ISSN 1392 - 1207. MECHANIKA. 2010. Nr.5(85)

Statistical evaluation of low cycle stress-strain curves parameters for alloyed structural steels weld metals at room and elevated temperature

M. Daunys*, A. Stulpinaitė, R. Šniuolis*****
**Kaunas University of Technology, Kęstučio str. 27, 44312 Kaunas, Lithuania, E-mail: Mykolas.Daunys@ktu.lt*
***Šiauliai University, Vilniaus str. 141, 76353 Šiauliai, Lithuania, E-mail: agette@gmail.com*
****Šiauliai University, Vilniaus str. 141, 76353 Šiauliai, Lithuania, E-mail: rsrs@tf.su.lt*

1. Introduction

To improve the durability of the critical importance constructions, it is necessary to analyze how working conditions and material properties are influencing the strength and reliability of these constructions. In the construction the fatigue damage under low cycling loading is one of the most frequent failure mode. Because the accumulation of plastic strain generally occurs in small volumes of the material, particularly in parts and structures near the stress concentrators, such as geometrical discontinuities, shoulders, keyways, oil holes, welded joints, technological, welded and foundry defects, termed notches [1 - 4]. Those components are surrounded by the elastically deformed material. That is why the conditions of loading with limited strain in these areas are similar to real constructions and machines.

For low cycle durability calculation the parameters A_1, α, $\bar{s}_T$, characterizing the low cycle stress-strain curves, are used. The cyclic proportionality limit stress $\bar{s}_T$ and parameters α and A_1 are determined at symmetric tension–compression low cycle loading. This loading cycle is the most universal and most correctly shows the characteristics of the materials, because at elastic plastic cyclic deformation almost evenly develop tension and compression deformations. Because it is complicated and rather expensive to determine precise values of these characteristics, particularly at elevated temperature, considering temperature control and the cyclic stress-strain curves recording, the dependences of the parameters A_1, α, $\bar{s}_T$ on main mechanical characteristics of the material were investigated. In our previous work detailed statistical analysis showed that those low cycle stress-strain curves characteristics correlate the best with modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$, i.e. the parameter depending on ultimate tensile and yield strengths and reduction of the area at fracture [5, 6].

In this work the materials are additionally specified in to three groups by chemical composition of the main metal, such as 22K, 19MN5, 10ChN1M, 10GN2MFA, 12Ch2NMFA, 15Ch2MF, 15Ch2MFA, 15Ch2MFAA, 15Ch3NMFAA and others. Analytical dependences of the cyclic stress-strain parameters α, A_1 and the proportionality limit stress $\bar{s}_T$ on the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ for Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V steels and theirs weld metals at room and elevated (250°C - 350°C) temperature are considered. The data of investigation of 75 welded joint materials at room temperature and 40 at elevated temperature are obtained by the methods and testing equipment with computer control and recording of stress-strain curves in Low Cycle Fatigue laboratory of Kaunas University of Technology during 30 years.

2. Determination of low cycle stress-strain curves characteristics

At the best usable relationship it is assumed the relationship between standard mechanical characteristic σ_{pl}, σ_u, $\sigma_{0.2}$, σ_f, Z (where σ_{pl} is the proportional limit, σ_f is the fracture stress and Z is the reduction of area at fracture) and cyclic characteristics. The low cycle loading experiments were carried out under symmetrical tension compression and strain controlled conditions. Low cycle loading with k semicycle curve is described by the equation [5]

$$\bar{\varepsilon}_k = \bar{S}_k + A_1\left(\bar{e}_0 - \frac{\bar{s}_T}{2}\right)k^{\alpha} \tag{1}$$

where $\bar{\varepsilon}_k$ is cyclic strain; $\bar{S}_k$ is stress amplitude for k semi cycle; $\bar{e}_0$ is initial stain; $\bar{s}_T$ is the cyclic proportionality limit stress and A_1, α are constants.

