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Determination of lifetime for railway carriages automatic coupler SA – 3

M. Daunys*, D. Putnaitė**
**Kaunas University of Technology, Kęstučio 27, LT-44025 Kaunas, Lithuania, E-mail: Mykolas.Daunys@ktu.lt*
***Kaunas University of Technology, Kęstučio 27, LT-44025 Kaunas, Lithuania, E-mail: Donata.Putnaite@ktu.lt*

1. Introduction

Railway is one of the main transport branches for freight transportation and carriage of passengers. Traction mechanisms connecting the carriages (i.e. automatic couplers) are the parts of the main importance. The intensity of freight transportation and carriage of passengers, economy and safety depends on technical state of the mentioned traction mechanisms [1].

During exploitation of automatic coupler stresses are varying in very wide range and depend on weight and speed of a train, railway relief [2]. The range of stress variation is from a few tenths of proportional limit of its material up to stresses exceeding proportional and yield limits of the material. Furthermore, stresses are varying nonregularly, i.e. nonstationary. Thus it is possible to determine characteristics of stress variation for each particular case only directly measuring the forces acting on automatic coupler. In such wide variation range the material of automatic coupler experiences low cycle and high cycle fatigue damage.

Low cycle fracture occurs because of accumulated fatigue damage, characterized by elastic-plastic hysteresis loop and by quasistatic damage, characterized by accumulated plastic strain in tension direction. The forces acting on railway carriages automatic coupler are varying, therefore this is stress limited low cycle loading, with freely developing strain in tension direction, so quasistatic and fatigue damages are accumulated.

2. Damage accumulation under stationary loading

Since performed experiments showed, that grade 20GL steel under stress limited low cycle loading accumulates plastic strain in tension direction, consequently material of automatic coupler accumulates low cycle quasistatic and fatigue damage, under stresses above proportional limit, and high cycle fatigue damage, under stresses below proportional limit. Therefore total damage in the material of automatic coupler should be determined by the dependence

$$d = d_n + d_K + d_N \tag{1}$$

where high cycle fatigue damage

$$d_n = \sum_i \frac{n_i}{N_i} \tag{2}$$

In Eq. (2) n_i is the number of cycles under high cycle fatigue loading at level i, N_i is the number of cycles under high cycle fatigue loading before crack initiation at this same level.

Low cycle fatigue damage [3]

$$d_N = \frac{\sum_1^k \bar{\delta}_k}{\sum_1^{k_N} \bar{\delta}_k} \tag{3}$$

and low cycle quasistatic damage

$$d_K = \sum \bar{e}_{pk} / \bar{e}_u \tag{4}$$

In Eqs. (3) and (4) and further in the text strains are normalized to the strain of materials proportional limit, i.e. $\bar{\delta}_k = \frac{\delta_k}{e_{pl}}$; $\bar{\varepsilon}_k = \frac{\varepsilon_k}{e_{pl}}$; $\bar{e}_{pk} = \frac{e_{pk}}{e_{pl}}$; $\bar{e}_u = \frac{e_u}{e_{pl}}$.

To evaluate the damage d_N under stress limited loading it is necessary for low cycle fatigue curve to calculate the number of semicycles k_N, which characterizes only fatigue damage. To determine the mentioned curve stress limited loading would be analyzed as nonstationary strain limited loading, where for the whole process of deformation up to crack initiation the following should be written [3]

$$\frac{\bar{\delta}_1}{\sum_1^{k_{N1}} \delta_k} + \frac{\bar{\delta}_2}{\sum_1^{k_{N2}} \bar{\delta}_k} + \frac{\bar{\delta}_3}{\sum_1^{k_{N3}} \bar{\delta}_k} + \ldots + \frac{\bar{\delta}_N}{\sum_1^{k_{NN}} \bar{\delta}_k} = 1 \tag{5}$$

where $\sum_1^{k_{N1}} \delta_k$ is accumulated fatigue damage before crack initiation under loading level with corresponding hysteresis loop $\bar{\delta}_1$; $\sum_1^{k_{N2}} \delta_k$ is accumulated fatigue damage before crack initiation under loading level with corresponding hysteresis loop $\bar{\delta}_2$ and etc.

