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Dear Fellow Engineers,

In this summer, there is soothing green colour seen on the simmering hot streets, moving with elegance and attracting every one. Even kids have started asking why these vehicles have different but well decorated green design on the buses, vans, cars, even on some autos and Scooties ?

Answer is simple it's a colour of change for vehicles using fossil fuels to electric vehicles. We too are having some brainstorming session and a paper on effect of this change on the Forging industry. I am sure you would have book-marked your dates in your diary for September 16^{th}/17^{th} in bold letters and on your calendar to join us for the forth coming Conference & Exhibition, being organized by our forum "Foundry and Forging Technology" on "TOMORROW'S FORGING INDUSTRY" at The Pride Hotel, Pune.

We see a buzz word in every industry - Forging ahead to meet new targets, new achievements and new products. Ukraine / Russia war has much deeper impact on the forging industry due to destruction of major steel mills in Ukraine, but yes, show must go on and people are trying hard to set aside problems arose due to war and converting them in to opportunity.

So friends, see you all in the forthcoming conference on "TOMORROW'S FORGING INDUSTRY" in September, with your whole hearted support for participation, sponsorships, stalls and deep involvement.

With Best Regards,
Dr. V. V. Kanetkar - Editor

FOR YOU ?

First Correct Answer will be given one delegate free for any one training programme

Why a whitish circle is seen in the centre in macrostructure of some concast products rolled ?

COOLING INTENSITY OF INVERSE SOLUBILITY POLYALKYLENE GLYKOL POLYMERS AND SOME RESULTS OF INVESTIGATIONS FOCUSED ON MINIMIZING DISTORTION OF METAL COMPONENTS

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Abstract

Poly(Alkylene Glycol) polymers of inverse solubility (PAG) provide ideal uniform cooling for minimizing distortion and preventing crack formation during hardening machine components and tools. However, in spite of ideal cooling, from time to time, a big distortion takes place during hardening process. A reason for a big distortion development during hardening in PAG solutions is explained and an idea how to fix the problem is suggested. It is shown that at the end of cooling coating can be locally dissolved by a cold water flow creating local open area where martensite transformation starts first. Due to greater specific volume of martensite, it creates a big distortion. To solve the problem, one should interrupt cooling process or stop agitation before insulating coating is dissolved.

To perform correctly proposed technology, cooling intensity of inverse solubility PAG polymers of 1–20 % were investigated on the basis of use of regular thermal condition theory. As a result, dimensionless effective numbers Kn were obtained for recipes development. A technique for solving the problem is proposed by author. Examples of calculations are provided.

Keywords: PAG polymers, effective number Kn, polymeric layer, local dissolving, local tranformation, low PAG concentration, intensity, distortion, reduction, recipes, technique, benefits.

1. Introduction

The molecular formula for PAG is [1–3]:

$$HO-(CH_2-CH_2-O)_n-(CH_2-CH(CH_3)-O)_n-H$$

High molecular weight PAG is completely soluble in water at room temperature. PAG also exhibits a unique property in which it has inverse solubility as temperature increases in water.

As the temperature rises, the PAG precipitates out of the solution and deposits on the surface of the part. At temperatures above 74 °C (165 °F), the polymer separates from water as an insoluble phase. The deposited layer serves as an insulator which, in turn, governs the rate of heat extraction from the quenched part. This layer decreases initial heat flux density since it thermal conductivity is within 0.1–0.145 W/mK [2, 3]. As the temperature of the part decreases, the polymer dissolves back into the aqueous solution. Quenchant concentration, quenchant temperature and quenchant agitation govern the rate of heat transfer. Until now, there is no method available for transition from standard probe to real steel parts in order to develop recipes improving srength of materials and decreasing distortion. Results of investigations in this area are discussed in this short communication.

2. Methods used for evaluation cooling intensity of polymers

2. 1. Standard Inconel 600 probe used for investigation of PAG polymers

At present time polymer quenchants are manufactured and further investigated by The Dow Chemical Company [2, 3]. Each type of PAG water solution with corrosion inhibitor is nonflammable polymeric quenchant. The standardized probes for evaluation of cooling intensity of quenchants are discussed in [4, 5]. Test methods based on ASTM Standards D6200-01, D6482-99, and D6649-00 for determining the cooling characteristics of quenchants by cooling of probes made from Inconel 600 material are widely used in practice [4, 5]. The chemical composition of Inconel 600 is: 72 % nickel; 14–17 % chromium; 6–10 % iron; 0.15 % carbon; 0.5 % copper; and 0.5 % silicon. The diameter of the probe is 12.5 mm and its length is 60 mm. Unfortunately, cooling curves obtained by standard probe are not suitable for evaluation of real heat transfer coefficients during transient nucleate boiling processes [6]. The standard Inconel 600 probe was developed to check and maintain stability of quenchants and can provide only effective heat transfer coefficients [7, 8].