Under strain limited conditions $\bar{\varepsilon}_k = 2\bar{e}_0 = const$. To calculate the low cycle strain and stresses the following units are used: $\bar{S}_k = \frac{S_k}{\sigma_{pl}}$; $\bar{S}_1 = \frac{S_1}{\sigma_{pl}}$; $\bar{s}_T = \frac{s_T}{\sigma_{pl}}$; $\bar{e}_0 = \frac{e_0}{e_{pl}}$; $\bar{\varepsilon} = \frac{\varepsilon}{e_{pl}}$; $\bar{\delta} = \frac{\delta}{e_{pl}}$.

The parameters A_1 and α of low cycle loading under limited strain are calculated by the k semicycle diagram using the equations

$$\alpha = \frac{1}{logk} log \frac{\bar{\varepsilon} - \bar{S}_k}{A_1\left(\bar{e}_0 - \bar{s}_T/2\right)} \tag{2}$$

or graphically from the equation

$$\alpha = \frac{log\bar{\delta}_k - log\bar{\delta}_1}{logk} \tag{3}$$

and when $k = 1$

$$A_1 = \frac{\bar{\varepsilon} - \bar{S}_1}{\bar{e}_0 - \bar{s}_T/2} \tag{4}$$

or graphically from the equation

$$A_1 = \frac{\bar{\delta}_1}{\bar{e}_0 - \bar{s}_T/2} \quad (5)$$

Due to unsettled of cyclic stress-strain curves for 1-9 semicycles the values of $\bar{\delta}_1 - \bar{\delta}_9$ were rejected. The parameters A_1 and α were determined from Eqs. (1) - (5) and experimental results of all materials tested under low cycle straining. When $\alpha < 0$ – the materials cyclic harden, when $\alpha > 0$ – the materials cyclic soften and when $\alpha = 0$ – the materials are stable.

3. Statistic evaluation of cyclic stress-strain curves parameters

The machines used in nuclear power energetic, metallurgy and other industries are operating at different temperatures. Therefore the results of the materials investigated in work [5] were divided according in-service temperature into groups: 1) at room temperature; 2) at elevated temperature. In this work the materials are specified in to three groups by chemical composition: 1) Cr–Ni; 2) Cr–Ni–Mo; 3) Cr–Ni–Mo–V. The numbers of percentage of the investigated materials are given in Table 1. As we can see 65.2% of the analyzed of alloyed steels were tested at room temperature. In this work the largest part of the investigated materials fall in to chemical classified Cr–Ni–Mo–V group at room and elevated temperature.

Kurtosis coefficient and skewness coefficient are rating numerical characteristics, which describe empirical distribution asymmetry and flatness of the parameter's data comparing with normal distribution. Histogram of stress-strain curves parameter A_1 for Cr–Ni–Mo steels weld metals at room temperature is represented at Fig. 1. It has the left skewness compared with normal distribution ($A_s = 0.25$). The kurtosis coefficient ($E_K = -0.33$) evidence that analyzed parameters of A_1 for Cr–Ni–Mo of alloyed structural steels weld metals at room temperature are spread in a wider interval comparing with normal distribution.

To reduce the variance of the results, to define the more precise mean value and obtain the better correlation relationship between the analyzed data, clearly distinct results were eliminated, considering the graphic view, using N. Smirnov criterion and the quartile width method. Rectangular diagram in Fig. 2 shows that the scatter interval of the results of the parameter $\bar{s}_T$ for Cr–Ni–Mo–V steels weld metals at elevated temperature is not wide (within limits x_{min} - x_{max}) and there are no clearly distinct results. The represented median value x_{me} of investigated n number of materials divides the scatter of the results into two equal parts. Defined area (within quartiles limits $x_{0.25} - x_{0.75}$) describes the 50% scatter of the middle values. Statistical characteristics of the proportionality limit stress $\bar{s}_T$ and the cyclic stress-strain curves parameters α and A_1 at room (20°C) and elevated (250°C–350°C) temperatures are given in Table 2. There is no strongly outstanding result of the materials because mean values of the parameters are similar to median values.

