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Effect of Quench Severity and Hardness of Aluminium 2585 Alloyusing Eco Friendly Quenchants

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Abstract: ***Rate of cooling, hardness and severity during quenching of various media viz; cow urine, distilled water, tap water, engine oil (unused) SAE40 soap nut solution, shikakai nut solution for industrial heat treatment was investigated using 2585 Al alloy. For all media, nucleate boiling and convective heat transfer are being carried out and out of which maximum and minimum cooling rates are observed for cow urine. From the study it has been observed that cow urine, tap water and distilled water, cow urine has high heat transfer coefficient 6.577W/m²K, whereas Engine oil, Shikakai nut solution, Soap nut solution are considered Soap nut solution has high heat transfer coefficient 3.654 W/m²K. For all the quenchants, the hardness of Al 2585 alloy increased cow urine.***

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Keywords : Cooling rate, Cow urine, Heat transfer, Quench severity.

I. INTRODUCTION

A.S. Adekule [1] Rate of cooling, hardness and severity of both edible and non edible bio quenchants for industrial heat treatment was investigated using AISI 4137 medium carbon steel. Among the vegetable oils, the highest Heat transfer coefficient and cooling rate was obtained for jathropa oil, where as the lowest HTC and cooling rate was obtained for palm oil. Ljiljana pedisic [2] Right section of quenching media important to improve the mechanical properties. In this study are presented the examination result of physical chemical properties and also cooling characteristics of new quenching oils with different composition. Cooling characteristics are changed by adding different types of base oils also depend on the concentration additives. Kahtan K Al-Khazraji [3] Polymer as quenching media for heat treating industry. Polymer physical properties directly affect the cooling rate of quenched part, various test conducted hardness and wear rate Al-si alloy. 0.6 wt% PVA maximum hardness and decrease of wear rate of eutectic Al-Si alloy over the traditional quenching media. J.Ridhwan[4] Effect of various cooling rate and precipitation hardening on micro structure and mechanical properties of 6061 Al alloy. Samples quenched cooling in furnace, air and water quench. It was observed that fast cooling rate fine grain obtained and high strength while slow cooling rate by annealing. Vivek Tiwary[5] Quench severities of heat treatment purposes 10% Brine, Distilled water, oil as quenching medium. Quench severity is predicted based on hardness number. Martensity phase transformation can be arranged in the descending order Brine>water>oil.

Lijun Hou [6] The different quenching media quenched of Gcr15 steel is studied experimentally and final result showed the different quenchant, different cooling performance. In order to increase the cooling capacity of gas, the spray water is added during gas quenching. Daniel Komatsu [7] Cooling curve analysis was used to evaluate the effect of corrosion inhibitor additives and anti oxidants an the quenching properties of soybean oil. Addition of corrosion inhibitors provide significant changes in the cooling curve behavior and greatest rate of acceleration of heat transfer. NI Kobasko [8] Different vegetable oils evaluated could be blended with minimal impact of viscosity. Cooling curve analysis showed that similar cooling profiles were obtained for different vegetable oils. High temperature cooling properties of vegetable oils are considerable faster than those observed for petroleum oil based quenchants. B.Matijevic [9] Mineral, synthetic and natural oil cooling characteristics of new quenching oils with different compositions cooling curves have been evaluated according to ISO 9950 Standard. By adding additives, the cooling rate is increased. Heat transfer characteristics are also changed. AlirafaAltaweel [10] Investigated the influence of different media, size and shape of the specimen on the hardened depth of AISI 4140 steel. Samples cooling rate mainly depends on the type of quenching medium and specimen shape and size. Newton's law of cooling and first law of thermo dynamics equations were developed for finding the hardness values of specimens when using different quenching media.

III. MECHANISM OF HEAT REMOVAL DURING QUENCHING:

Transient heat flow is of great practical importance in industrial heating and cooling. We shall first analyze problems where the temperature is uniform throughout the system at any instant and it varies only with time. This type of analysis is called the Lumped Heat Capacity Analysis. Let us consider LHCA cooling of a work piece or metal casting in a quenching bath after it is removed from a hot furnace. Neglecting any temperature gradient with the solid(work piece), an energy balance for the work piece over a small time interval dt gives,

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Change of Internal energy of work piece during time dt = Net heat flow form the work piece to the bath

$$-\rho V c\, dT = hA\,(T - T_\infty)dt \quad (1)$$

Where ρ = density of solid kg/m^3, V=volume of solid m^3, c = specific heat of solid J/Kg K, A= Solid area m^2, h= convective heat transfer coefficient between the solid and surrounds is w/m^{2}K, dT = temperature change, K, during time interval dt, sec. where T_0 = initial temperature, T_∞ surrounding fluid temperature, T is the average temperature of solid.

