SJST **Surman Journal for Science and Technology |** ISSN: E 2790-5721 P 2790-5713
Vol**3**, No.**1**, Dec_2021 , pp. 028 ~ 036

Isothermal Transformation Temperatures and Its Effect in Hardiness of Pearlite Eutectic Steels R350HT Rails

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الملخص

يتميز الفولاذ المقاوم للصدأ بعدد من الخواص الميكانيكية المرغوبة ، وبالتالي تمت دراسته على أنه بنية مجهرية مرشحة للسكك الحديدية المقواة برأس R350HT وفقًا لمعيار EN-13674. يدرس هذا العمل دور درجة حرارة التحويل لصف السكك الحديدية R350HT وتأثيرها على صلابة السكك الحديدية. تم الحصول على بنية الدقيقة المرغوبة تحت درجات حرارة تحويل مختلفة. يتوافق تباين صلابة البرليت التي يتم الحصول عليها في ظل ظروف TTT مع التغيرات في تركيبها الداخلي ودرجة حرارة التحول

Abstract

Fine pearlitic eutectic steel have a number of desirable mechanical properties and have thus been studied as candidate microstructure for R350HT head hardened rail according to EN-13674 standard. This work examines the role of transformation temperature of R350HT rail grade and their effect on rail hardiness. The fine pearlite structure has been obtained under different isothermal transformation temperatures. The variation of pearlite hardiness that obtained under TTT conditions conform to the changes in its structure and transformation temperature.

Keywords: *TTT, Pearlitic, R350HT rails, isothermal temperatures, Hardiness.*

1- Introduction

Time transform occur when steel holding at any constant austenitic temperature lower than the minimum, where austenite is stable. Isothermal transformation can be represented by recorded the austenite transformed plotting percentage against corresponding elapsed time at constant temperature. Hardness, toughness and strength from the most important mechanical properties, which related to cooling rate as well as interlamellar spacing. From other hand, inter lamellar spacing controlled by the heat treatment variable [1]. Because of their remarkable effect on functional and structural properties the Studies on the microstructures of alloys continues to be conclusive. Pearlitic steel, from the alloys that have lamellar structures, which are in practical use and have been studied extensively [1, 2]. As principles of the controlled cooling and heat treatment of steels and their alloys, TTT curves (Time Temperature Transformation or isothermal transformation) [3]. The TTT curves idea is description of phase transformation and analyze quantitatively the transformation process of steels and the relationship between the microstructure and the resulted mechanical properties [3, 4]. The pearlite mechanical properties and microstructure can be tailored out of difference of the interlamellar spacing during processing which is immediately connected to strength [5].

Displacement and charge sensing indentation technology enables the determination of mechanical properties at penetration depths as low as 20 nm, avoiding the influence of the substrate on measurements. The ability to test at very small scales makes this technology one of the tools of choice for characterizing the mechanical properties of thin films, coatings, second-stage particles, and magnetic hard drive recording media [6].

A well-defined bleed geometry is required to obtain well-defined bleed prints. It is difficult to achieve a perfect tip shape. Berkowitz is a three-sided pyramid, which provides a sharp point, compared to the Vickers indenter, which is a quadrangular pyramid and has a slight offset (0.5 - µm). This is the main reason for using the Berkovich three-sided notch in depth sensing machines. However, any sharp point notch has a limitation, but it is exceptionally difficult to measure. Experimental procedures were developed to correct the edge shape of the Vickers and Berkovich indentations.

In this study, the investigated of rails R350HT hardness with different cooling rate and isothermal temperature during the isothermal transformation. Which measured by experiments, with focused on the relationship models and obtained by data regression. All TTT cooling condition done by used in dilatometer tester DIL805 sample, which is austenitised in a specially designed furnace and then controlled cooled.

1.1 Objectives

The study aimed to investigation in relationship between cooling rate and hardiness of pearlitic eutectic steels in R350HT head hardened rails. With applying different isothermal transformation temperatures. In addition, finding out the following:

- Sensitivity of hardiness to transformation temperatures
- The relationship between cooling rate and hardiness.