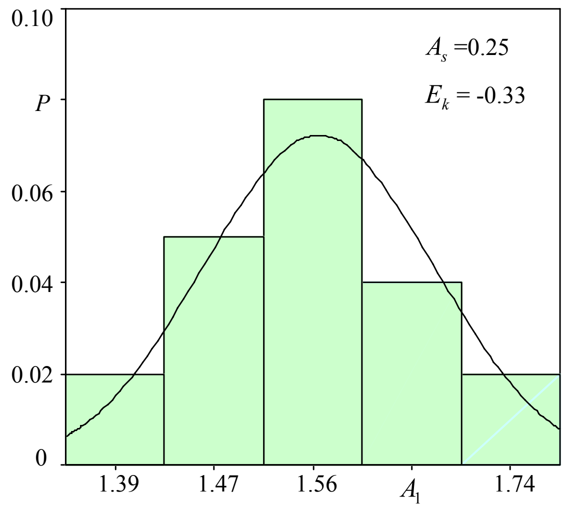


Fig. 1 Histogram of parameter A_1 for Cr–Ni–Mo steels weld metals at room temperature

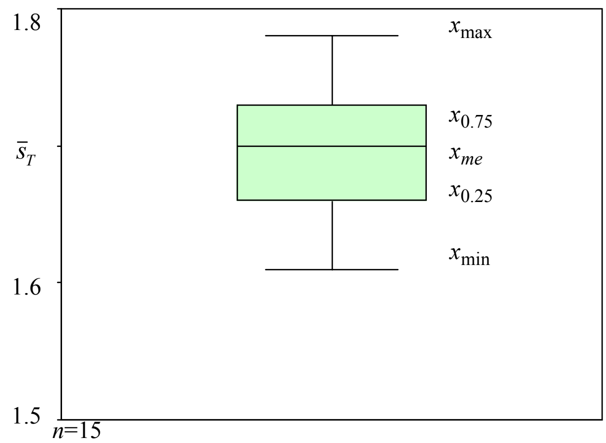


Fig. 2 Rectangular diagram of parameters $\bar{s}_T$ for Cr–Ni–Mo–V steels weld metals at elevated temperature

Table 1

Number and percentage of the material's groups

Group of the material	Room temperature		Elevated temperature	
	Number	%	Number	%
Cr–Ni	20	26.7	10	25.0
Cr–Ni–Mo	27	36.0	12	30.0
Cr–Ni–Mo–V	28	37.3	18	45.0
Total	75	100.0	40	100.0

Table 2

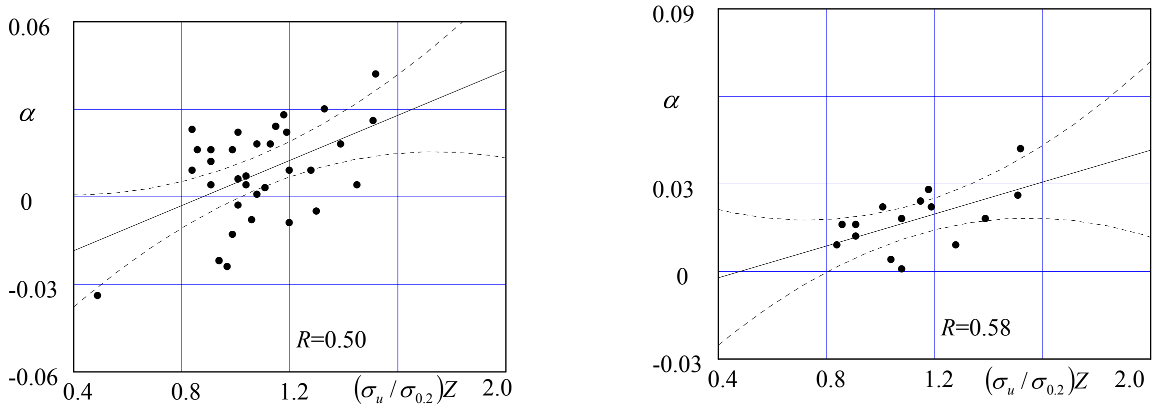
Statistical characteristics of stress-strain curves parameters A_1, α, $\bar{s}_T$ of weld metals at room and elevated temperatures