From strain limited low cycle loading curve in coordinates $lg\,\bar{\delta}_{mean} - lg\,k_N$ the following was derived

$$\sum_1^{k_N} \bar{\delta}_k = C_2 k_N^{1-\alpha_2} \tag{6}$$

Applying coordinates $lg\,\bar{\varepsilon} - lg\,k_N$ it was derived that $\bar{\varepsilon} k_N^{\alpha_1} = C_3$, where $C_3 = 2^{m_1} C_1$, and

$$k_N = \frac{C_3^{1/\alpha_1}}{\bar{\varepsilon}^{1/\alpha_1}} \quad (7)$$

Inserting Eqs. (6) and (7) into (5) and introducing variable $1-\alpha_2/\alpha_1=\alpha_3$ we obtain

$$\frac{\bar{\delta}_1\bar{\varepsilon}_1^{\alpha_3}}{C_2C_3^{\alpha_3}}+\frac{\bar{\delta}_2\bar{\varepsilon}_3^{\alpha_3}}{C_2C_3^{\alpha_3}}+\frac{\bar{\delta}_3\bar{\varepsilon}_3^{\alpha_3}}{C_2C_3^{\alpha_3}}+...+\frac{\bar{\delta}_{kN}\bar{\varepsilon}_{kN}^{\alpha_3}}{C_2C_3^{\alpha_3}}=1 \quad (8)$$

Fig. 1 shows low cycle fatigue curves under stress limited loading, taking into account fatigue damage according to dependence (8). The curve *1* corresponds to symmetric cycle and curve *2* – pulsating cycle.

Table 1 presents fatigue damage d_N, quasistatic damage d_K and total damage d under symmetrical stress limited loading. It is seen that at higher loading levels larger is quasistatic damage, and at lower loading levels larger is fatigue damage. Mean value of total damage under symmetric loading for the investigated levels is $d=1.0148$.

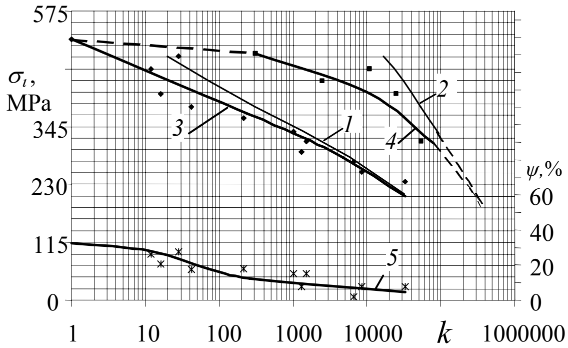

Fig. 1 Low cycle curves of grade 20GL steel (*3*, *4*) and reduction of area (*5*); ◆ - experimental points for symmetric cycle (*R*=-1); ■ - experimental points for pulsating cycle (*R*=0), ⁎ - experimental points for reduction of area

Table 1

Damage accumulation under symmetric stress limited loading

Damage \ σ_i, MPa	410	385	362	335	315	295	275	255
d_N	0.405	0.510	0.608	0.612	0.632	0.643	0.65	0.66
d_K	0.689	0.637	0.443	0.388	0.356	0.337	0.288	0.263
d	1.09	1.148	1.051	1.000	0.988	0.98	0.938	0.923

Fig. 2 shows how at symmetric loading varies fatigue damage d_N and quasistatic damage d_K as the number of semicycles is varying from 1 up to fracture semicycle k_N. Damage values up to fracture semicycle are presented in Table 1.