2- Materials and Equipment.

As the principal requirements involved, the steels used for wheels and rails have a majority pearlitic microstructure involving hard cementite lamellae that ensures high resistance to wear. Material properties of rails requiring verification are set out in European standard EN 13674-1 [7]. Due to EN 13674-1 exclusively covers pearlitic steels for rails, those being R220, R260, R320Cr and R350HT, whose carbon content lies between 0.6 and 0.8 % [8]. In addition, the main chemical composition of R350HT tested samples showing in table (1):

Table 1: showing the chemical composition of R350HT rails.

The chemical composition					
R350HT	C	Si	Mn	P	S
	0.65~0.77	0.15~0.35	1.10~1.5	<0.04	<0.04

Figure 1, R350HT head hardened Rail profile. Where the specific descriptions are: Cross-sectional area: 76,70 cm^2, Mass per meter : 60,21 kg/m, Moment of inertia x-x axis : 3038,3 cm^4, Section modulus - Head : 333,6 cm^3, Section modulus - Base : 375,5 cm^3, Moment of inertia y-y axis : 512,3 cm^4, Section modulus y-y axis : 68,3 cm^3 and Indicative dimensions : A = 20,456 mm, B = 52,053 mm.

R350HT rail samples as shown in figure 2, with 4 mm in width, 2 mm in thickness and 10 mm length to dial with dilatometer DIL805 taken from the head of rail.

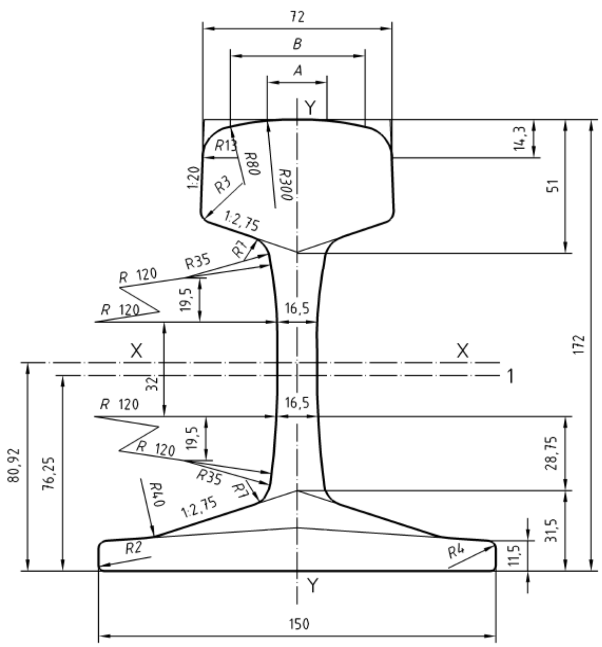

Figure 1: R350HT Rail profile [8].

Figure 2: showing samples dimensions

By dilatometer DIL805 a solid or hollow samples is inductively heated as shown in figure 3 under air and the system can be vacuum or inert gas to a specific temperature and is then continuously cooled with different (linear or exponential) rates. The phase transitions occurring in both continuous cooling process or in the time temperature transformation and it can be seen in the change of length.