Parameters	Cr–Ni			Cr–Ni–Mo			Cr–Ni–Mo–V		
	Room temperature								
	$\bar{s}_T$	α	A_1	$\bar{s}_T$	α	A_1	$\bar{s}_T$	α	A_1
Number of materials	15	17	17	22	22	21	23	22	21
Mean value	1.66	0.013	1.67	1.74	0.016	1.57	1.84	0.022	1.63
Median value	1.62	0.010	1.71	1.77	0.017	1.57	1.83	0.024	1.63
Minimum value	1.55	-0.002	1.42	1.38	-0.002	1.39	1.6	-0.003	1.49
Maximum value	1.87	0.040	1.84	2.11	0.036	1.78	2.25	0.055	1.85
Kurtosis coefficient	-0.14	0.73	0.50	-0.78	-1.32	-0.33	-0.32	0.10	-0.38
Skewness coefficient	0.89	1.12	-1.05	-0.41	-0.07	0.25	0.56	0.14	0.45
	Elevated temperature								
Number of materials	5	3	6	9	10	10	15	15	15
Mean value	1.74	-0.003	1.57	1.71	-0.003	1.38	1.70	0.018	1.40
Median value	1.72	-0.005	1.58	1.70	0.001	1.37	1.70	0.018	1.36
Minimum value	1.64	-0.009	1.43	1.64	-0.034	1.10	1.61	0.001	1.16
Maximum value	1.85	0.004	1.69	1.78	0.018	1.71	1.78	0.042	1.73
Kurtosis coefficient	0.53	-	-1.42	-0.17	-0.25	-1.33	-0.63	1.12	-0.76
Skewness coefficient	0.41	1.06	-0.25	0.16	-0.60	0.20	0.025	0.52	0.52

In previous works [5, 6] the accomplished statistical analysis conformed that the results of the parameters $\bar{s}_T$, α and A_1 of cyclic stress-strain curves correlate the best with the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ at room and elevated temperatures. Accordantly the dependences of the cyclic stress-strain parameters α on the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ for integrated group of Cr–Ni–Mo–V steels weld metals and 95% confidence interval boundaries (dotted line) for the theoretical regression line at elevated temperature are depicted in Fig. 3. The same dependences of the proportionality limit stress $\bar{s}_T$ on the mechanical characteristic for integrated group of Cr–Ni–Mo–V steels weld metals at elevated temperature and 95% confidence interval ranges (dotted line) to theoretic line are represented in Fig. 4. As we can see from Figs. 3 and 4 the scatter of the results, dependences for the characteristics α and $\bar{s}_T$ of cyclic stress-strain curves on the modified plasticity criterion, that fall in to 95% confidence interval boundaries to theoretic line are better for separated group than for integrated group at elevated temperature. The number of percentage for the results inside 95% confidence interval for cyclic stress-strain curves parameters α on the modified plasticity criterion of Cr–Ni–Mo–V steels weld metals is 53.3%, while for the integrated group it includes only 21.2%. Analogical results are for the dependence of the characteristics $\bar{s}_T$ on the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$. It is 60% for Cr–Ni–Mo–V welded joints and 40% for integrated group. Therefore we can say that with 95% guaranty the scatter of the results of proportionality limit stress $\bar{s}_T$ and low cycle stress-strain curve's parameters α, A_1 on the modified plasticity criterion is better for separated group than the scatter of results for integrated group.