2. 2. Investigation cooling intensity of PAG polymers based on regular thermal condition theory

Cooling intensity of PAG polymers was evaluated using generalized equation for cooling rate calculation [9, 10]:

$$v = \frac{aKn}{K}\left(T - T_m\right),$$

where v – cooling rate in oC/s; a – average thermal diffusivity of a material in m2/s; Kn – dimensionless Kondratjev number; K – Konratjev form factor in m2 [9]; T – current temperature in oC; Tm – temperature of quenchant in oC. Dimensionless number Kn changes within 0 and 1 when heat transfer coefficient or generalized Biot number changes from 0 to infinity [10].

Experiments of author and many experimental data on cooling rates versus time provided in the Internet and published in books and scientific journal were used for calculating dimensinless number Kn for polymer solutions versus concebtration and size of probes [11, 12]. The summaring results are provided in **Fig. 1.**

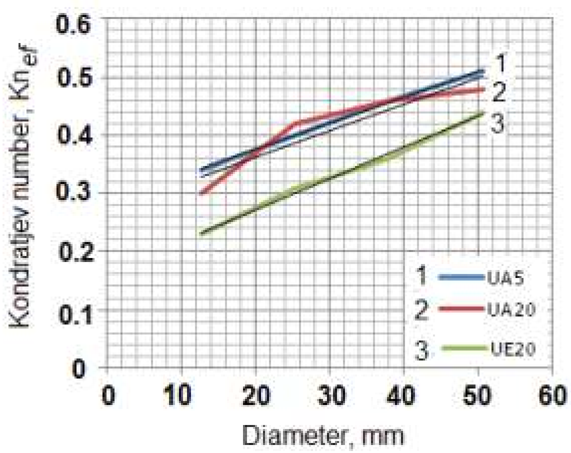

Fig. 1. Effective numbers Kn vs. diameter of cylindrical samples made of AISI 4140 steel during their queching in water PAG solutions of different concentration at 43 oC and agitation:
1 – UCON A of 5 % water solution agitated with 0.254 m/s; 2 – UCON A of 20 % water solution agitated with 0.508 m/s; 3 UCON E f 20 % water solution agitated with 0.508 m/s

Similar results were obtained for still and agitated water salt solutions of optimal concentration (Fig. 2) [7].

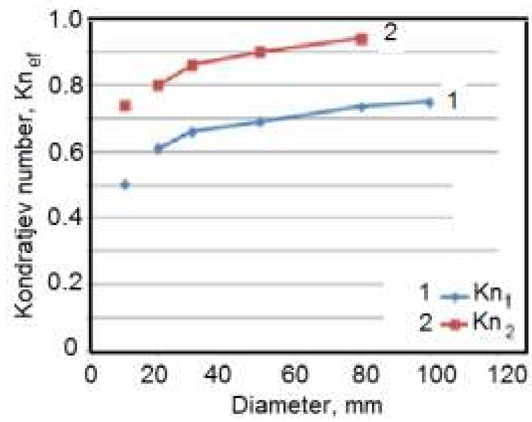

Fig. 2. Effective Kondratjev number Kn versus diameter of cylindrical probes made of
AISI 304 steel when quenching in 8 % water solution of NaNO3 at 20 oC:
1 – quenching in still solution; 2 – quenching in solution flow 1.5 m/s

Water solutions have higher dimensionless Kn number because no insulating polymeric layer on the surface of metal during quenching in water salt solutions (Fig. 1, 2). Let's note that shape of steel part effect insignificantly the effective value of Kn [10].

3. Effect of insulating layer on temperature field in coated metal

For investigating effect of insulating coating on temperature distribution in a coated metal, namely in long cylinder, the next mathematical model was analyzed:

$$\frac{\partial T_1}{\partial \tau} = a_1\left(\frac{\partial^2 T_1}{\partial r^2} + \frac{1}{r}\frac{\partial T_1}{\partial r}\right) \quad (\tau > 0; \quad 0 \le r \le R_1); \tag{2}$$

$$\frac{\partial T_2}{\partial \tau} = a_2 \frac{\partial^2 T_2}{\partial r^2} \quad (R_1 \le r \le R_2); \tag{3}$$

$$T_1\left(R_1,\tau\right) = T_2\left(R_1,\tau\right); \quad \lambda_1 \frac{T_1\left(R_1,\tau\right)}{\partial r} = \lambda_2 \frac{T_2\left(R_1,\tau\right)}{\partial r}; \tag{4}$$

$$\lambda_2 \frac{T_2\left(R_2,\tau\right)}{\partial r} + \alpha\left[T_2\left(R_2,\tau\right) - T_c\right] = 0; \tag{5}$$

$$T_1\left(0,\tau\right) = T_2\left(0,\tau\right) = T_0. \tag{6}$$

Analytical solution for (2)–(6) is known and can be presented as ((7), [13])

$$\frac{T_1(r,\tau)-T_c}{T_o-T_c}=\sum_{n=1}^{\infty}A_nJ_0(\mu_n r/R_1)\exp(-\mu_n^{\ 2}Fo), \qquad (7)$$

which is true for insulated metal.