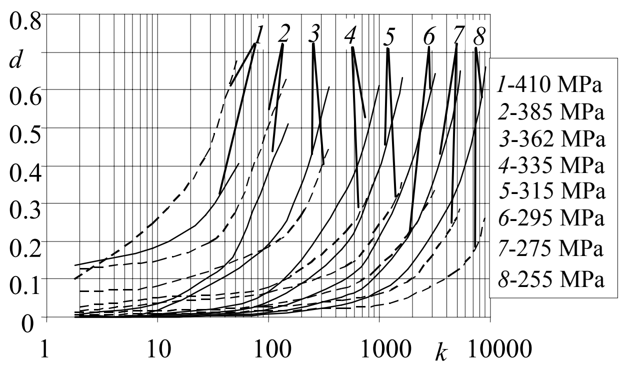

Fig. 2 Damage variation at symmetric loading: ____ fatigue damage, _ _ _ _ quasistatic damage

Fig. 3 and 4 presents quasistatic and fatigue damage variation at symmetric loading calculated by real width of the hysteresis loop (dotted curve) and calculated by mean width of the hysteresis loop (dashed curve). As it is seen the more significant discrepancy between the curves is at a small number of loading cycles. Furthermore, under loading from 410 to 335 MPa larger is the damage calculated by real width of the hysteresis loop, but for lower loading levels larger becomes the damage calculated by mean width of the hysteresis loop. Total quasistatic damage calculated by real width of the hysteresis loop is $d_K = 0.425$, and calculated by mean width of the hysteresis loop is $d_K = 0.393$. Total fatigue damage calculated by real width of the hysteresis loop is $d_N = 0.59$, and calculated by mean width of the hysteresis loop is $d_N = 0.579$.

Table 2 presents fatigue damage d_N, quasistatic damage d_K and total damage d under pulsating loading. It is observable, that at higher loading levels larger is quasistatic damage, and at lower loading levels larger is fatigue damage. Mean value of total damage under pulsating loading for the investigated levels is $d=0.969$.

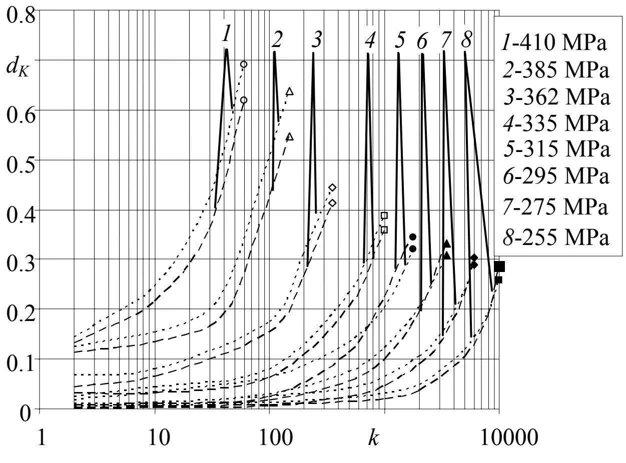

Fig. 3 Quasistatic damage variation at symmetric loading: ...... calculated by real width of the hysteresis loop, _ _ _ _ calculated by mean width of the hysteresis loop

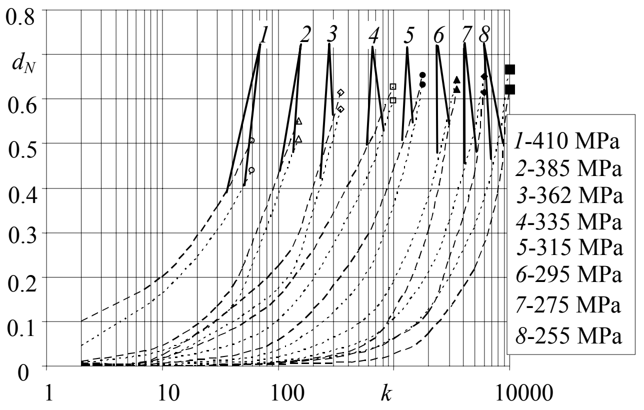

Fig. 4 Fatigue damage variation at symmetric loading: .... calculated by real width of the hysteresis loop, – – – – calculated by mean width of the hysteresis loop