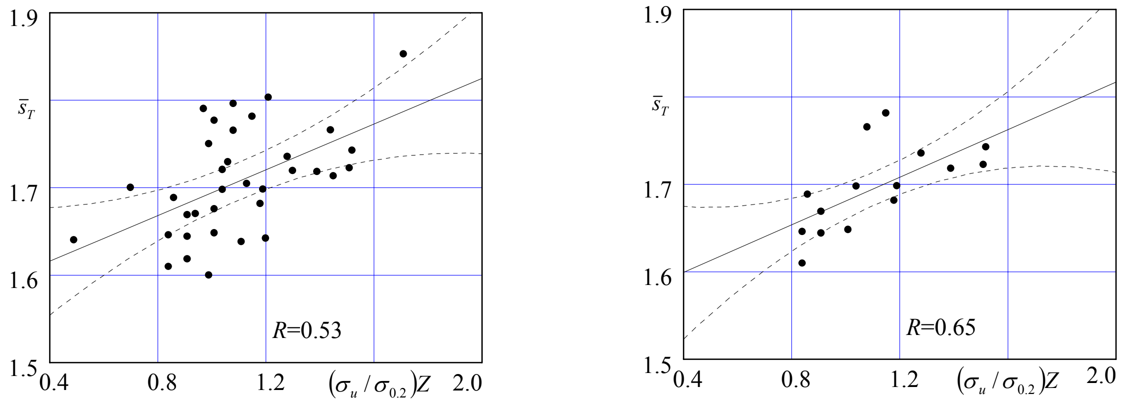
Correlation analysis is statistical relation strength between analyzed variables, which is expressed by correlation coefficient. Pearson's correlation coefficient describes the strength of linear dependence between the random and normally distributed results. Correlation analysis is used to determine linear correlations [7]. If linear model is not adequate, it is necessary to adapt nonlinear model. It other works it was determined, that the best approximation choice for the analyzed parameters is linear regression, accordingly the accomplished statistical analysis conformed that the low cycle stress-strain curve's parameters correlate the best with the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ at room and elevated temperatures. The result given in Table 3 confirmed, that the parameters A_1, α and $\bar{s}_T$ of low cycle stress-strain curves for the grouped weld metals are linearly dependent on the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ at room and elevated temperatures. Pearson correlation coefficient vary from the minimum value $|-0.24|$ for the parameter α of integrated group of weld metals at room temperature to the maximum value $|0.99|$ for Cr–Ni steelsweld metals of alloyed structural steels at elevated temperature. The correlation coefficient for the classified by the chemical composition groups of the weld metals is better than for integrated group at room and elevated temperature. Therefore we can say, that the grouping of the random and normally distributed results by the chemical composition influences the stronger linear relationship between the parameters A_1, α, $\bar{s}_T$ of low cycle stress-strain curves and the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ for weld metals at room and elevated temperatures.

The correlation analysis of weld metals, grouping them by chemical composition, showed, that cyclic characteristics and the modified plasticity criterion are significant by correlated by linear regression. Accordinglyanalytical linear dependences of these parameters for weld metals of Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V alloyed struc-



a b

Fig. 3 Dependence of parameter α on modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ at elevated temperature and 95% confidence interval (doted line): a – for integrated group of weld metals; b – for Cr–Ni–Mo–V steels weld metals



a b

Fig. 4 Dependence of proportionality limit stress $\bar{s}_T$ on modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ at elevated temperature and 95% confidence interval (doted line): a – for integrated group of weld metals; b – for Cr–Ni–Mo–V steels weld metals

Table 3

Correlation analysis of the parameters $\bar{s}_T$, α, A_1 and the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ at room and elevated temperature

Chemical composition (groups)	Pearson correlation coefficient *r*					
	Room temperature			Elevated temperature		
	$\bar{s}_T$	α	A_1	$\bar{s}_T$	α	A_1
Cr–Ni	0.73	-0.63	0.63	0.93	0.99	-0.72
Cr–Ni–Mo	0.43	-0.47	0.48	0.58	0.76	-0.59
Cr–Ni–Mo–V	0.44	0.51	0.36	0.65	0.58	-0.69
Integrated group	0.37	-0.24	0.34	0.53	0.50	-0.37

tural steels at room and elevated temperature are given in Table 4.

