The Applying Of The Romanowski Test For Identification Of Data Affected By Errors

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doi: 10.19044/esj.2016.v12n21p18 URL:http://dx.doi.org/10.19044/esj.2016.v12n21p18

Abstract

The paper presents an example of calculation to identify data affected by aberrant errors and removing these data from the values of elongation (A) and impact strength (KC) of Ni-Cu austempered ductile iron, by applying the Romanowski tests. All accepted values as fair were noted with the Yes and all values affected by errors were noted with No. This test has identified two aberrant errors of the experimental data. In this way, the experimental results obtained are validated with a statistical confidence level of 95%.

Keywords: ADI, data affected by aberrant errors, Romanowski test

Introduction

In Materials Science, the statistical methods are very important in an understanding and interpreted the results of a scientific researched work.

In a lot of experimental data it can happen that some abnormal values to be higher or lower than the rest of the results so it is very important to identify data affected by aberrant errors. Errors is defined by Webster (Bevington et al., 2003) as "the different between an observed or calculated value and the true value" so if we can eliminate the errors of our researched work, with accurate data we can interpret the correct evolution of the processes

The measured value of our experimental data, are never exactly representative of the studied processes, because of a numerous factors involved in the studied process and because of the tools and of the measurement mode (Peters, 2001). Mathematically this was materialized in the relationship:

measured value = true value ± error (1)

The question which arises is to use statistical tests to identify abnormalities and removing these data because of incorrect information about the study that they can induce.

Research objectives

This research have an important objective, to made an calculation for identification of data affected by aberrant errors by applying the Romanowski test. for the results of elongation (A) and impact strength (KC) of Ni-Cu austempered ductile iron.

Steps for applying the Romanowski test

Identifying data affected by aberrant errors can be accomplished by applying the Romanowski tests.

Solving the test is done in the following steps (Costescu, 2008; Tanasescu, 1987):

(1) Grouping of data and determining the minimum (x_{min}) and maximum (x_{max}) of the experimental values;

(2) Calculating the arithmetic average, with the relationships:

$$\bar{x} = \frac{1}{n-1}(x_1 + x_2 + .. + x_n) = \frac{1}{n-1}\sum_{i=1}^{n-1} x_i \qquad (2)$$

where:

n = the number of experimental determinations;

$\bar{x}$ = the arithmetic average of the experimental data. For Romanowski test, the average value $\bar{x}$ is calculated without considering the value x_0 which is analysed;

x_0 = the liable data to be affected by aberrant errors for the Romanowski test;

(3) Calculating the dispersion, with the relationships:

$$s^2 = \frac{1}{n-1}[(x_1 - \bar{x})^2 + .. + (x_n - \bar{x})^2 = \frac{1}{n-1}\sum_{i=1}^{n-1}(x_i - \bar{x})^2 \qquad (3)$$

where: s^2 = the dispersion of the experimental data;

(4) Calculating the average square diverting, with the relationships:

$$s = \sqrt{s^2} \qquad (4)$$

where: s = the average square diverting of the experimental data;

(5) Calculating the Romanowski test, with the relationships:

$$t_{calc} = \frac{\left| x_0 - \bar{x} \right|}{s\sqrt{n/(n-1)}} \qquad (5)$$

where: *t* calculated value

(6) Determining the critical value of test the Romanowki test, with the relationships:

$$t_{crit} = t_{\alpha;\nu} \qquad (6)$$

where:

t_{crit} = the critical value for the *t* test is the tabular value on the basis of the number of values in the series of data and confidence interval;
α = the coefficient of statistical confidence level, $\alpha = 0.05$ (Bulgaru et al., 2001). In this way, the experimental results obtained are validated with a statistical confidence level of 95%. For a 95% probability, level $1-\alpha = 0.95$ and $\alpha = 0.05$. Conventionally used probability levels are the 90% (somewhat confident), 95% (fairly confident), and 99% (quite confident) probability levels (Peters, 2001);
ν = the number of degrees of freedom, $\nu = n-1$ for the Romanowski test;

(7) Comparing the *t* calculated value with the critical value t_{crit} and analyzing the results and the conclusions of this test; two situations can occur (Banica, 2015):

a) If $t < t_{crit}$ the values of the liable data to be affected by aberrant errors (x_0) of the experimental values are normal for our experimental research;

b) If $t > t_{crit}$ the values of liable data to be affected by aberrant errors (x_0) of the experimental values; In both cases when determining abnormal after removing them, the calculations will made using new parameters required analysis.

