Salt Bath Heat Treatment Process To Replace Usage Of Toxic Lead Bath In Quenching Application Of High Carbon Steel Wire.

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SALT BATH TREATMENT PROCESS

ABSTRACT

The optimisation of salt heat treatment process of high carbon steel wires, using salt bath furnace. The experiments have been carried out in an electrical heated neutral atmosphere furnace and quenched in electrically heated salt bath furnace.

This array consist of four input process parameters, i.e. type of steel, wire diameter, salt bath temperature, and transformation time. The response of salt quenching process are Ultimate Tensile Strength (UTS) & elongation. The challenge is to get right kind of salt chemistry with a suitable operating range.

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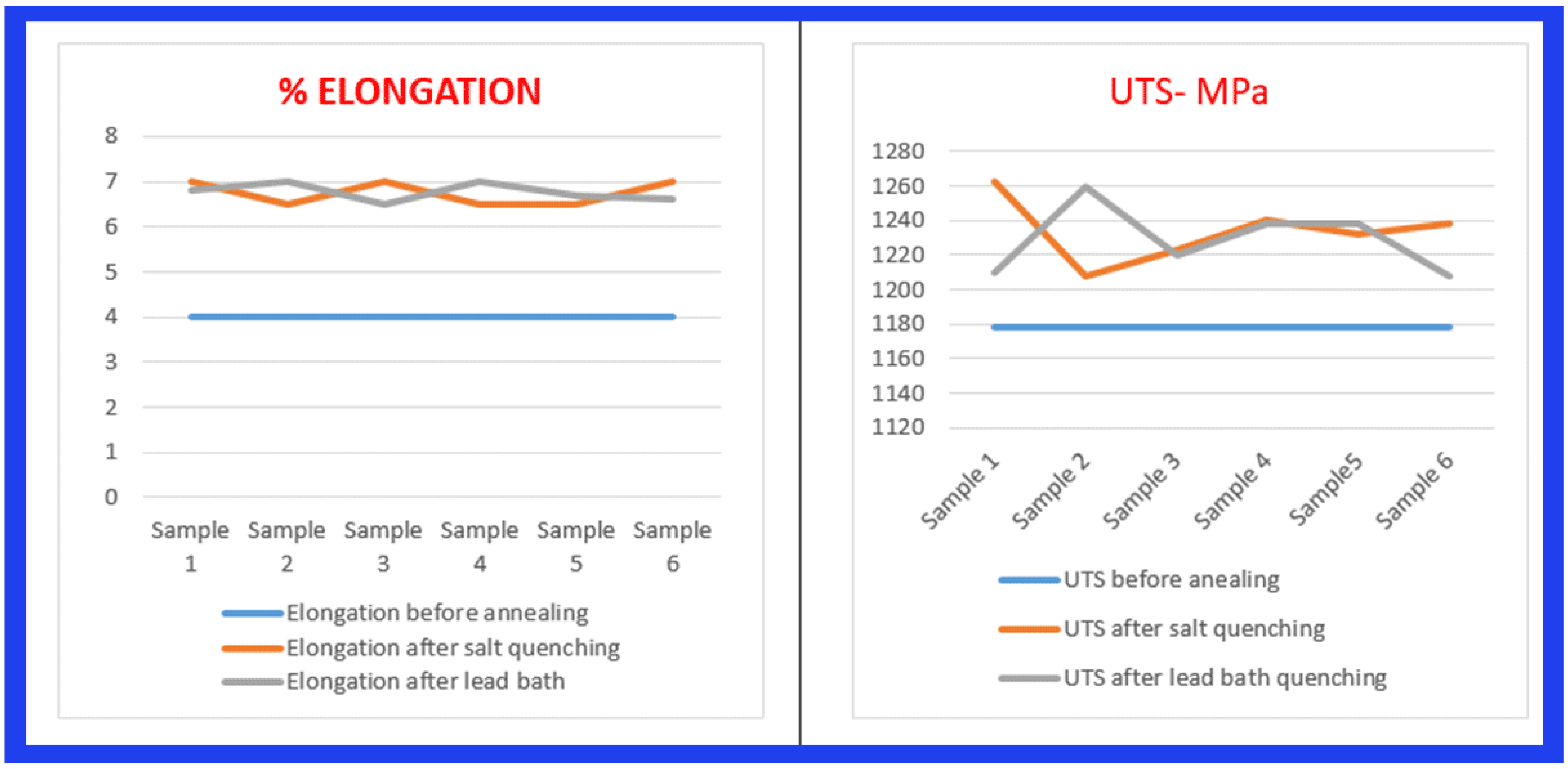


INTRODUCTION

Why lead

Lead is soft and malleable, and also has a relatively low melting point, and is poor conductor of electricity. It is resistant to corrosion. It has low melting point of 327 deg. C & that makes it usable for industrial application as a liquid media for various kind of application like tempering, annealing and quenching.