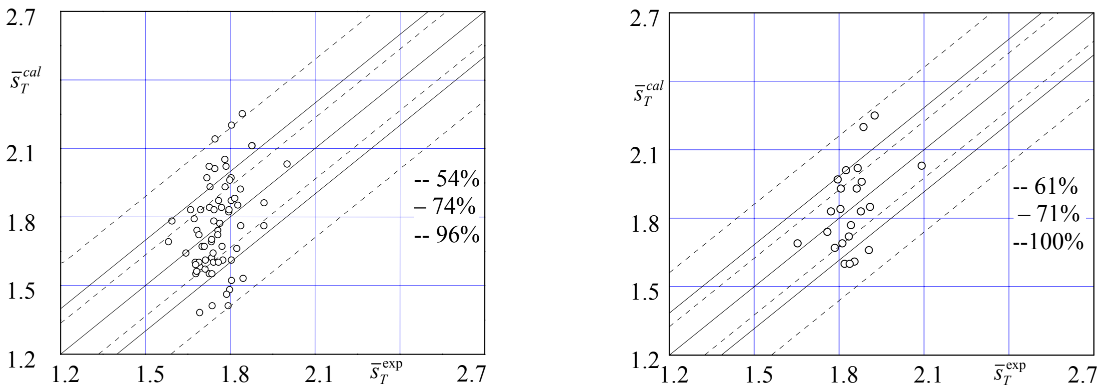
The experimental and calculated results were distributed according normal law in the intervals: $\bar{x} \pm 1.96s$ with the propobility $P \approx 0.95$ (95% of the normal curve area); $\bar{x} \pm s$ with the propobility $P \approx 0.68$; $\bar{x} \pm 1.96s$ with the propobility $P \approx 0.95$. Here $\bar{x}$ is the mean value of the cyclic stress–stain curves characteristics $\bar{s}_T$, α and A_1; s is standard deviation [8]. The comparison of experimental $\bar{s}_T^{\exp}$ and calculated $\bar{s}_T^{cal}$ parameters of integrated and grouped Cr–Ni–Mo–V steelsweld metals at room temperature are shown in Fig. 5. The intervals are narrower for Cr–Ni–Mo–V group than for the integrated group (because the correlation cofficients are better) therefore the standart deviation is smaller.

However, in the intervals $\bar{x} \pm 0.675 \cdot s$, $\bar{x} \pm s$, $\bar{x} \pm 1.96 \cdot s$ the scatter of results is better for the group of the materials, classified by chemical composition, than for the integrated group at room temperature. The comparison of the experimental $\bar{s}_T^{exp}$ and calculated $\bar{s}_T^{cal}$ parameters at room temperature showed, that the scatter of the results, within the interval $\bar{x} \pm 1.96s$ is 4% greater for the integrated group of weld metals of alloyed structural steels comparing with the results of grouped Cr–Ni–Mo–V steels

Table 4

Analytical dependences of the parameters α , A_1 , $\bar{s}_T$ on the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ at room and elevated temperature

Weld metals of Cr–Ni alloyed structural steels	Weld metals of Cr–Ni–Mo alloyed structural steels	Weld metals of Cr–Ni–Mo–V alloyed structural steels
Room temperature		
$\alpha = 0.053 - 0.040(\sigma_u/\sigma_{0.2})Z$ $A_1 = 1.26 + 0.426(\sigma_u/\sigma_{0.2})Z$ $\bar{s}_T = 1.27 + 0.395(\sigma_u/\sigma_{0.2})Z$	$\alpha = 0.051 - 0.036(\sigma_u/\sigma_{0.2})Z$ $A_1 = 1.30 + 0.284(\sigma_u/\sigma_{0.2})Z$ $\bar{s}_T = 1.18 + 0.575(\sigma_u/\sigma_{0.2})Z$	$\alpha = -0.023 + 0.044(\sigma_u/\sigma_{0.2})Z$ $A_1 = 1.45 + 0.179(\sigma_u/\sigma_{0.2})Z$ $\bar{s}_T = 1.43 + 0.410(\sigma_u/\sigma_{0.2})Z$
Elevated temperature		
$\alpha = -0.073 + 0.053(\sigma_u/\sigma_{0.2})Z$ $A_1 = 2.08 - 0.369(\sigma_u/\sigma_{0.2})Z$ $\bar{s}_T = 1.20 + 0.381(\sigma_u/\sigma_{0.2})Z$	$\alpha = -0.071 + 0.070(\sigma_u/\sigma_{0.2})Z$ $A_1 = 2.53 - 1.156(\sigma_u/\sigma_{0.2})Z$ $\bar{s}_T = 1.60 + 0.121(\sigma_u/\sigma_{0.2})Z$	$\alpha = -0.013 + 0.027(\sigma_u/\sigma_{0.2})Z$ $A_1 = 2.04 - 0.588(\sigma_u/\sigma_{0.2})Z$ $\bar{s}_T = 1.55 + 0.136(\sigma_u/\sigma_{0.2})Z$



a b

Fig. 5 Comparison of experimental $\bar{s}_T^{\,exp}$ and calculated $\bar{s}_T^{\,cal}$ parameters at room temperature: a – for integrated group of weld metals; b – for Cr–Ni–Mo–V steels weld metals

