TESTING IN SIMULATED AND ACCELERATED REGIME OF RESISTANCE STRUCTURES / TESTAREA IN REGIM SIMULAT SI ACCELERAT A STRUCTURILOR DE REZISTENTA

Eng. Matache M.[1)], Eng. Persu I.[1)], Prof. Ph.D. Eng. Voicu Gh.[2)], Ph.D.Eng. Manea I.[3)], Assoc. Prof. PhD. Eng. Biriş S.Şt.[2)]
[1)]INMA Bucharest / Romania; [2)]P.U. Bucharest / Romania; [3)]SC Softronic SRL Craiova / Romania
Tel: 0727-957693; E-mail: matache@inma.ro

Abstract: *In the paper there are presented experimental researches regarding testing in simulated and accelerated regime of bogie frame type resistance structures. Starting from the loads at which the structure is exposed in daily exploitation , there was developed a testing programme in simulated and accelerated regime in order to verify its structural integrity and estimate its span of.*

Keywords: *testing, simulated and accelerated regime,* *resistance structure.*

Rezumat: *In lucrare sunt prezentate cercetările experimentale privind testarea in regim simulat si accelerat a structurilor de rezistenta de tip rama de boghiu. Plecând de la sarcinile la care este supusa structura in exploatare zilnic, s-a dezvoltat un program de testare in regim simulat si accelerat cu scopul de a verifica integritatea structurala a acesteia si de a-i estima durata activa de viata.*

Cuvinte cheie: *testare, regim simulat si accelerat,* *structura de rezistenta.*

INTRODUCTION

Testing in accelerated regime is the testing process of a product by subjecting it to working conditions (stress, specific strain, temperatures etc.) exceeding the normal operating parameters for discovering the failures and ways of failure in a short period of time. The purpose of the accelerated testing is to provide information on the reliability of the equipment over an as short as possible period of time [1]. By analyzing the product response to such tests, the engineers can predict the active span of life and its maintenance intervals.

Testing in simulated and accelerated regime of the resistance structure of bogie frame type equipping the passenger wagons is imposed mainly by the product final destination. The bogie frame is a critical resistance structure of the component of passenger wagons that support the wagon bodywork and taking over the most of the stresses that occur in operation. Thus, this structure must be subjected to a validation program, consisting of the following stages:

- designing;
- structural analysis with finite element;
- simulated and accelerated regime testing in the laboratory;
- testing on the railway.

As shown, the testing stage follows after the stage of structural analysis. Within the stage of structural analysis it simulates on the computer the stresses that may arise in operation and which will generate some internal stress states within the structure of the bogie. Thus, it identifies the simulated loading configurations of the bogie frame and the points likely to be subjected to maximum stresses during service duration. Within the testing phase is verified the structural integrity of the bogie frame and its resistance to fatigue. Thus the testing stage is composed of two types of tests: tests carried out in static regime and test carried out in dynamic regime that follows on the first ones.

The tests carried out in static regime simulate the stress that occurs in service. The static tests are divided into tests in which the loadings are made with exceptional strains, loads that rarely occur during exploitation of the bogie frame and testings in which the loadings are done with service chargings, strains that occur routinely during its exploitation. The tests with exceptional loads have the role to check the condition

INTRODUCERE

Testarea in regim accelerat reprezinta procesul de testare a unui produs prin supunerea la conditii de lucru (tensiune, deformatie specifica, temperaturi etc) care depasesc parametrii normali de exploatare in scopul descoperirii defectelor si a modalitatilor de esuare intr-o perioada scurta de timp. Scopul incercarilor accelerate este acela de a furniza informatii privind fiabilitatea echipamentelor intr-o perioada cat mai scurta de timp [1]. Prin analizarea raspunsului produsului la asemenea teste, inginerii pot previziona durata activa de viata si intervalele de mentenanta ale acestuia.