LEAD

Atomic number	82
Atomic mass	207.2 g.mol -1
Electronegativity according to Pauling	1.8
Density	11.34 g.cm-3 at 20˚C
Melting point	327˚C
Boiling point	1755˚C

Lead is a bluish-white lustrous metal. It is very soft, highly malleable, ductile and a relatively poor conductor of electricity. It is very resistant to corrosion but tarnishes upon exposure to air.

Health Effects of Lead

Lead is one out of four metals that have the most damaging effects on human health. It can enter the human body through intake of food (65%), water (20%) and air (15%)

Foods such as fruit, vegetables, meats, grains, seafood, soft drinks and wine may contain small amounts of lead. Cigarette smoke also contains small amounts of lead.

Lead can enter (drinking) water through corrosion of pipes. This is more likely to happen when the water is slightly acidic. That is why public water treatment systems are now required to carry out pH-adjustments in water that will serve drinking purposes.

For as far as we know, lead fulfils no essential function in the human body, it can merely do harm after uptake from food, air or water.

Lead can cause several unwanted effects, such as:

- Disruption of the biosynthesis of haemoglobin and anaemia
- A rise in blood pressure
- Kidney damage
- Miscarriages and subtle abortions
- Disruption of nervous systems
- Brain damage

Environmental Effects of Lead

Not only leaded gasoline causes lead concentrations in the environment to rise. Other human activities, such as fuel combustion, industrial processes and solid waste combustion, also contribute.

Lead can end up in water and soils through corrosion of leaded pipelines in a water transporting system and through corrosion of leaded paints. It cannot be broken down; it can only converted to other forms.

Lead accumulates in the bodies of water organisms and soil organisms. These will experience health effects from lead poisoning. Health effects on shellfish can take place even when only very small concentrations of lead are present. Body functions of phytoplankton can be disturbed when lead interferes. Phytoplankton is an important source of oxygen production in sea and many larger sea-animals eat it. That is why we now begin to wonder whether lead pollution can influence global balances.

Soil functions are disturbed by lead intervention, especially near highways and farmlands, where extreme concentrations may be present. Soil organisms than suffer from lead poisoning, too.

Lead is a particularly dangerous chemical, as it can accumulate in individual organisms, but also in entire food chains.

Salt Bath

The challenge was to get replacement of poisonous lead bath with combination of salts bath. Properties to consider are the environment and human friendly, easy disposal and non-toxic; at the same time, achieve the mechanical and metallurgical requirements in the quenched job.

HISALT HCSW has a sharp, low melting point and a wide operating range. For these reasons it is one of the most widely used salts for quenching, tempering and drawing. It forms a water clear bath that does not fume. There is no adhering as in a lead baths. Work is readily cleaned with just warm water. The surface of work processed in HISALT HCSW is passivated. It is less prone to rusting.

Specific Heat
v/s
Bath Temperature

HISALT HCSW

TEMPERATURE OF BATH	SPECIFIC HEAT
21 to 130	0.46
150 to 200	0.41
200 to 260	0.39
260 to 315	0.36
315 to 425	0.33
425 to 540	0.30

Specific Gravity
v/s
Bath Temperature

HISALT HCSW

TEMPERATURE	SPECIFIC GRAVITY
20	2.118
150	2.010
200	1.925
315	1.839
425	1.768
540	1.680

APPLICATION

Use HISALT HCSW in a steel pot and salt bath furnace at a temperature of 180 to 540˚C. Do not exceed 540˚C. The furnace should be controlled by a thermostat to prevent excessive bath temperatures. Melt the salt slowly. Add salt to the bath in small quantities. Since HISALT HCSW melts rapidly, there is no need to force heat it. When first starting a fresh bath, a slight floating cover may form. It may be skimmed off or allowed to evaporate as the bath is used.