weld metals. The analogical results are obtained for parameters α and A_1 of weld metals at room temperature. The scatter of the results at elevated temperature for all grouped weld metals in interval $\bar{x} \pm 1.96s$ with the probilistic $P \approx 0.95$, is 100% . However, in the narrower intervals $\bar{x} \pm 0.675s$ and $\bar{x} \pm s$ with the probabilities $P \approx 0.50$ and $P \approx 0.68$ accordingly, the scatter of results is better for all the groups of materials, classified by chemical composition, than for the integrated group. Therefore, it is possible to conclude that grouping of the random, normally distributed data by the chemical composition gives more valuable information, because the stronger linear relationship between the low cycle stress-strain curves' parameters and the modified plasticity criterion is obtained for different groups at room and elevated temperature.

4. Conclusions

1. Correlation coefficient of the parameters α , A_1 and $\bar{s}_T$ for integrated group is smaller $|0.02| - |0.49|$ than for Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo– V steels weld metals at room and elevated temperature.

2. With 95% guaranty the scatter of the results of proportionality limit stress $\bar{s}_T$ and cyclic stress-strain parameters α , A_1 on the modified plasticity criterion for separated groups is smaller than the scatter of results for integrated group.

3. The scatter of the results, within the interval $\bar{x} \pm 1.96s$ is 4% greater for integrated group of weld metals comparing with the results of grouped Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V steels weld metals at room temperature. The number of the results for all weld materials' groups at elevated temperature between the experimental α^{exp} , A_1^{exp} , $\bar{s}_T^{exp}$ and calculated α^{cal} , A_1^{cal} , $\bar{s}_T^{cal}$ parameters that fall in to the interval $\bar{x} \pm 1.96 \cdot s$ boundaries is 100%. But in the narrower intervals $\bar{x} \pm 0.675 \cdot s$ and $\bar{x} \pm s$ the scatter of results is from 10% to 52% better for all the groups of materials, classified by chemical composition, than for the integrated group.

4. Proposed analytical dependencies are recommended for preliminary evaluation of the low cycle stress-strain parameters and durability. Accomplished analysis showed that additional grouping of the materials by the chemical composition has influence while defining the parameters by the modified plasticity criterion at room and elevated temperatures.

References

1. **Zeng, Z., Fatemi, A.** Elasto-plastic stress and stain behavior at notch roots under monotonic and cyclic loadings. -Journal of Strain Analysis, 2001, vol.36, no.3, p.287-300.
2. **Daunys, M., Bazaras, Z., Timofeev, B.T.** Low cycle fatigue of materials in nuclear industry. -Mechanika. -Kaunas: Technologija, 2008, Nr.5(73), p.12-17.
3. **Serdjuks, D., Rocēns K., Pakrastiņš L.** Hybrid com-

posite cable with an increased specific strength for tensioned structures. -The Baltic Journal of Road and Bridge Engineering. -Vilnius: Technika, 2008, vol.III, No3, p.129-136.

4. **Kuranovas, A., Goode, D., Kvedaras, A. K., Zhong, S.** Load-bearing capacity of concrete-filled steel columns. -Journal of Civil Engineering and Management International research and Achievements. -Vilnius: Technika, 2009, vol.15, No.1, p.21-33.
5. **Daunys, M., Šniuolis, R.** Statistical evaluation of low cycle loading curves parameters for structural materials by mechanical characteristics. -Nuclear Engineering and Design, 2006, vol.236, no.13, p.1352-136.
6. **Daunys, M.** Strength and fatigue life under low cycle non-stationary loading. -Vilnius: Mokslas. 1989, p.46-64 (in Russian).
7. **Ctepnov, M.N.** Statistical Evaluation Methods of the Mechanical Research Results. Catalog. -Moscow: Mashinostroenie, 1985.-232p. (in Russian).
8. **Zaks, L.** Statistical Estimation. Statistics. -Moscow, 1976, p.138-153 (in Russian).