Testarea in regim simulat si accelerat a structurii de rezistenta de tip rama de boghiu care echipeaza vagoanele de calatori este impusa in principal de destinatia finala a produsului, acesta intrand in componenta unui tren de calatori. Rama de boghiu este o structura de rezistenta critica din componenta vagoanelor de calatori pe care se sprijina caroseria vagonului si care preia majoritatea sarcinilor care apar in exploatare. Astfel aceasta structura trebuie supusa unui program de validare, compus din urmatoarele etape:

- proiectare;
- analiza structurala cu element finit;
- testare in regim simulat si accelerat in laborator;
- testare pe cale ferată.

Dupa cum se observa, etapa de testare urmeaza etapei de analiza structurala. In cadrul etapei de analiza structurala se simuleaza pe calculator sarcinile care pot aparea in exploatare si care vor genera anumite stari de tensiuni interne in cadrul structurii de boghiu. Astfel se identifica configuratiile de incarcare simulata ale ramei de boghiu si punctele susceptibile a fi supuse unor tensiuni maxime in timpul duratei de exploatare. In cadrul etapei de testare se verifica integritatea structurala a ramei de boghiu si rezistenta acesteia la oboseala. Astfel etapa de testare este compusa din doua tipuri de teste: teste efectuate in regim static si teste efectuate in regim dinamic care le succeda pe primele.

Testele efectuate in regim static simuleaza sarcinile care apar in exploatare. Testele statice sunt impartite in teste in care incarcarile se fac cu sarcini exceptionale, sarcini care apar foarte rar in timpul exploatarii ramei de boghiu si teste in care incarcarile se fac cu sarcini de serviciu, sarcini care apar in mod curent in timpul exploatarii. Testele cu sarcini exceptionale au rolul de a that during work the yield strength of the material in which the bogie frame it is built,should not be surpassed, namely not to enter the field of plastic deformations. The tests with exploitation loadings represent tests that are performed in static regime, using for loading the extreme values that occur in the testing phase in dynamical regime. Using the results of these tests it checks the framing within the Goodmann-Smith diagram of the recorded stresses, thus estimating an "infinite" lifetime.

The tests carried out in dynamic regime actually verify the active length of life of the resistance structure of bogie frame type, this being subjected to a combination of loadings that simulate the state of stresses at which it is subjected in real working regime. The testing is accelerated because the loads are applied with a higher frequency than the actual working frequency, ratio between the two frequencies being the acceleration factor.

The test program presented is based on the European norm EN 13749:2011 which stipulates the methods for specifying the requirements regarding the resistance of the bogie frame structures.

MATERIALS AND METHODS

Researches regarding testing in simulated and accelerated regime of resistance structures of bogie frame type were carried out on a Hidropuls type testing installation, following a fatigue testing accelerated programm for one bogie frame. This paper presents the program of accelerated fatigue testing regime of a prototype bogie frame.

In operation, the bogie frame is subjected to the following load cases:

- vehicle weight including the payload,
- variations in the payload,
- irregularities of the rolling track,
- travel in curves,
- accelerations and brakings,
- minor derailments,
- impact (collision).

In reality, the loads are combining in a complex manner difficult to achieve in laboratory testing conditions. Therefore, in the current practice, are normalized load cases that are considered to be coverings for the real situations encountered on the duration of exploitation.

Fatigue tests are intended to confirm that the bogie frame is able to withstand the stresses caused by operating loads on its whole lifetime. The main acting loads are those responsible for inducing mechanical stresses in the whole structure of the bogie frame, namely: vertical forces, transversal forces and the forces due to twisting strains.

Fatigue testing program consists of repeating of cycles based on vertical and transversal forces combined with the shear demands (twisting)

The vertical forces applied on both longerons comprise:

- one statical part (1))
- one quasi-statical part: (2)
- one dynamical part: (3)

(defined in Annex G2 of SR EN 13749:2011).

verifica conditia ca in lucru sa nu se depaseasa limita de curgere a materialului din care este construita rama de boghiu, adica de a nu intra in domeniul deformatiilor plastice. Testele cu sarcini de exploatare reprezinta teste care se fac in regim static, folosind pentru incarcare valorile extreme care apar in cadrul etapei de testare in regim dinamic. Folosind rezultatele acestor teste se verifica incadrarea in interiorul diagramei Goodmann-Smith a tensiunilor inregistrate, estimandu-se astfel o durata de viata ”infinita”.

