemental,Mechanical metallographic & Thermal) of representative wire rope samples was done.Energy Dispersive Spectroscopy along with mapping was carried out for elemental analysis of the wire rope .To Know about the accurate carbon percentage in the steel sample ,Chemical wet analysis was employed.In addition Spark tests were used as well . Tensile tests were conducted on both the wire and the wire rope as a whole. Hardness of the steel was judged by a suitable hardness test . Scanning electron microscope was employed for metallurgical investigations.The effect of temperature (from 100° C to 866.40° C) on the weight of wire rope was also investigated by Thermogravimetric analysis. Differential Thermal Analysis was also used to know about any transformations that can occur with increasing temperature.

I. INTRODUCTION :

Wire rope is a type of cable which consists of several strands of metal wire laid (twisted) into a helix. Wire Rope is made up of steel wires, generally braided in a helix (spiral) forming units known as strands. The strands in the wire rope can vary in accordance with specific and desired properties.

Wires are produced by reducing the diameter of the base wire, after passing through a series of dies and formers while have an axial force applied to it.

The wire´s properties depend on its chemical composition, microstructures, grain size, segregations and process conditions.

They are very useful and have wide range applications especially in the mechanical and industrial sector. Wire ropes have got widespread applications in the oil drilling sector, from drilling cables to hoisting in drilling rigs .Its vast usage in the oil and drilling sector makes it a very important thing because its failure not only brings financial losses but can lead to catastrophic events .

II. OBJECTIVE :

Our objectives are to determine,

- chemistry and grade of steel employed,
- microstructure of the wire rope steel
- The effect of temperature on various properties .

III. EXPERIMENTAL PROCEDURE :

Samples were cut from the wire rope for elemental analysis, mechanical testing and metallography.

A. Elemental Analysis :

Chemical Wet analyses was carried out to know the exact percentage of the amount Carbon used in our steel specimen whereas for knowing percentage weights of the other elements Electron Dispersive Spectrometry was employed. Spark test was also used .

B. Mechanical Testing:

Tensile testing was carried out both with individual wires. and the wire rope as a whole (ASTM A931).

For micro hardness measurements, a Vickers hardness testing machine with a micro load of 0.025 kgf and 1 kgf was used. (ASTM standard E384).

C. Metallography :

For microstructural SEM analysis, standard procedure was adopted , specimens were mounted then polished and finally Nital (2%)etched .The mounted specimen was immersed in the etchant for 2 minutes to ensure proper chemical reaction.

D. Thermal Analysis :

Thermogravimetric and Differential Thermal Analyses (TG/DTA) of samples were carried using a Diamond TG/DTA, (Perken Elmer) in the temperature range 0 to 865.4 degree Centigrades .

IV. RESULTS AND DISCUSSIONS :

A. Elemental Analysis:

Chemical composition of the wires is shown in the table 1 and from that we can conclude that the wire rope steel corresponds to AISI 1074 High Carbon steel .

ELEMENTS	WIRE ROPE %	AISI 1074 %
CARBON	0.73	0.70-0.80
MANGANESE	0.66	0.50-0.80
SILICON	0.35	...
IRON	Balance	Balance

Table 1 Elemental Analysis of Specimen

Spark Tests further confirmed these results . As we can see from the figure that the colour of the spark stream of our specimen is not very bright. The colour of the spark near the wheel is a bit brighter, stream is shorter but the volume is larger. Spark stream is bushy and there is lots of forking which start to originate near the wheel. All of these factors make us believe that our specimen is a high carbon steel. Due to the presence of other alloying elements such as silicon, manganese, tungsten; the nature of the spark stream is not exactly the same as depicted in the standard high carbon steel spark stream in figure 1.

Figure 1 Spark test results

B. Mechanical Testing :

Tensile test typical load–elongation curves are shown in fig 2 and fig 3. Tensile results and mechanical properties of strand and wire rope are shown in attached tables.

The behaviour shown by the strand/wire is typical of High-carbon steels which behave in a brittle manner, not exactly brittle but in a strong non ductile way because they stretch very little and they just break suddenly. They may have a very high yield stress but fracture occurs at an elongation of only a few percent and the case is same here i.e. Elongation of only 5.772 mm at break point. Brittle materials actually fracture or break at the maximum load. Coming to the wire rope, it may also be noted from Fig. 2 that initially outer wires fail one by one, and as the sample has reached its maximum strength therefore further continuation of the test is not needed and we should not wait until all strands in the sample have failed. It is apparent that there is general yielding before the maximum in yield is reached attesting to the inherent ductility of wire rope under tensile loading.

If we look at a single wire we find that it is extremely brittle and that is because of higher percentage of Carbon in it which is depicted in its high Hardness value. But if we take our wire rope, we find that it is quite elastic and possess high strength and toughness and the reason behind this is wire rope's structure.

The Vickers hardness measured was 576.6 which corresponded to 1834 N/mm2 UTS when compared with standard charts.