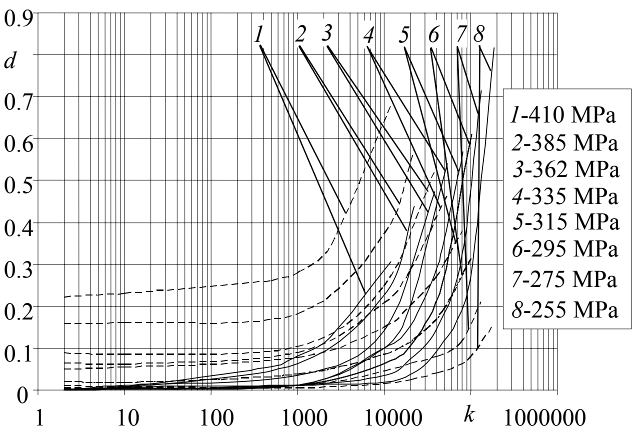

Fig. 5 Damage variation at pulsating loading: —— fatigue damage, – – – – quasistatic damage

Table 2

Damage accumulation under pulsating stress limited loading

Damage \ σ_i, MPa	410	385	362	335	315	295	275	255
d_N	0.305	0.439	0.472	0.541	0.568	0.61	0.714	0.817
d_K	0.676	0.573	0.522	0.462	0.381	0.312	0.211	0.146
d	0.982	1.012	0.994	1.003	0.949	0.922	0.925	0.963

Fig. 5 shows how at pulsating loading varies fatigue damage d_N and quasistatic damage d_K as the number of semicycles is varying from 1 up to fracture semicycle k_N. Damage values up to the fracture semicycle are presented in Table 2.

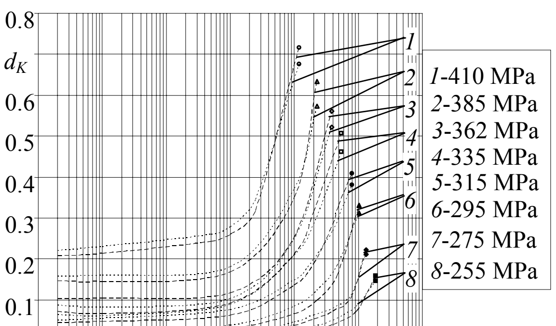

Fig. 6 Quasistatic damage variation at pulsating loading: .... calculated by real width of the hysteresis loop, – – – – calculated by mean width of the hysteresis loop

Fig. 6 and 7 shows quasistatic and fatigue damage variation at pulsating loading calculated by real width of the hysteresis loop (dotted curve) and calculated by mean width of the hysteresis loop (dashed curve). As it is seen the more significant discrepancy between the curves is under a small number of loading cycles. Furthermore, under loading 410 to 315 MPa larger is the damage calculated by real width of the hysteresis loop, but for lower loading levels larger becomes the damage calculated by mean width of the hysteresis loop. Total quasistatic damage which was calculated by real width of the hysteresis loop is $d_K = 0.410$, and calculated by mean width of the hysteresis loop is $d_K = 0.442$. Total fatigue damage calculated by real width of hysteresis hysteresis loop is $d_N = 0.558$, and calculated by mean width of hysteresis loop is $d_N = 0.520$.