Testele efectuate in regim dinamic verifica efectiv durata activa de viata a structurii de rezistenta de tip rama de boghiu, aceasta fiind supusa la o combinatie de sarcini care simuleaza starea de tensiuni la care aceasta este supusa in regim real de lucru. Testarea este accelerata deoarece sarcinile sunt aplicate cu o frecventa superioara frecventei reale de lucru, raportul dintre cele doua frecvente fiind factorul de accelerare.

Programul de testare prezentat are la baza norma europeana EN 13749:2011 care stipuleaza metodele pentru specificarea cerintelor referitoare la rezistenta structurilor cadrelor de boghiuri.

MATERIALE ŞI METODE

Cercetările privind testarea in regim simulat si accelerat a structurilor de rezistenta de tip rama de boghiu s-au realizat pe o instalaţie de incercari de tip Hidropuls, urmărind un program de testare in regim accelerat la oboseala pentru un prototip de rama de boghiu.

In exploatare, rama de boghiu este supusa la urmatoarele cazuri de incarcare:

- greutatea vehicolului, incluzând sarcina utila,
- variaţii in sarcina utila,
- neregularitaţi ale caii de rulare,
- mers in curbe,
- acceleraţii şi frânari,
- deraieri minore,
- impact (tamponare).

In realitate sarcinile se combina intr-o maniera complexa, greu de realizat in condiţiile incercarilor de laborator. In consecinţa, in practica curenta, sunt normate cazuri de incarcare, care se considera a fi acoperitoare pentru situaţiile reale intâlnite pe durata de exploatare.

Incercarile la oboseala sunt destinate sa confirme ca rama boghiului este capabila sa reziste solicitarilor datorate sarcinilor de exploatare pe toata durata de viaţa a acestuia. Sarcinile principale care actioneaza sunt cele responsabile de inducerea solicitarilor mecanice in intreaga structura a ramei de boghiu, anume: forţele verticale, forţele transversale şi forţele datorate solicitarilor de răsucire.

Programul incercarilor la oboseala consta in repetarea ciclurilor bazate pe forţele verticale şi transversale combinate cu solicitarile de forfecare (răsucire).

Forţele verticale, aplicate pe ambele lonjeroane cuprind:

- o parte statica (1)
- o parte cvasi-statica: (2)
- o parte dinamica: (3)

(definite conform anexei G2 din SR EN 13749:2011).

$$Fz1 = Fz2 = \frac{Fz}{2} = \frac{\left(Mv + 1.2P2 - 2m^{+}\right)g}{4} \quad (1)$$

$$Fzqs1 = Fzqs2 = \frac{\pm 0.1Fz}{2} \quad (2)$$

$$Fzd1 = Fzd2 = \frac{\pm 0.2Fz}{2} \quad (3)$$

The transversal forces applied on each axis, comprise:
- the quasi-static component (4);
- the dinamical component (5).

(defined in Annex G2 of SR EN 13749:2011).

Forţele transversale, aplicate pe fiecare axa, cuprind:
- componenta cvasi-statica (4);
- componenta dinamica (5).

(definite conform anexei G2 din SR EN 13749:2011).

$$Fyqs1 = Fyqs2 = \pm 0.063\left(Fz + m^{+}g\right) \quad (4)$$

$$Fyd1 = Fyd2 = \pm 0.063\left(Fz + m^{+}g\right) \quad (5)$$

where "g" has the approximate value of 9.81 m/s^2 and represents the gravitational acceleration and m + represents the mass of the wagon loaded.

The variations of these forces in relation to the time are indicated in Figure 1.

unde „g" are valoarea aproximativa 9.81 m/s2 şi reprezinta acceleraţia gravitaţionala si m^{+} reprezinta masa vagonului incarcat.

Variaţiile acestor forţe in raport cu timpul sunt indicate in figura 1.