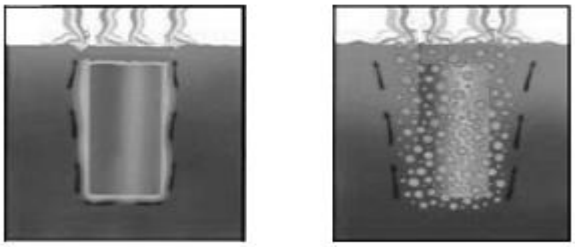
$$\frac{dT}{T-T_\infty} = \frac{d\,(T-T_\infty)}{T-T_\infty} = \frac{-hA}{\rho c V}\,dt$$

$$\frac{T-T_\infty}{T-T_\infty} = e^{-\frac{hA}{\rho c V}t} \quad (2)$$

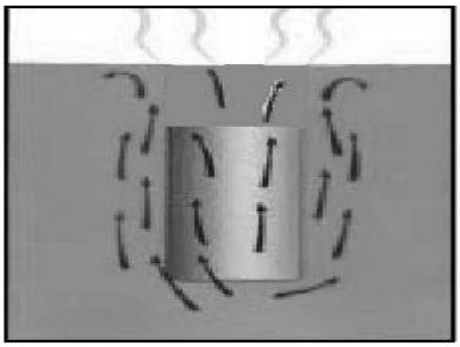
The structure, hardness and strength resulting from a heat treating operation are determined by the actual cooling rating obtained by the quenching process. If the actual cooling rate exceeds the critical cooling rate, only martensite will result. If the actual cooling rate less than the critical cooling rate, the part will not completely harden. The greater the difference between the two cooling rates the softer will be the transformation products and the lower the hardness. At this point, it is necessary to understand the mechanism of heat removal during quenching. There are three stages of cooling process during the immersion of the hot work piece into a quenching medium which tends to produce a vapor layer. They are : a) the vapor layer stage b) the boiling state and c) the convection stage, as its shown in Fig.1. a) As soon as the component is quenched from a high temperature into the liquid medium, the liquid gets vaporized and forms a vapour blanket around the component. This vapour blanket does not allow to extract the heat and reduces the cooling rate. b) severe boiling after some time, the vapour blanket breaks and the liquid comes in contact with the surface of hot component and hence, the cooling rate is highest during this stage. In the last cooling stage © when the temperature of the work piece decreases under the boiling point of the quench ant, the heat is released only by the convection of the quenc hant.

II. QUENCHING MEDIUM

Water and oil are the most common quenching mediums for hardening of metals. However, water gives a fast cooling rate at lower temperatures and oil gives a slow cooling rate at higher temperatures. This goes against the requirements of an ideal quenching medium for hardening purpose. The above drawbacks of water and oil are overcome by using a new quenching medium called cow urine. This quenching medium provide a faster cooling rate in the higher temperature range and a slow cooling rate in the low temperature range, thus satisfying requirements of an ideal quenching medium. Cow urine quenchant is a solution different additives, elements, vitamins present homogeneously refine grain size and interlocking grain boundaries.



a) vapour layer stage **b) boiling stage**



c) convection stage

Table –I:Chemical Composition Al 2585 %by weight

Cu	*Mg*	*Si*	*Fe*	*Mn*
10	*0.3*	*2*	*0.7*	*0.5*
Ni	*Zn*	*Pb*	*Sn*	*Al*
0.5	*0.1*	*0.01*	*0.01*	*Rest*

IV. EXPERIMENT PROCESS:

The specimen is shown in fig. It is a 2585 Al alloy cylinder whose material chemical composition (Wt%) is presented Table-I. The specimen was heated muffle furnace to 530(±5). Held for 15 min; and then quenched in different quench media. The change in temperature during quenching was measured by thermocouple, experimental data were recorded by computer data logger. The experimental conditions is shown in Table-II.

Table-II: The experimental conditions.