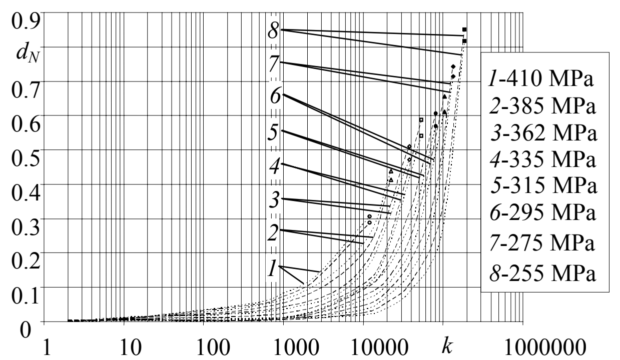

Fig. 7 Fatigue damage variation at pulsating loading: .... calculated by real width of the hysteresis loop, – – – – calculated by mean width of the hysteresis loop

The material of analyzed railway carriages automatic coupler, i.e. grade 20GL steel, is nonsignificantly cyclicallity softening ($\alpha = 0.123$), so earlier assumptions were examined, regarding the application of stable hysteresis loop width, when calculating fatigue and quasistatic damages by real width and mean width of the hysteresis loop, determined by $k_f / 2$. After checking this for symmetric and pulsating loading cycles it was determined that significantly smaller is the error of pulsating cycle, as so is the automatic coupler loaded. The performed calculations let us suppose that the used assumption gives small errors of calculation, however the process of calculation is significantly simplified in this case, furthermore, it is not necessary to know loading history of the part, and is enough to have stress levels and the number of loading semicycles for each level.

3. Damage accumulation under nonstationary loading

During exploitation an automatic coupler is under time dependent nonstationary loading. Therefore lifetime calculations of mentioned coupler, having determined during exploitation loading history, should be performed according to earlier obtained dependencies for the calculation of damage at stress concentration zones under nonstationary loading [3]. Thus in the zones without concentration the elements and parts involved are under nonstationary loading due to external forces or semicycles, and in the zones of concentration exists dual non-stationarity due to redistribution of stresses and strains caused by concentrator and because of nonstationarity of external loading.

In such cases when cyclically hardening or softening of material is nonsignificant it is possible to use simplified linear summation by cycles, do not taking into account the variation of hysteresis loop and supposing that the later does not depend on the number of semicycles. Therefore

$$d_{N_{ij}} = \frac{\sum^{k_{1j}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2}}{C_2^{\,1/m_2}} + \frac{\sum^{k_{2j}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2}}{C_2^{\,1/m_2}} + \ldots + \frac{\sum^{k_{ij}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2}}{C_2^{\,1/m_2}} \quad (9)$$

where

$$\left.\begin{aligned}
&\sum^{k_{1j}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} = \sum_{1}^{k_1} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} + \sum_{k_{12}}^{k_{12}+k_i} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} + \ldots \\
&\quad + \sum_{k_{1j}}^{k_{1j}+k_1} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2}, \\
&\sum^{k_{2j}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} = \sum_{k_{21}}^{k_{21}+k_2} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} + \sum_{k_{22}}^{k_{22}+k_2} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} + \ldots \\
&\quad + \sum_{k_{2j}}^{k_{2j}+k_2} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2}, \\
&= = = = = = = = = = = = = = = = = = \\
&\sum^{k_{ij}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} = \sum_{k_{i1}}^{k_{i1}+k_i} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} + \sum_{k_{i2}}^{k_{i2}+k_i} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} + \ldots \\
&\quad + \sum_{k_{ij}}^{k_{ij}+k_i} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2}
\end{aligned}\right\} \quad (10)$$

In Eqs. (9) and (10): D_e is stress state coefficient evaluating the decrease of the material plasticity

$$D_e = \frac{\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}}{\sqrt{2}(\sigma_1 + \sigma_2 + \sigma_3)} \quad (11)$$

where $\sigma_1, \sigma_2, \sigma_3$ are principals stresses; i is the number of loading levels, j is the number of loading blocks.