Materials

Over the last few years, a number of thermal processes have been developed to modify the matrix structure and thus the properties of ductile cast iron (Harding, 2007).

Austempered Ductile Iron (A.D.I.) with a bainitic matrix, obtained by heat treatment and isothermal hardening is the material which combines a lot of superior attributes of the classical Austempered Ductile Irons or forged iron, being in a serious competition with the iron used by the moment in the automotive industry (Rimmer, 2004).

Depending on heat treatment parameters, in these material components owing to changes in proportions of the major phases present in the microstructure: bainitic ferrite, high carbon austenite and graphite nodules. Martensite, ferrite, iron carbides and other alloy carbides may also be present (Chou et al., 1992).

Because the final structure obtained, influence property values, a wide range of properties can be obtained in these special material.

The studied cast iron had the following composition: 3.63 %C; 2.88 %Si; 0.45 %Mn; 0.012 %P; 0.006 %S; 0.48 %Ni; 0.42 %Cu; 0.050 %Mg.

This cast iron was elaborated in an induction furnace. Nodular changes were obtained with the "In mold" method, with the help of prealloy FeSiCuMg with 10-16% Mg, added into the reaction chamber in a proportion of 1.1% of the treated cast iron.

The structure in raw state is perlito-feritic typical for a cast iron with geometrically regular nodular form. The casted raw iron had the following mechanical properties: Rm = 652 N/mm^2, HB = 176, KC = 11 J/cm^2, A = 13 %.

Heat treatments

The parameters of the heat treatment done were the following: for the lots A, B and C, submitted to isothermal hardening, the austenizing temperature T_A = 900 [°C], the maintained time at austenizing temperature, τ_A = 60 [min] for all the lots.

The temperature at isothermal level, for all the lots was: T_{iz} = 350 [°C] for lot A, 375 [°C] for lot B and 400 [°C] for lot C; the maintained time at the isothermal level, t_{iz} = 60 [min]. All these 3 experimental lots were performed at isothermal maintenance in salt-bath, being the cooling after the isothermal maintenance was done in air.

Experimental results

The experiment groups performed at isothermal maintenance in salt-bath (55% KNO_3 + 45% $NaNO_3$), being the cooling after the isothermal maintenance was done in air. From this material, 30 specific elongation (A) and impact strength (KC) specimens and was done. For the impact strength the specimens was notched. For each KC and A determination it was done 10 parallel determination (r=10). The values of the mechanical results are presented in table 1 and 2.

Table 1. Data Analysis of elongation (A) values for T_A 900° C

Parallel observations	Samples, k = 30		
r = 10	T_{iz} = 350°C (lot A)	T_{iz} = 375°C (lot B)	T_{iz} = 400°C (lot C)
Obs 1	5.8	6.6	8.0
Obs 2	5.7	7.3	7.9
Obs 3	6.0	6.9	7.7
Obs 4	6.3	6.6	8.0
Obs 5	5.4	6.3	7.5
Obs 6	5.8	7.2	7.6
Obs 7	5.5	7.4	7.9
Obs 8	6.5	7.5	7.9
Obs 9	5.6	7.3	6.8
Obs 10	5.5	6.4	7.1

Table 2. Data Analysis of impact strength (KC) values for T_A 900° C

Parallel observations	Samples, k = 30		
r = 10	T_{iz} = 350°C (lot A)	T_{iz} = 375°C (lot B)	T_{iz} = 400°C (lot C)
Obs 1	72	82	99
Obs 2	71	91	98
Obs 3	75	86	96
Obs 4	78	82	99
Obs 5	67	78	93
Obs 6	72	90	94
Obs 7	68	92	98
Obs 8	81	93	98
Obs 9	70	91	84
Obs 10	68	79	88

It can be certainly observed a normal evolution of the values for mechanical characteristics (Batra et al., 2003):

- with increasing temperature from 350 to 400 degrees is observed that increased the values of the studied mechanical properties.