No	Specimen	Material	QM
1.	Cylinder Φ20X200mm	Al2585	CU
2.	Cylinder Φ20X200mm	Al2585	TP
3.	Cylinder Φ20X200mm	Al2585	DW
4.	Cylinder Φ20X200mm	Al2585	SN
5.	Cylinder Φ20X200mm	Al2585	Shi N
6.	Cylinder Φ20X200mm	Al2585	EO

Fig.2.Specimen quenched in media

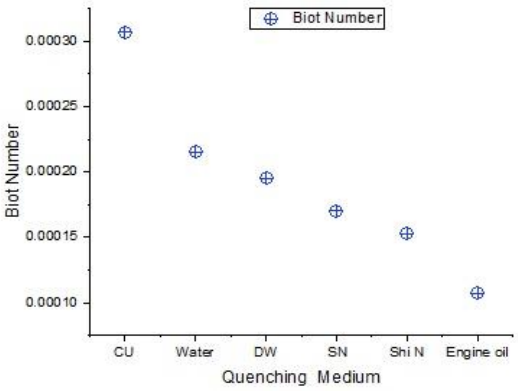


Fig:3: Biot Number for different media

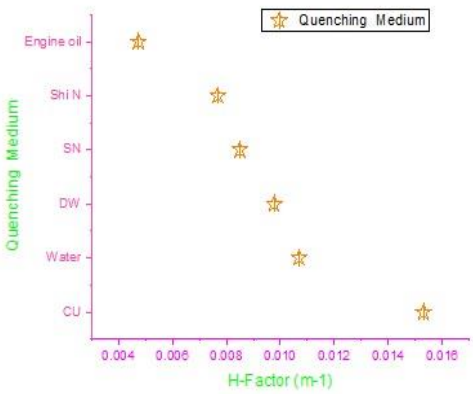


Fig.5: Quench severity for different media

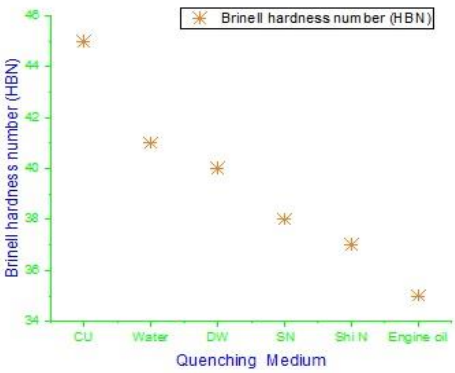


Fig.7: BHN with different media

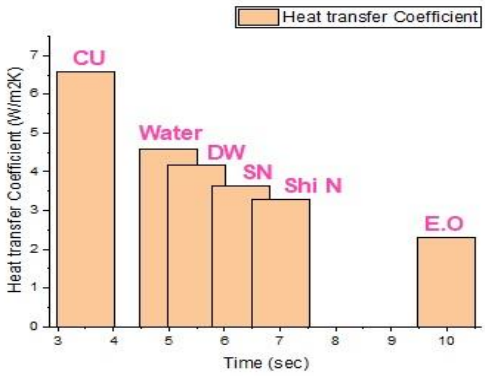


Fig.4: Change of HTC of different quenching media

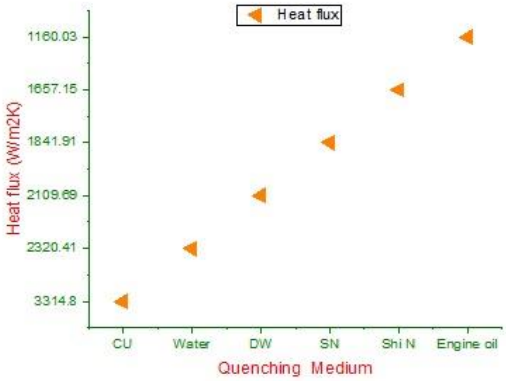


Fig.6: Heat flux various quench media

From the cooling curve data (Fig.7) to determine the time dependent Heat transfer coefficient by LHCM. From the figure (Fig:4) high heat transfer coefficients 6.57, 4.60, 4.18 W/m^2K were obtained for CU, TW, DW. SN, Shi N, EO have heat transfer coefficients of 3.65, 3.28, 2.30 W/m^2K .

The Heat transfer coefficients were found to be highly dependent on the minerals and ions and other elements of the quench media. Higher Heat flux value for cow urine solution(Fig:6), first stage of cooling vapour blanket formed around the work piece. Ions and minerals present cow urine solution destabilize the vapour blanket. The maximum heat flux 3314.8W/m^2K was obtained for cow urine solution. From the Fig.5 quench severity of the quench media used were found to be related directly to the Biot number, higher the Biot number, the higher the quench severity. From the fig. 7 HBN increases in cow urine solution sodium, silicon other elements present, these elements interlocking the grain boundaries and refine the grain size.