As for Eq. (9) material stability is valid, so for cyclically anisotropic materials, i.e. materials which accumulate plastic strain in tension direction, fatigue failure is calculated according to hysteresis loops of 1st and 2nd semicycles. So it is possible to perform the simplification of Eq. (9) into Eq. (12).

$$\left.\begin{aligned}
&\sum^{k_{1j}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} = jn_1 \left[\left(\frac{\bar{\delta}_{i1}}{D_e} \right)^{1/m_2} + \left(\frac{\bar{\delta}_{i1}}{D_e} \right)^{1/m_2} \right] \\
&\sum^{k_{2j}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} = jn_2 \left[\left(\frac{\bar{\delta}_{i1}}{D_e} \right)^{1/m_2} + \left(\frac{\bar{\delta}_{i2}}{D_e} \right)^{1/m_2} \right] \\
&= = = = = = = = = = = = = = = \\
&\sum^{k_{ij}} \left(\frac{\bar{\delta}_{ik}}{D_e} \right)^{1/m_2} = jn_i \left[\left(\frac{\bar{\delta}_{i1}}{D_e} \right)^{1/m_2} + \left(\frac{\bar{\delta}_{i2}}{D_e} \right)^{1/m_2} \right]
\end{aligned}\right\} \quad (12)$$

Damage due to plastic strain in tension direction accumulated at the zones of concentration under nonstationary stress limited loading is calculated by the dependence

$$d_{Kij} = \frac{1}{D_e \bar{e}_u} \left(\bar{e}_{ipk1j} + \bar{e}_{ipk2j} + \ldots + \bar{e}_{ipkij} \right) \quad (13)$$

where

$$\left.\begin{aligned}
&\bar{e}_{ipk1j} = \bar{e}_{i1} - \bar{\sigma}_{i1} + \sum_{1}^{k_1} (-1)^k \bar{\delta}_{ik} + \sum_{k_{12}}^{k_{12}+k_1} (-1)^k \bar{\delta}_{ik} + \ldots \\
&\quad + \sum_{k_{1j}}^{k_{1j}+k_1} (-1)^k \bar{\delta}_{ik} \\
&\bar{e}_{ipk2j} = \sum_{k_{21}}^{k_{21}+k_2} (-1)^k \bar{\delta}_{ik} + \sum_{k_{22}}^{k_{22}+k_2} (-1)^k \bar{\delta}_{ik} + \ldots \\
&\quad + \sum_{k_{2j}}^{k_{2j}+k_2} (-1)^k \bar{\delta}_{ik} \\
&= = = = = = = = = = = = = = = = = \\
&\bar{e}_{ipkij} = \sum_{k_{i1}}^{k_{i1}+k_i} (-1)^k \bar{\delta}_{ik} + \sum_{k_{i2}}^{k_{i2}+k_i} (-1)^k \bar{\delta}_{ik} + \ldots \\
&\quad + \sum_{k_{ij}}^{k_{ij}+k_i} (-1)^k \bar{\delta}_{ik}
\end{aligned}\right\} \quad (14)$$

Commonly quasistatic damage because of accumulated plastic strain in tension direction is calculated by dependencies (13) and (14). Applying simplifications, used for the calculation of fatigue damage, it is possible to calculate quasistatic damage by dependence.

$$\left.\begin{aligned}
&\bar{e}_{ipk_{1j}} = \bar{e}_{i1} - \bar{\sigma}_{i1} + jn_1 \left(\bar{\delta}_{i2} - \bar{\delta}_{i1} \right) \\
&\bar{e}_{ipk_{2j}} = jn_2 \left(\bar{\delta}_{i2} - \bar{\delta}_{i1} \right) \\
&= = = = = = = = = = = = = = = = \\
&\bar{e}_{ipki_j} = jn_i \left(\bar{\delta}_{i2} - \bar{\delta}_{i1} \right)
\end{aligned}\right\} \quad (15)$$

Table 3 presents low cycle fatigue damage $\left(d_N\right)$, quasistatic fatigue damage $\left(d_K\right)$ and static loading damage $\left(\frac{\bar{e}_0-\bar{\sigma}_0}{\bar{e}_u}\right)$, which arises in null (initial) semicycle and total low cycle fatigue damage (d) for one pulsating loading cycle.