This evolution of the mechanical properties is determined by the structural changes reported to the parameters of the heat treating. This evolution of the mechanical properties is determining by the structural constituents for each heat treatment.

In the case of lot A, structure can be constituted of inferior bainite, superior bainite and residual austenite.

In the case of lot C, structure can be constituted of superior bainite, residual austenite and the inferior bainite will disappear. These constituents are determining high values for A and KC for lot C compared with lot A.

The values of the Romanowski test for the data sets are presented in tables 3 and 4.

Table 3. Romanowski test for elongation (A) data sets

Lot	x	Measured values	$\bar{x}$	s	t_{calc}	t_{crit}	Values remains Yes/No
A (T_{iz} =350°C)	x_{max}	6.5	5.733	0.071	0.266	2.35	YES
	x_{min}	5.4	5.855	0.109	0.330		YES
B (T_{iz} =375°C)	x_{max}	7.5	6.888	0.161	0.401		YES
	x_{min}	6.3	7.022	0.146	0.382		YES
C (T_{iz} =400°C)	x_{max}	8.0	7.600	0.149	0.386		YES
	x_{min}	6.8	7.733	0.078	0.279		YES

Comparing the t calculated value, t_{calc} with the critical value t_{crit} and analyzing the results for the Romanowski test, two situations can occur:

a) If $t_{calc} < t_{crit}$ the values of the minimum (x_{min}) and maximum (

x_{max}) of the experimental values are normal for our experimental research, in this case it noted with a *Yes;*

b) If $t_{calc} > t_{crit}$ the values of the minimum (x_{min}) and maximum (x_{max}) of the experimental values are identified as data affected by aberrant errors for our experimental research, in this case it noted with a *No;*

Table 4. Romanowski test for impact strength (KC) data sets

Lot	x	Measured values	$\bar{x}$	s	t_{calc}	t_{crit}	Values remains Yes/No
A (T_{iz} =350°C)	x_{max}	81	71.222	3.359	2.927	2.35	NO
	x_{min}	67	72.778	4.184	1.311		YES
B (T_{iz} =375°C)	x_{max}	93	85.667	5.228	1.807		YES
	x_{min}	78	87.333	4.899	1.332		YES
C (T_{iz} =400°C)	x_{max}	99	94.222	4.871	3.273		NO
	x_{min}	84	95.889	3.446	0.930		YES

By studying all the data presented in table 3 and 4, following a general remarkable conclusions:

(a) all values are accepted as correct data (Yes) with exception the following values noted with No, which have been identified as data affected by aberrant errors :

- the value of x_{max} =81, from the impact strength (KC) data of lot A, t_{calc} = 2.927, r_{crit}=2.35 so $t_{calc} > t_{crit}$;
- the value of x_{max} = 99, from the impact strength (KC) data of lot C, t_{calc} = 3.273, r_{crit}=2.35 so $t_{calc} > t_{crit}$;

For this two experiments it was eliminated the value affected by aberrant errors and recovery the test without these values, until they finally obtain a value that confirms initial relationship: $t_{calc} < t_{crit}$. These new experimental value is normal for our experimental research and in this case it noted with a *Yes* for the column of the table representing values remains.

Conclusion:

Analyzing all data taken into account, there can say the following:

(a) The evolution of the mechanical properties is determined by the structural changes reported to the parameters of the heat treating and this evolution of the mechanical properties is determining by the structural constituents for each heat treatment;

(b) In the case of lot A, structure can be constituted of inferior bainite, superior bainite and residual austenite.

(c) In the case of lot C, structure can be constituted of superior bainite, residual austenite and the inferior bainite will disappear. These constituents are determining high values for A and KC for lot C compared with lot A (e) In the case of lots A, structure can be constituted of inferior bainite, residual austenite and martensite .These constituents are determining high values for R_m and HB, and less high for A and KCU;

(d) By studying all the data presented in the table 3 and 4, following a general remarkable conclusions: all experimental data as correct were noted with *Yes* and all experimental data as aberrant errors resulting from application, were noted with *No*;

(e) The *t* test has identified two aberrant errors. For this two experiments it was eliminated the value affected by aberrant errors and recovery the test without these values, until they finally obtain a value that confirms initial relationship: $t_{calc} < t_{crit}$.

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