Temperature distribution within the insulating layer is calculated by Eq; (8):

$$\frac{T_2(r,\tau)-T_c}{T_o-T_c}=\sum_{n=1}^{\infty}A_n\{J_0(\mu_n)\cos\left[\mu_nK_a^{1/2}(r/R_1-1)\right]- -K_aJ_1(\mu_n)\sin\left[\mu_nK_a^{1/2}(r/R_1-1)\right]\}\exp(-\mu_n^{\ 2}Fo), \qquad (8)$$

where $T_1(r,\tau)$ – temperature distribution in metallic section; $T_2(r,\tau)$ – temperature distribution in a coating; A_n temperature amplitudes; $J_0(\mu_n)$
$J_1(\mu_n)$ the first kind of Bessel function of first order; μ_n – roots of characteristics equation [13]; $K_a=\frac{a_1}{a_2}$; a_1 – thermal diffusivity of a metal in m^2/s; a_2 – thermal diffusivity of a coating in m^2/s; Fo – dimensionless Fourier number.

If thermal conductivity of coating is very low, effective heat transfer coefficient (HTC) on the surface created by radius R_1 is very low as well. Taking into account universal correlation of the regular thermal condition theory [10], one can analyze temperature distribution in a coated metal, i. e.:

$$\psi=\frac{\overline{T}_{sf}-T_c}{\overline{T}_V-T_c}=\frac{1}{\sqrt{Bi_V^{\ 2}+1.437Bi_V+1}}. \qquad (9)$$

To be continued...

FORGING TECHNOLOGY FORUM mega event 2022

Conference & Exhibition on
FORGING TECHNOLOGY FORUM

TOMORROW'S FORGING INDUSTRY

15th-16th (THU-FRI) SEPTEMBER 2022

- Venue -

The Pride Hotel
5, University Road,
Pune - 411005, Maharashtra, India

www.forgingtechnologyforum.com

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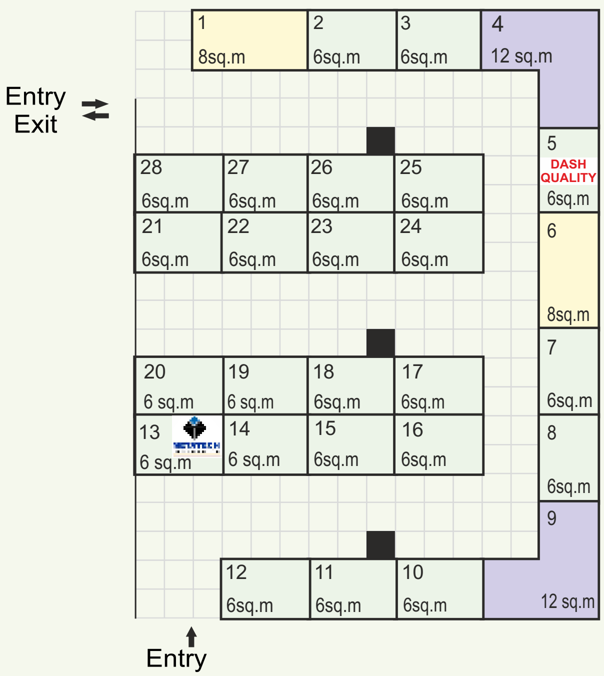
FORGINGS TODAY

Exhibition at The Pride Hotel, Pool Side, Covered area

EXHIBITION LAYOUT & TARIFF



Stall Details (Non Ac)

Stall Area	Stall Size	Total Stall	Total Sq. Mtr.	Constructed Stall Facilities	Rate (Rs)	Rate USD ($)
6 Sq. Mtr.	2m x 3m	24	144	1 Table, 2 Chairs, 3 Spotlights, 1 Plug Point, Facia, Carpet, 1 Dustbin One Delegate Free & additional 50% concession on delegates fee	40,000/- + GST	720
8 Sq. Mtr.	2m x 4m	2	16	1 Table, 2 Chairs, 3 Spotlights, 1 Plug Point, Facia, Carpet, 1 Dustbin One Delegate Free & additional 50% concession on delegates fee	50,000/- + GST	900
12 Sq. Mtr.	L Shape	2	24	2 Table, 2 Chairs, 4 Spotlights, 1 Plug Point, Facia, Carpet, 1 Dustbin Two Delegate Free & additional 50% concession on delegates fee	70,000/- + GST	1260
	Total	28	184			

- Exhibitors are free to Attend Technical Conference

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