M. Daunys, A. Stulpinaitė, R. Šniuolis

LEGIRUOTŲJŲ PLIENŲ SUVIRINIMO SIŪLIŲ MEDŽIAGŲ DEFORMAVIMO DIAGRAMŲ PARAMETRŲ STATISTINIS ĮVERTINIMAS KAMBARIO IR AUKŠTESNĖJE TEMPERATŪROJE

R e z i u m ė

Straipsnyje analizuojami 75 legiruotųjų plienų suvirinimo siūlių medžiagų tyrimo kambario temperatūroje ir 40 medžiagų tyrimo aukštesnėje temperatūroje duomenys, gauti 1970–2000 m. KTU Mašinų projektavimo katedros laboratorijoje. Šiame darbe medžiagos papildomai skirstomos į Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V grupes pagal legiravimo elementus. Nustatyta atskirų šių medžiagų grupių ciklinės proporcingumo ribos $\bar{s}_T$ ir mažaciklio nuovargio įtempių deformacijų kreivių parametrų α , A_1 priklausomybės nuo modifikuoto plastiškumo kriterijaus $(\sigma_u/\sigma_{0.2})Z$. Pasiūlytos Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V legiruotųjų plienų suvirinimo siūlių medžiagų deformavimo charakteristikų analitinės priklausomybės nuo modifikuoto plastiškumo kriterijaus kambario ir aukštesnėje temperatūroje. Deformavimo charakteristikų eksperimentinių ir skaičiuojamųjų rezultatų palyginimas parodė, kad papildomas medžiagų grupavimas pagal legiravimo elementus gali būti panaudotas tikslesnėms deformavimo charakteristikoms nustatyti pagal modifikuoto plastiškumo kriterijų.

M. Daunys, A. Stulpinaite, R. Sniuolis

STATISTICAL EVALUATION OF LOW CYCLE STRESS-STRAIN CURVES PARAMETERS FOR ALLOYED STRUCTURAL STEELS WELD METALS AT ROOM AND ELEVATED TEMPERATURE

S u m m a r y

The results, received in KTU Department of Machine Design laboratory in 1970–2000, of 75 weld metals of alloyed structural steels at room temperature and 40 welded joints at elevated temperature were analyzed in this paper. The results of the materials were additionally divided in to Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V groups. The proportionality limit stress $\bar{s}_T$ and the parameters α and A_1 of cyclic stress–stain curves linear dependences on the modified plasticity criterion $(\sigma_u/\sigma_{0.2})Z$ for separated groups of weld metals of alloyed structural steels were investigated. Analytical dependences of cyclic stress-strain parameters on the modified plasticity criterion for Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V welded joints are proposed at room and elevated temperatures. The comparison of cyclic stress-strain curves calculated and experimental characteristics results showed that additional grouping of the materials by the chemical composition has influence while defining the parameters by the modified plasticity criterion at room and elevated temperatures.

М. Даунис, А. Стулпинайте, Р. Щньуолис

СТАТИСТИЧЕСКИЙ АНАЛИЗ ПАРАМЕТРОВ ДЕФОРМИРОВАНИЯ И МАТЕРИАЛОВ СВАРНЫХ ШВОВ ЛЕГИРОВАННЫХ СТАЛЕЙ В УСЛОВИЯХ КОМНАТНОЙ И ПОВЫШЕННОЙ ТЕМПЕРАТУРЫ

Р е з ю м е

В статье анализируются данные 75 материалов сварных швов легированных сталей в условиях комнатной температуры и 40 материалов сварных швов в условиях повышенной температуры, получены в 1970–2000 г. в лаборатории кафедры проектирования машин Каунасского технологического университета. В данной работе материалы дополнительно распределены в Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V группы по легирующим элементам. Зависимости между цикловой пропорциональной границей $\bar{s}_T$ и малоцикловой усталости параметрами диаграммы деформации α , A_1 от критерия модифицированной пластичности $(\sigma_u/\sigma_{0.2})Z$ расследованы отдельно для каждой группы материалов. Предложены аналитические зависимости параметров $\bar{s}_T$, α и A_1 от критерия модифицированной пластичности для Cr–Ni, Cr–Ni–Mo, Cr–Ni–Mo–V материалов сварных швов в условиях комнатной и повышенной температуры. Сравнение результатов расчетных и экспериментальных характеристик деформации показали, что дополнительное распределение материалов может быть использовано для установки параметров деформации от критерия модифицированной пластичности.

Received July 01, 2010
Accepted October 22, 2010