Table 3

Low cycle damage for one pulsating cycle

Damage / σ_i, MPa	n	d_N	d_K	$\frac{\bar{e}_0-\bar{\sigma}_0}{\bar{e}_u}$	d
376.2	3.7	$3.19*10^{-5}$	$4.78*10^{-5}$	$5.58*10^{-2}$	$5.59*10^{-2}$
332	4.7	$1.83*10^{-5}$	$3.08*10^{-5}$	$3.35*10^{-2}$	$3.35*10^{-2}$
293	8.1	$1.15*10^{-5}$	$4.89*10^{-6}$	$3.36*10^{-3}$	$3.38*10^{-3}$
254	13.2	$7.66*10^{-6}$	$1.17*10^{-6}$	$1.86*10^{-4}$	$1.95*10^{-4}$
197	22.6	$4.74*10^{-6}$	-	-	$4.74*10^{-6}$

Having stresses of automatic coupler loading levels and the number of loading cycles for every level during specific time interval (per haul, per year and etc.) accumulated damage for that interval is calculated. According to the number of cycles n (Table 3) presented in literature [4, 5] and stresses from literature [6] annual damage is $d=5.66\cdot10^{-2}$. High cycle fatigue damage due to stresses from proportional limit $\sigma_{pl}=230$ MPa up to fatigue limit $\sigma_0=192$ MPa for symmetric cycle: $d=5.67\cdot10^{-2}$.

Fatigue limit is obtained by known ultimate strength applying dependencies [7] and performing conversion into pulsating cycle using Goodman diagram [8]

$$\sigma_{-1}=(0.35\div0.45)\cdot\sigma_u \quad (16)$$

$$\sigma_0=(0.65\div0.75)\cdot\sigma_{-1} \quad (17)$$

The results of calculation show that static overloads of automatic coupler, causing large quasistatic failures, are especially dangerous.

4. Conclusions

1. In order to determine crack initiation lifetime in automatic coupler it is necessary to know exact loading history, i.e. the sequence of loading levels, the number of cycles for each level. It is possible to obtain such data only by registering the variation of forces or strains in automatic coupler during the specific trip. Consequently we propose to perform general calculations do not taking into account loading history, but using only specific levels and the number of cycles therein, i.e. applying presented in literature statistically processed operation data.

2. The material of analyzed automatic coupler is nonsignificantly ($\alpha=0.123$) cyclically softening grade 20GL steel, therefore variation of accumulated fatigue and quasistatic damage, depending on the number of loading semicycles, showed that it is possible to calculate mentioned damages neglecting cyclic softening of the material and performing calculations by the width of the hysteresis loop at midpoint of lifetime within semicycle.

3. Taking into account the assumptions given in conclusions 1 and 2, it is possible to calculate low cycle fatigue, quasistatic damage, high cycle and static damage at one cycle due to stresses at dangerous zones of automatic coupler depending on loading level.

4. When stresses of automatic coupler, loading levels and the number of loading cycles for every level are known, during particular time interval (per haul, per year and etc.) accumulated failure for that interval may be calculated.

5. Calculation results presented in this paper show, that static overloads of automatic coupler causing large quasistatic failure are especially dangerous. Therefore after train accidents, i.e. train's carriages overturns, derailments automatic couplers must be checked especially thoroughly (i.e. it is necessary to perform expertise of automatic coupler for the presence of residual strain or cracks).

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M. Daunys, D. Putnaitė

GELEŽINKELIO RIEDMENŲ AUTOMATINĖS SANKABOS SA-3 ILGAAMŽIŠKUMO NUSTATYMAS

R e z i u m ė

Straipsnyje pateikta geležinkelio riedmenų automatinės sankabos ilgaamžiškumo analizė. Automatinės sankabos apkrovimas laikui bėgant kinta priklausomai nuo traukinio sąstato svorio, judėjimo greičio ir geležinkelio reljefo.