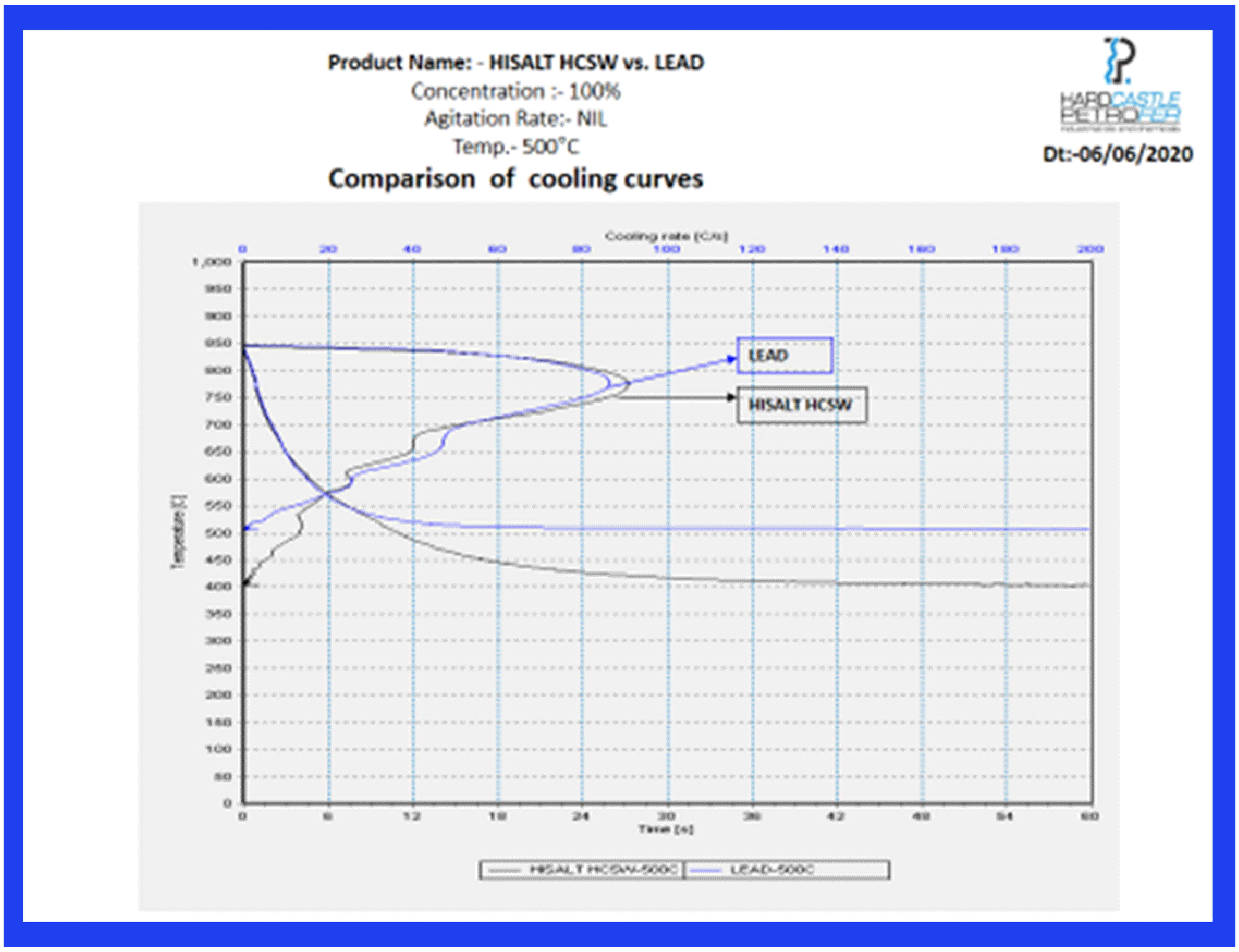
Do not permit work to touch the bottom or sides of the pot as this prevents circulation of the
molten salt. Keep the bath clean and free from sludge by periodic removal.

Use plain, low carbon steel pots. For externally fired pots, use calorized steel to minimize scaling. Avoid direct flame impingement and localized overheating.

All work must be thoroughly dry before it is placed in bath or spattering may result.

Typical Physical & Chemical Properties

Appearance: PINK POWDER
Melting Point: 140 °C



Cooling curves properties comparison HISALT HCSW Vs Lead

Properties	Unit	HISALT HCSW - Ivf	Lead – Ivf
Maximum cooling rate	C/s	90.71	86.24
Temp at max cooling rate	C	770.00	776.54
Temp at start of Boiling	C	846.17	847.65
Temp at start of convection	C	669.59	558.46
Cooling rate at 300°C	C/s	0.00	0.00
Time at 600 C	S	4.73	4.48
Time at 400 C	S	0.00	0.00
Time at 200 C	S	0.00	0.00
Theta 1	C	847.61	847.38
Theta 2	C	671.24	649.14

Experiments

Process
Muffle Furnace Heat Treatment for Wire

Application
Salt Quenching (Replacement of Lead Bath)

Material
High C Steel Wire– Grade – C 72

Sample Dimension
Dia. 5.1mm to 6.5mm & Length 250mm

Quenchant Temp
450-550˚C

Hardening Temp
940-950˚C

Soaking Time
1 min (Min.)