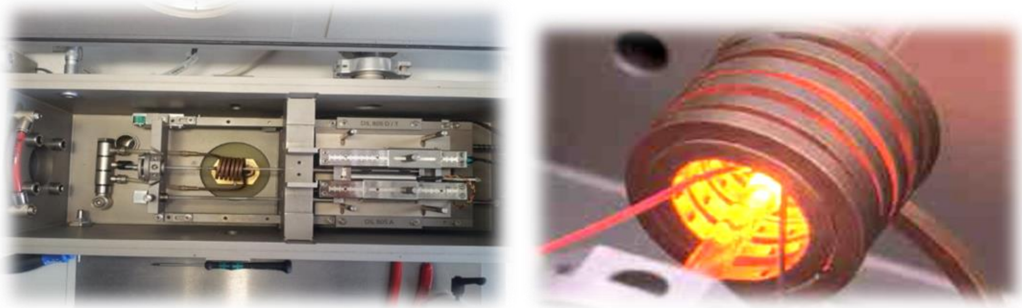

Figure 3: Dilatometer equipment

Dilatometer indicates phase transformation by monitoring slope change. Figure 4, gives more details by drawing dilation vs temperature where the dilation at different temperatures at different cooling rate. By behavior of sample shrink or expand the dilation due to thermal specific volume change because of changing in temperature. Generally, slope in dilation curve do not changed while amount of phase or the relative amount of phases in a phase mixture does not change during cooling or heating as well.

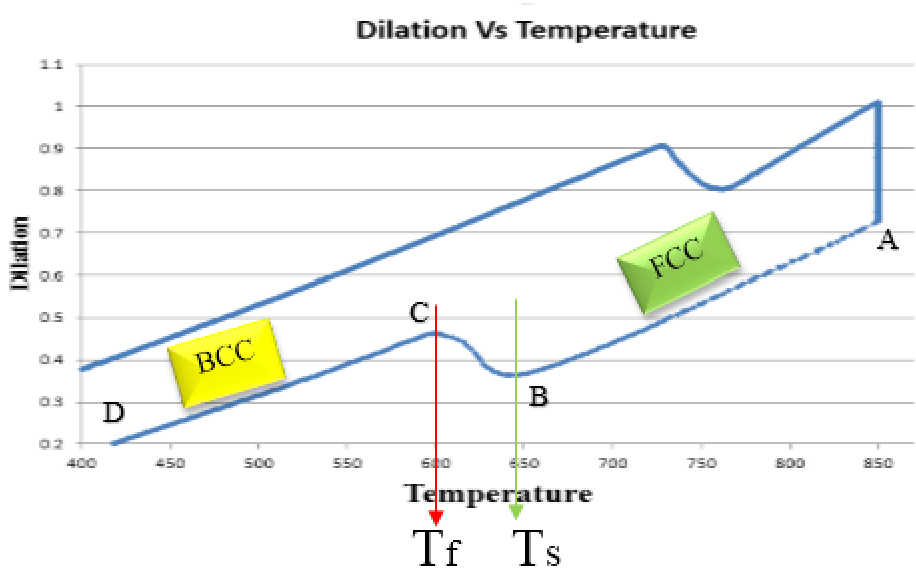

Figure 4: showing dilation vs temperature and transformation temperature.

Dilation from A to B is due to specific volume change of high temperature phase austenite. However, at Ts slope of the curve changes, the transformation starts at Ts from austenite to pearlite. One more time, slope of the curve from C to D is constant but is different from the slope of the curve from A to B. where there is no phase transformation between the temperatures from C to D. The curve from point B to C is variable with temperature that signal the change in relative amount of phase because of cooling.

Moreover, the phase density controls the sample expansion, some part of dilation compensates by thermal change due to cooling. So the dilation curve takes complex shape, firstly slope reduces and reaches to a minimum value and then rise to the characteristic value of the phase mixture at point C. as showing in figure 4, the mechanism of phase transformations start at point B at temperature Ts and the end of transformation at point C with temperature Tf. The nature of transformation has been determined in laboratory by metallography when austenite fully transforms to pearlite, the final pearlite phase transformation is immediately proportional to the relative change in length and this is the key. The ability of materials to resist deformation and destruction is the main idea of hardiness. Also hardiness can be known as the ability of materials to resist elastic deformation and plastic deformation as well [9, 10]. In addition, the major properties of the hardness are resist plastic deformation of a material, where the penetration is the main key of measured it. Moreover, according to EN 13674-1, Berinall vs Vickers hardness testing are measurement techniques [8]. The test measurement technique is applying constant load on the rail surface to printing an impression with an indenter of known geometry, then subsequently analyzing the load vs. displacement data [11]. Figure 5, showing surface printing with an indenter in Vickers hardness testing. Then apply those data in Vickers formula to obtain hardiness. Where, F is load in kgf. And d is Arithmetic mean of the two diagonals, d_1 and d_2 in mm.