Apskaičiavus įtempių deformacijų būvį automatinės sankabos korpuse, nustatyta, kad automatinė sankaba

yra veikiama statinių, mažaciklių kvazistacinių ir nuovargio pažeidimų, tai pat daugiaciklių pažeidimų. Todėl automatinės sankabos ilgaamžiškumui apskaičiuoti yra pasiūlytos mažaciklio nestacionaraus minkšto apkrovimo priklausomybės, įvertinančios mažaciklius kvazistacinius ir nuovargio pažeidimus.

Daugiacikliams nuovargio pažeidimams įvertinti siūloma taikyti linijinį apkrovimo ciklų skaičiaus sumavimo dėsnį. Mažacikliams pažeidimams sumuoti pasiūlyta skaičiavimo metodika, įvertinanti vieno apkrovimo ciklo sukeltus nuovargio ir kvazistacinį pažeidimus, įvertinant apkrovimo lygį ir ignoruojant ciklų seką. Todėl skaičiuojant automatinę sankabą būtina kiekvienu konkrečiu atveju nustatyti jos apkrovimo ciklų skaičių kiekviename apkrovimo lygyje ir pagal anksčiau pateiktas priklausomybes apskaičiuoti ilgaamžiškumą.

M. Daunys, D. Putnaitė

DETERMINATION OF LIFETIME FOR RAILWAY CARRIAGES AUTOMATIC COUPLER SA-3

S u m m a r y

The paper presents lifetime analysis for railway carriages automatic coupler. The loading of automatic coupler, predetermined by the weight of a train, train speed and railway relief, is time-dependent variable.

By the calculation of strain stress state in the body of automatic coupler it was determined, that automatic coupler is under static, low cycle and high cycle loading. Therefore, to calculate lifetime of automatic coupler the dependencies for low cycle nonstationary stress limited loading, evaluating low cycle quasistatic and fatigue damages, has been proposed.

To evaluate high cycle fatigue damage a linear law for the summation of loading cycles has been proposed. For low cycle damage summation a calculation method was proposed for the evaluation of fatigue and quasistatic damages created at one loading cycle, taking into account loading level and neglecting sequence of cycles. Therefore, working on calculations of automatic coupler for each specific case it is necessary to determine number of loading cycles at each loading level and calculate lifetime by presented in this work dependencies.

М. Даунис, Д. Путнаите

ОПРЕДЕЛЕНИЕ ДОЛГОВЕЧНОСТИ АВТОСЦЕПКИ СА-3 ЖЕЛЕЗНОДОРОЖНОГО ПОДВИЖНОГО СОСТАВА

Р е з ю м е

В статье приведен анализ долговечности автосцепки железнодорожного подвижного состава. Нагрузка автосцепки носит случайнопеременный во времени характер в зависимости от веса железнодорожного состава, скорости движения и рельефа железной дороги,.

При расчете напряженно – деформированного состояния корпуса автосцепки было установлено, что автосцепка подвергается статическим, малоцикловым квазистатическим и усталостным повреждениям, а также многоцикловым повреждениям. Поэтому для расчета долговечности автосцепки были предложены зависимости малоциклового нестационарного мягкого нагружения, учитывающие малоцикловые квазистатические и усталостные повреждения.

Для оценки многоцикловых повреждений предложен закон линейного суммирования числа циклов нагружения. Для сумирования малоцикловых повреждений предложена методика, оценивающая усталостные и квазистатические повреждения, созданые одним циклом нагрузки, учитывающая уровни нагрузки и игнорирующая последовательность циклов. Поэтому при расчете автосцепки, в каждом конкретном случае необходимо определить число циклов на каждом уровне нагружения и, пользуясь в работе выше приведенными зависимостями, рассчитать долговечность.

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