One of the index commonly referred in many literatures for quantifying quench severity (Fig;5) is Grossman Number, (Eq:3) defined as; Although the Grossman Number is closely related to harden ability and ideal diameter concept, it is better explained form the view of fundamental heat transfer and this view can give us a better idea of the limitation of the number.

$$H = \frac{h}{2k} \quad (3)$$

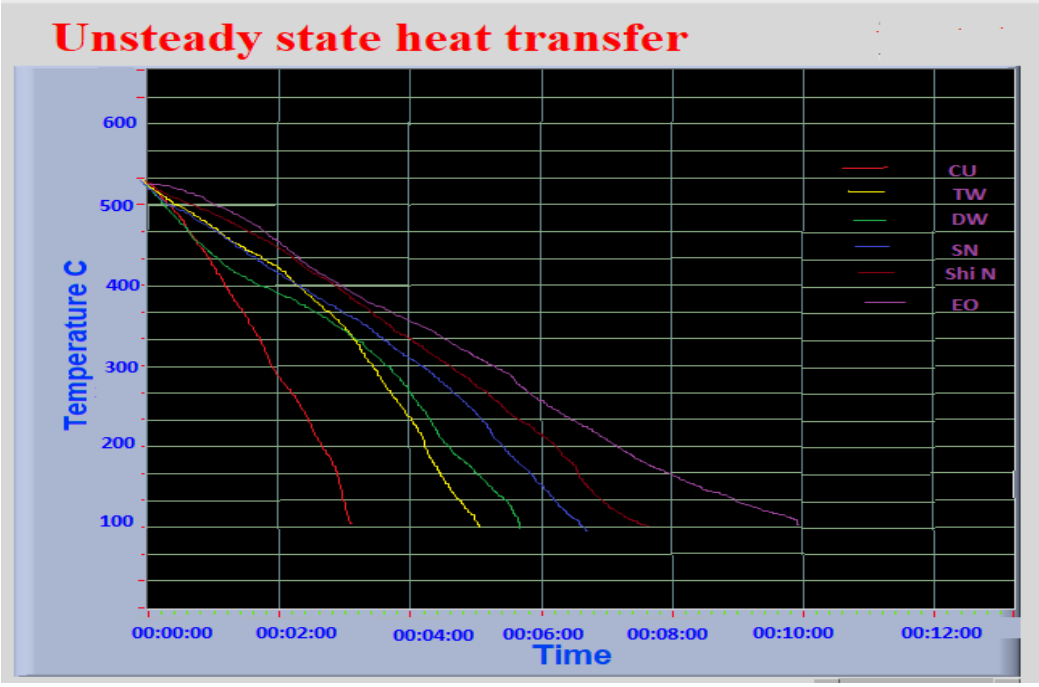


Fig.7:Cooling rates for various quenching media

V. RESULT AND DISCUSSION

Among the quenchants. It can be observed that the cow urine quenching resulted in highest heat transfer coefficient and cooling rate was obtained. Maximum heat flux is obtained and the quench severity (The Grossmann quench severity) H was calculated from the experimental data and the values obtained showed that the quench severity of different media. The quench severities of the media used were found directly to the biot number, higher the biot number, the higher the quench severity. Hardness value increase. The reason is attributed to the elements and ions present homogenously, destabilizing the vapour blanket that is formed around the sample during the first stage of cooling. Where as the lowest heat transfer coefficient and cooling rate was obtained for engine oil due to viscosity of oil. Soap nut solution and Shikakai nut solution fatty acids present it reduces the heat transfer coefficient and heat flux comparing with tap water and distilled water gave intermediate heat transfer coefficient and hardness value. The cooling rates were determined to be in the following order.

CU > TW > DW > SN > Shi N > Engine oil

VI. CONCLUSION

1. The cooling rate of samples largely depends on the type of quenching medium and specimen shape and size.
2. Agitation of quenching media can significantly increase the peak heat flux during quenching treatment of the sample.
3. Based on the Newton's law of cooling and first law of thermodynamics equations were developed for estimating hardness values of samples when using different quenching medium.
4. Based on above conclusions, in order to increase the physical properties of the metallic material through quenching, the proper quenchant can be used.

APPENDIX

CU	Cow Urine
TW(W)	Tap water
DW	Distilled water
SN	Soap nut solution
Shi N	Shikakai Nut solution
EO	Engine oil
QM	Quenching Media
LHCM	Lumped Heat Capacity method

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