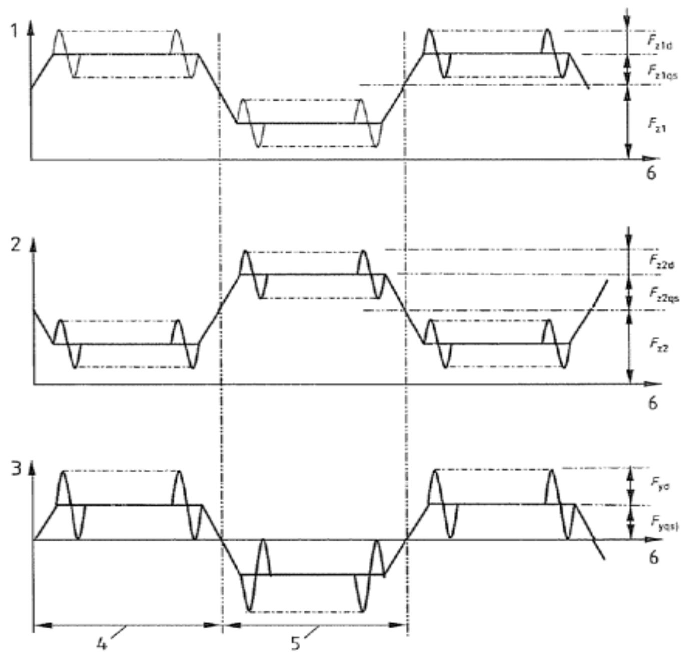

Fig.1 – The form of strains at the dynamic test to fatigue of bogies [5]

where:

1 – Fz1 – the vertical force applied on the longeron 1;
2 – Fz2 – the vertical force applied on the longeron 2;
3 – Fy – transversal force;
4 – n cycles in the curve on the right side;
5 – n cycles in the curve on the left side;
6 – number of cycles;
Fz1d – dynamic force applied on the longeron 1;
Fz2d – dynamic force applied on the longeron 2;
Fz1qs – quasi-statical force on the longeron 1;
Fz2qs – quasi-statical force on the longeron 2;
Fyqs – quasi-statical transversal force;
Fyd – dynamic transversal force.

The quasi-static stress cycles are normally reversed every 10 ... 20 dynamic cycles and the number of these cycles will be proportionally lower comparing to the number of dynamic cycles.

The torsional stress cycles (of twisting) consist of loads (or equivalent displacements) applied to primary suspension to generate a torsion in vertical plane of angle $+\theta_y$ followed by a torsion of angle $-\theta_y$ of the bogie

unde:

1 – Fz1 – forta verticala aplicata pe lonjeronul 1;
2 – Fz2 – forta verticala aplicata pe lonjeronul 2;
3 – Fy – forta transversala;
4 – n cicluri in curba pe partea dreapta;
5 – n cicluri in curba pe partea stanga;
6 – numarul de cicluri;
Fz1d – forta dinamica aplicata pe lonjeronul 1;
Fz2d – forta dinamica aplicata pe lonjeronul 2;
Fz1qs – forta cvasistatica pe pe lonjeronul 1;
Fz2qs – forta cvasistatica pe lonjeronul 2;
Fyqs – forta transversala cvasistatica;
Fyd – forta transversala dinamica.

Ciclurile de solicitare cvasi-statica sunt inversate in mod normal la fiecare 10 ... 20 cicluri dinamice, iar numarul acestor cicluri va fi proporţional mai mic comparativ cu numarul ciclurilor dinamice.

Ciclurile de solicitare de torsiune (de răsucire) constau in sarcini (sau deplasari echivalente) aplicate suspensiei primare pentru a genera o torsiune in plan vertical de unghi $+\theta_y$ urmata de o torsiune de unghi $-\theta_y$, a frame longerons, which are synchronous with the sequence of quasi-static loads. The twisting force applied to the bogie frame corresponds to an angular misalignment of the longerons in vertical plane of 0.5%.

The dynamic components of vertical and transversal forces are applied in phase, at the same frequency, so that to allow a simulation of loadings acting on the bogie frame. The same thing applies to the quasi-static components at an appropriate frequency of changing the curves direction. The sense of curves is alternately changed at every 10 dynamic cycles.