Test speed : 2.000 mm/min
Diameter : 0.810 mm
Sample Length : 137.770 mm
Pretension : Off

Area (mm²)	Plastic Strain @ Break (%)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Elong. @ Yield (mm)	Energy @ Break (N.m)	Energy @ Peak (N.m)	Energy @ Yield (N.m)	Inner Diameter (mm)	Load @ Break (N)	Load @ Peak (N)	Load @ Yield (N)	Strain @ Break (%)
0.8100	1.8300	5.7720	5.7060	1.0590	3.3777	3.3138	0.0867	0.8100	847.00	975.00	200.00	4.1896

Strain @ Peak (%)	Strain @ Yield (%)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Youngs Modulus (N/mm²)
4.1417	0.7687	1643.7	1892.1	69660

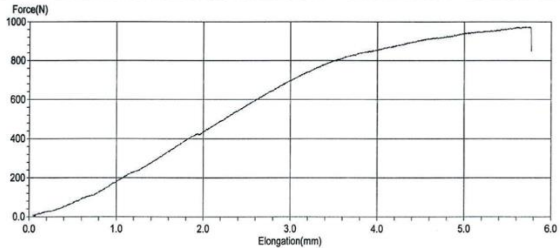


Figure 2 Tensile Test of a single wire

Test speed : 2.000 mm/min
Diameter : 5.860 mm
Sample Length : 112.000 mm
Pretension : Off

Area (mm²)	Plastic Strain @ Break (%)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Elong. @ Yield (mm)	Energy @ Break (N.m)	Energy @ Peak (N.m)	Energy @ Yield (N.m)	Inner Diameter (mm)	Load @ Break (N)	Load @ Peak (N)	Lo Y
5.8600	20.650	25.136	13.761	6.1570	122.45	84.580	12.930	5.8600	1189.0	17420	34

Strain @ Peak (%)	Strain @ Yield (%)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Youngs Modulus (N/mm²)
12.287	5.4973	44.086	645.90	2458.8

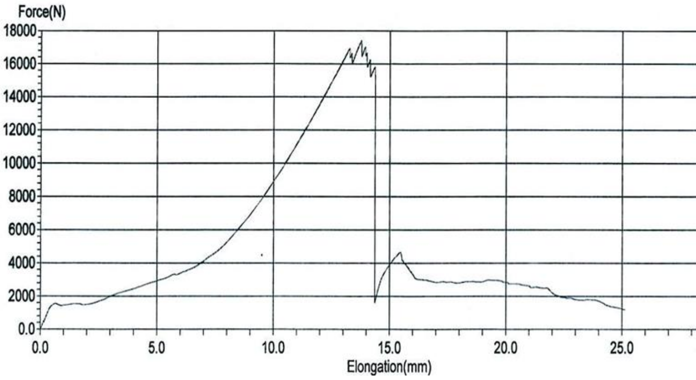


Figure 3 Tensile Test of the whole wire rope

C. Metallography :

Fig 4 shows the cross section of wirerope . As it is relatively new so we see no corrosion and pitting.SEM images show extreme drawn pearlitic structure and the reason for that is excessive cold drawing .After the usual patenting process is done on the wirerods during wire manufacture ,a pearlitic sorbitic structure is obtained with grain boundaries but after excessive drawing ,grain boundaries vanish out and we get alternate lamellas of ferrite and cementite in the pearlitic structure .Cementite acts as the strengthening component with a barrier effect similar to that of grain boundaries (Embury and Fisher). This lamella structure resists any fatigue crack or growth.