$$HV = \frac{2F\sin\frac{136°}{2}}{d^2}$$

Approximately $$HV = 1.854\frac{F}{d^2}$$

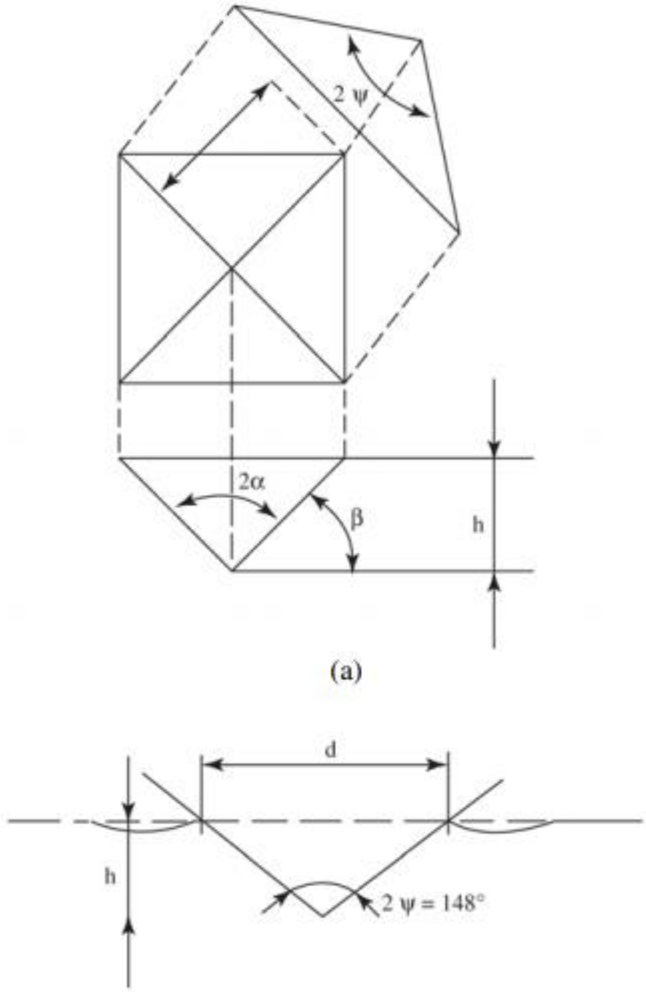

Figure 5: Showing surface printing with an indenter in Vickers hardness testing [11].

3- Extramarital methods

Measuring some physical properties during cooling are the main key to determine the TTT, which normally the specific volume. However, the plurality of the work has been done by measured specific volume change (dilatometric method). Usually, this method is complete by metallography and hardness measurement. In this case, dilatometer test done in vacuum. Cooling data recorded as temperature vs time as shown in figure 5, as same as cooling data the dilation is recorded against temperature, where Figure 4 shown in details and phase transformation indicates by slope change. the TTT diagram mechanism are after cooling to a transformation temperature then keep the temperature constant until the austenite transformation finished, the required transformation product (in our case pearlite) and then cool to the room temperature.

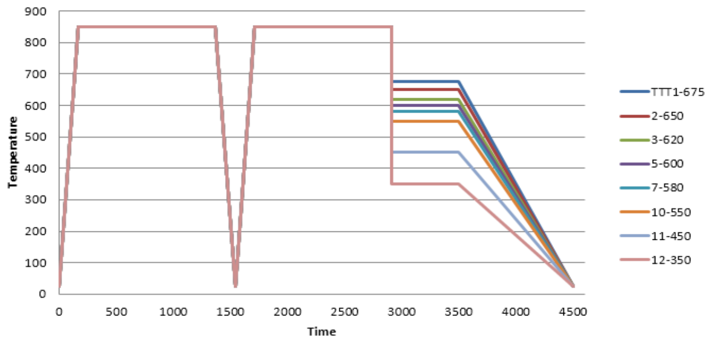

Figure 6: shown TTT curve with 20 minute holding time and different transformation temperature.