Quenching media
HISALT HCSW

The chemical composition of steel C72, %

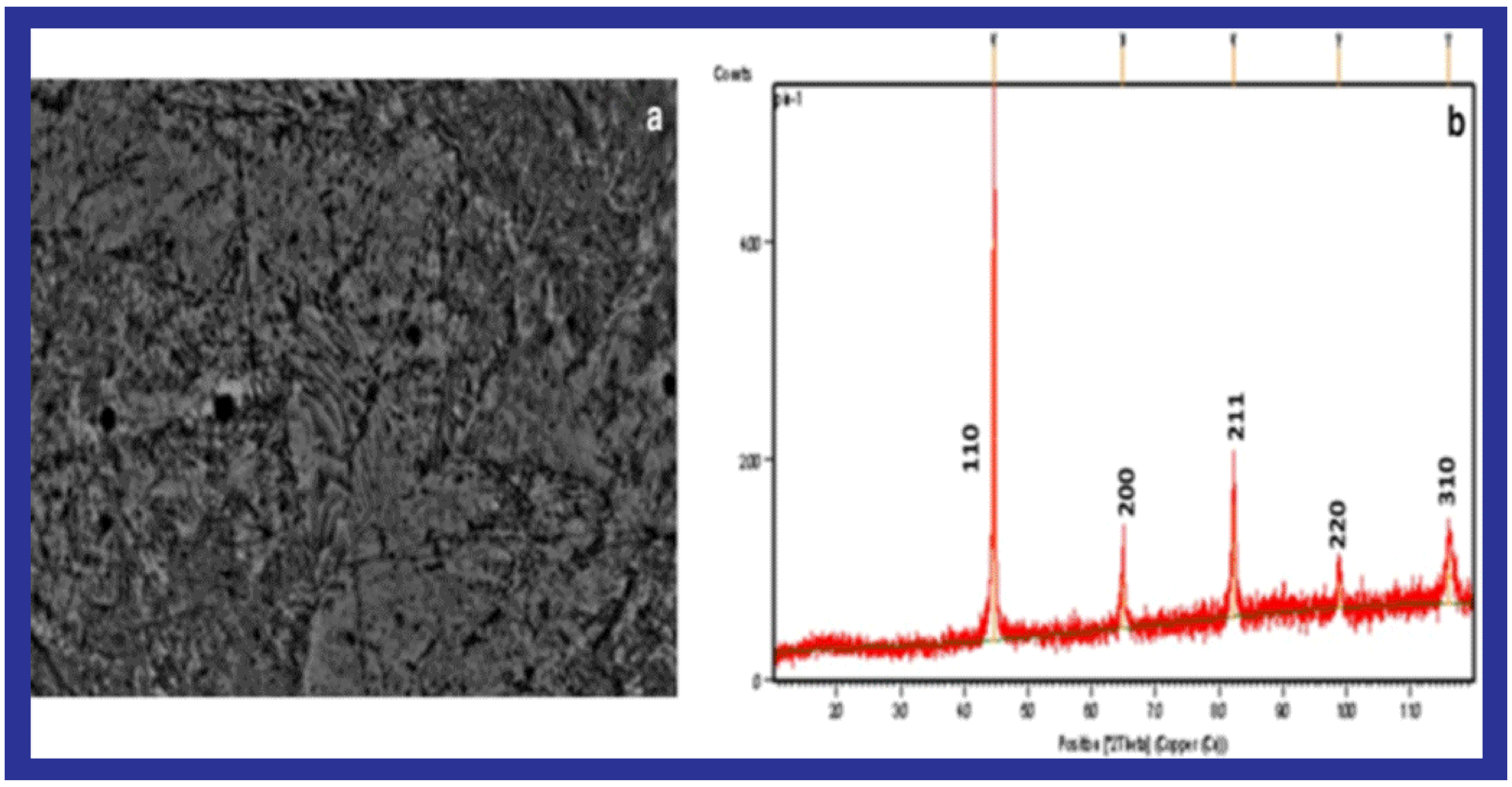
C	Mn	Si	P max	S max	Cr max	Ni max	Mo max	Cu max	Ni max
0.70 - 075	0.50 - 0.80	0.1 - 0.3	0.035	0.035	0.15	0.20	0.05	0.25	0.01