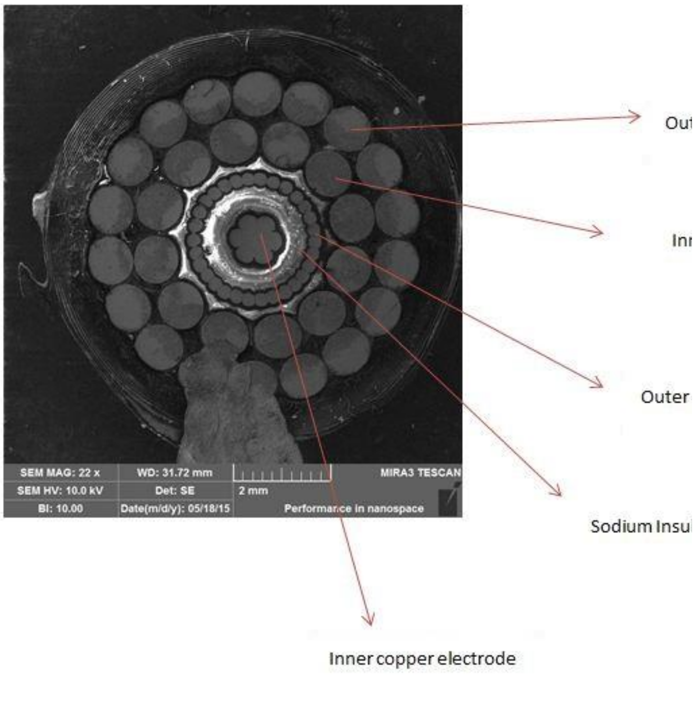


Figure 4 Cross sectional view of the wire rope

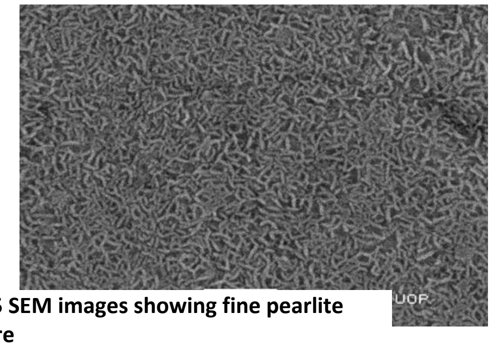
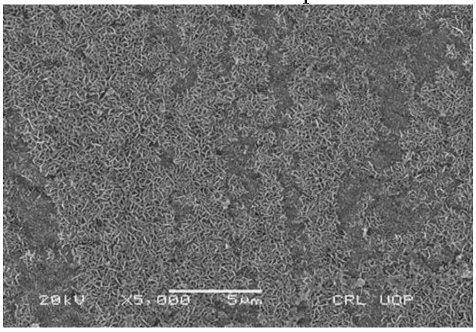


Figure 5 SEM images showing fine pearlite structure



D. Thermal Analysis :

The TG curve (Red) did not show wt% loss at temperatures up to ~ 270°C; however, temperatures above ~390° C, the sample gained extra weight, probably because of the chemical reaction with nitrogen used as purging gas which may form nitrides.

The DTA curve(Blue) showed upward sloping upto ~210° C and after that downward sloping .This maybe because of Cementite changing from ferromagnetic to paramagnetic at its Curie temperature of approximately 207 ° C . At~750° C , there is a change recorded .The reason for this change is most probably because of a change in crystal structure ‘α+ FeC3’ converted to ‘α+ γ iron’ (two phases).

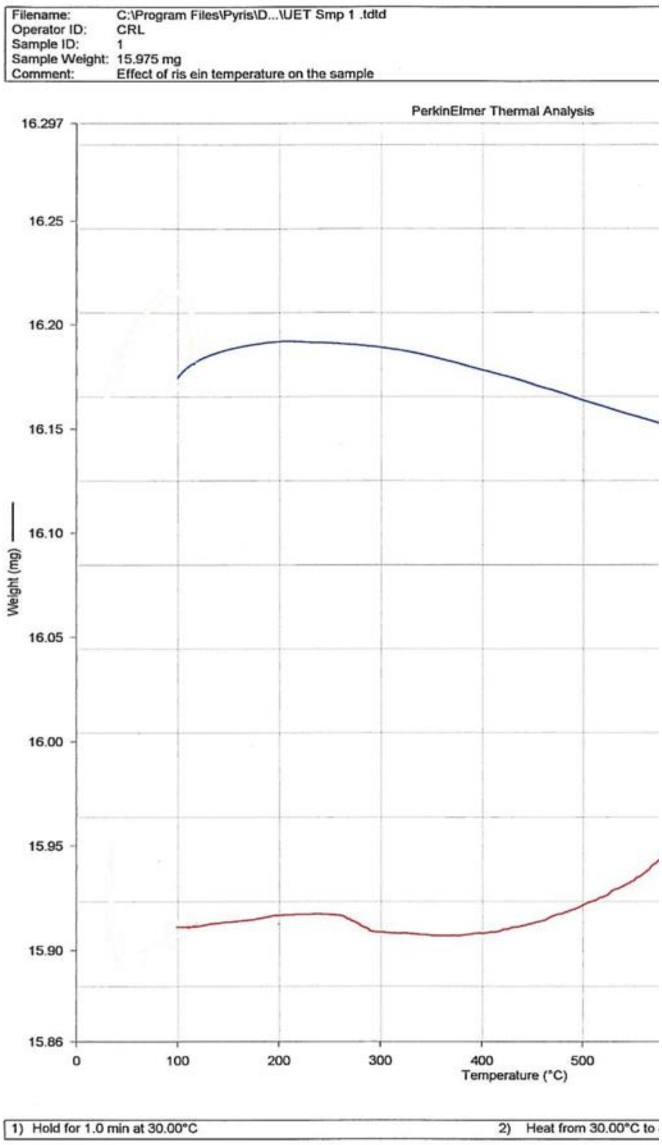


Figure 6 TGA (Red) & DTA (Blue)

V. CONCLUSIONS :

e may know Tensile strength from hardness value from standard chart = 266,000 psi =1834 MPa where as Tensile strength from tensile test (Stress strain calculations) =1892.1 MPa .

The high hardness values, chemical composition,and the pearlitic structure of wires may indicate that this is a type of extra improved plow steel (EIPS) grade wire ropes. Due to their high load bearing capacities ,they are considered as heavy-duty wire ropes and are primarily used in engineering applications.If we want to attain much higher strength we may increase the quantity of carbon along with altering quantities of Magnesium and Silicon .

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