4- Results and discussion

4.1 Hardiness

The isothermal transformation of austenite to R350HT head hardened rails has been studied, with different isothermal temperature and then morphologies examination and finally hardiness test recorded against different transformation temperature as showing in table 3. Where isothermal temperature started from 350 C° that recorded 494 Hv0.2 until 675 C° with 186 Hv0.2. The relationship between transformation temperature and hardiness has been recorded and explain graphically in figure 8.

Table 3: showing different transformation temperature and hardiness.

No:	I T	Hv0.2
1	675	186
2	650	207
3	620	225
4	610	260
5	600	293
6	590	301
7	580	308
8	570	337

9	560	345
10	550	349
13	500	339
11	450	378
12	350	494

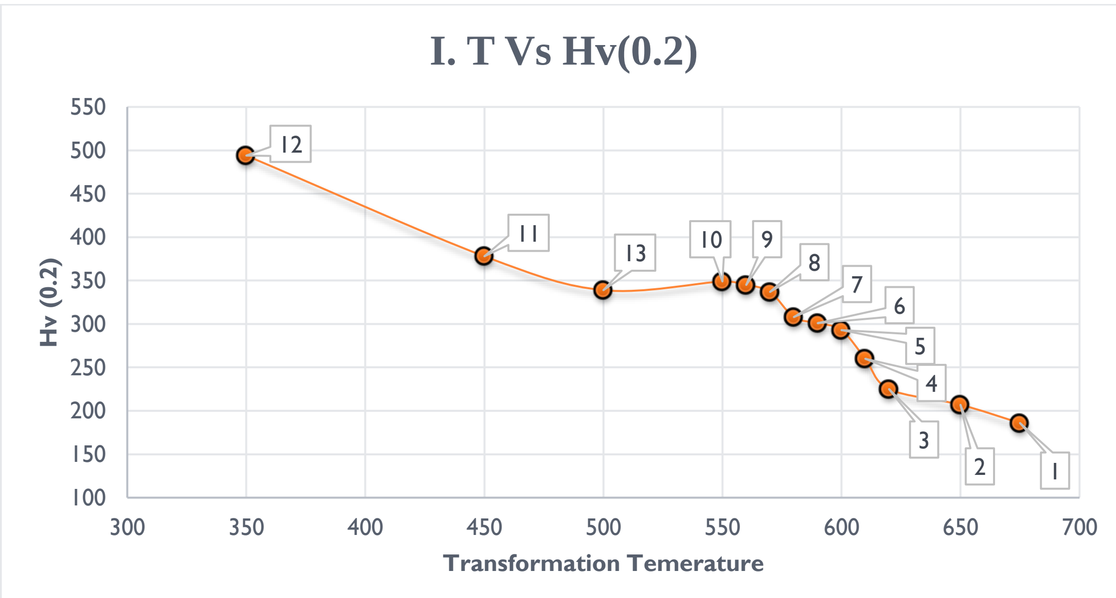

Figure 7: showing transformation temperature Vs hardiness of R350HT rails.

5- Conclusion

In the isothermal transformation temperatures, TTT process with different isothermal temperatures the hardness were measure and the relationship model between the cooling rate and hardiness was obtained to R350HT head hardened rail duo to EN-13674 slandered. Where, experimental results showing sensitivity and relationship that connected hardiness and isothermal temperatures of pearlitic eutectic steel, which can be listed as:

- Lanier positive relationship connected between interlamellar spacing and isothermal temperature, the best isothermal temperatures produced clear fine pearlitic are between (625, 600 and 575 C°/s).

- Study results display inverse relationship connected hardiness to transformation temperatures, where with the increase of isothermal temperature the hardiness decreases, where best transformation group that in between (550 to 575 C°).

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