Experimental data and trials conducted with varying various parameters

Trials	Furnace Temp °C	Soaking	Salt Temp °C	Time in salt	UTS Before Annealing MPA	UTS after salt quench			Elongation Before Annealing	Elongation After salt quench			Diff in UTS Avg.	Diff in EL Avg.
Trial1	950 °C	15 Min	515 experiem	2 Min	1178	1,079	1073	1083	4	5.5	5.2	6.5	100	1.73
Trial2	950 °C	15 Min	515	5 Min	1178	1,055	1073	1068.4075	4	7.5	7	7.5	112	3.33
Trial3	950 °C	15 Min	515	7 Min	1178	1,050	1067	1061.8153	4	6.5	5.5	7	119	2.33
Trial4	950 °C	15 Min	515	10 Min	1178	1,048	1030	1027.9125	4	6.5	5.5	5.5	143	1.83
Trial5	950 °C	15 Min	315	1 Min	1178	Wire become brittle broken during straightening in tensile test								
Trial6	950 °C	15 Min	315	2 Min	1178									
Trial7	950 °C	15 Min	415	1 Min	1178	1200	1207	1199	4	5	5	5.5	-24	1.17
Trial8	950 °C	15 Min	415	2 Min	1178	1175	1188	1162	4	5	5.5	4.5	3	1
Trial9	950 °C	15 Min	400	2Min	1178	1245	1240	1237	4	5.5	4.5	6	-63	1.33
Trial10	950 °C	15 Min	420	2Min	1178	1262	1221	1219	4	6	4.5	4.5	-56	1
Trial11	950 °C	15 Min	440	2Min	1178	1215	1200	1221	4	4	4.5	4	-34	0.17
Trial12	950 °C	15 Min	460	2Min	1178	1217	1198	1132	4	4.5	4.5	4.5	-5	0.5
Trial13	950 °C	15 Min	480	2Min	1178	1183	1182	1179	4	5	5.5	5	-3	1.17
Trial14	950 °C	15 Min	500	2Min	1178	1160	1147	1166	4	5	4	5.5	20	0.83
Trial15	30 °C	15 Min	500	2Min	1178	1116	1115	1125	4	8	7.5	7	60	3.5
Trial16	850 °C	15 Min	420	5Min	1178	1263	1259	1266	4	6.5	6.5	6.5	-85	2.5
Trial17	850 °C	15 Min	440	5Min	1178	1223	1231	1232	4	7	7	7	-51	3
Trial18	850 °C	15 Min	460	5Min	1178	1240	1241	1238	4	7	6.5	7	-62	2.83
Trial19	850 °C	15 Min	480	5Min	1178	1208	1205	1211	4	7	7	7	-30	3

Observations

- Salt Temperature 440˚C observed optimum for balance between Tensile and Elongation properties of drawn wire
- Higher salt temperature increases elongation but lowers the tensile strength
- Holding time in salt has no major effect in properties
- Scaling formed in muffle furnace causes low tensile and elongation of drawn wire
- Lowering austenitizing temperature from 950 to 850 ˚C given more elongation and better tensile strength



Microstructure: Salt Quenched wire - nano composite multi-layer structure of ferrite and cementite. (pearlite) – (Fig 2) XRD plot of wire

Final Results

Salt -HISALT HCSW used for phase transformation of steel plays the most crucial role in achieving the ultra-high strength wires after wire drawing, it transforms the randomly distributed ferrite and cementite of hot rolled wire rods in to nano composite multilayer structure called perlite.

Trials	Furnace Temp °C	Soaking	Salt Temp °C	Time in salt	UTS Before Annealing MPa	UTS after salt quench			Elongation Before Annealing	Elongation After salt quench		
Trial16	850 °C	15 Min	420	5Min	1178	1263	1259	1266	4	6.5	6.5	6.5
Trial17	**850 °C**	**15 Min**	**440**	**5Min**	**1178**	**1223**	**1231**	**1232**	**4**	**7**	**7**	**7**
Trial18	850 °C	15 Min	460	5Min	1178	1240	1241	1238	4	7	6.5	7
Trial19	850 °C	15 Min	480	5Min	1178	1208	1205	1211	4	7	7	7

Summary

As a result of investigation carried out it has been concluded that salt quenching for C72 grade steel wire yields in to correct mechanical properties, tensile strength and elongation at salt bath temperature of $440^{\circ}C$ & austenitizing temperature at $850^{\circ}C$ and HISALT HCSW can successfully replace toxic Lead baths.

The Implementation of this technology is expected to provide the possibility of intensifying the lead bath replacement process thus resulting also in the measurable economic, environmental and health benefits.

Experimental Support:

Mr Ganesh Lone - (Metallurgist)

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HARDCASTLE PETROFER
industrial oils and chemicals
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