Dynamic stress fatigue loads are applied to a total of $10x10^6$ cycles as follows:

- 6×10^6 cycles with the loads calculated according to 5.2.2 and Annexes C, F and G of SR EN 13749:2011;
- 2×10^6 cycles with the loads calculated above, increased by 20%;
- 2×10^6 cycles with the loads calculated at the first point, increased by 40%.

The assessment method of resistance to fatigue chosen was the method of fatigue limit achieving, which according to [2] is the most commonly used method. For this purpose, during the application of loads are recorded the mechanical stresses and the forces applied to the bogie frame. It analyzes mechanical stresses and it is evaluated the return to "zero" after removal of loadings. For each measurement point is determined the maximum values, σ_{max}, and minimum values, σ_{min}, from which are calculated the mean values and the mechanical stress amplitudes (σ_m - the abscissa and σ_a – the ordinate in the Goodman-Smith diagram) using the relations (6):

lonjeroanelor cadrului boghiului, acestea fiind sincrone cu secvenţa sarcinilor cvasi-statice. Forţa de răsucire aplicată ramei boghiului corespunde unei dezalinieri unghiulare a lonjeroanelor in plan vertical de 0.5%.

Componentele dinamice ale forţelor verticale şi transversale sunt aplicate in faza, la aceeaşi frecvenţa, astfel incât sa permita o simulare a sarcinilor care acţioneaza asupra ramei boghiului. Acelaşi lucru se aplica la componentele cvasi-statice, la o frecvenţa corespunzatoare schimbarii sensului curbelor. Sensul curbelor este schimbat alternativ, la fiecare 10 cicluri dinamice.

Sarcinile de solicitare dinamica la oboseala sunt aplicate pe un numar total de $10x10^6$ cicluri, dupa cum urmeaza:

- 6×10^6 cicluri cu sarcinile calculate conform 5.2.2 şi anexelor C, F si G din SR EN 13749:2011;
- 2×10^6 cicluri cu sarcinile calculate mai sus crescute cu 20%;
- 2×10^6 cicluri cu sarcinile calculate la primul punct crescute cu 40%.

Metoda de evaluare a rezistentei la oboseala aleasa a fost metoda atingerii limitei de oboseala, care dupa [2] este cea mai des utilizata metoda. In acest scop, pe durata aplicarii sarcinilor se inregistreaza tensiunile mecanice si fortele aplicate ramei de boghiu. Se analizeaza tensiunile mecanice şi se evalueaza revenirea la „zero” dupa indepartarea sarcinilor. Pentru fiecare punct de masura se determina valorile maxime, σ_{max}, si minime, σ_{min}, din care se calculeaza valorile medii si amplitudinile tensiunilor mecanice (σ_m - abscisa si σ_a – ordonata in diagrama Goodman-Smith) utilizand relatiile (6):

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} \qquad \sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} \tag{6}$$

Table 1 shows the calculated values of the loadings that have been applied within the bogie frame fatigue testings performed in simulated and accelerated regime for the first 6×106 dynamic stress cycles to fatigue.

Figure 2 shows a schematic diagram of loadings used for the application of loadings at static and fatigue tests of the trailer bogie frame.

In tabelul 1 se prezinta valorile calculate ale sarcinilor care au fost aplicate ramei de boghiu purtator in cadrul testarilor de oboseala efectuate in regim simulat si accelerat, pentru primele 6×10^6 cicluri de solicitare dinamica la oboseala.

In figura 2 este prezentata schema de principiu folosita pentru aplicarea sarcinilor la incercarile statice si oboseala ale ramei de boghiu purtator.

Table 1

Type of strain	Component type	Strain value	
		[kN]	[mm]
F_y (Transversal)	quasi-static	19.85	-
	dynamic	19.85	-
F_z (Vertical)	static	128	-
	quasi-static	12.8	-
	dynamic	25.6	-
Twisting (Torsion)	quasi-static	-	1,6

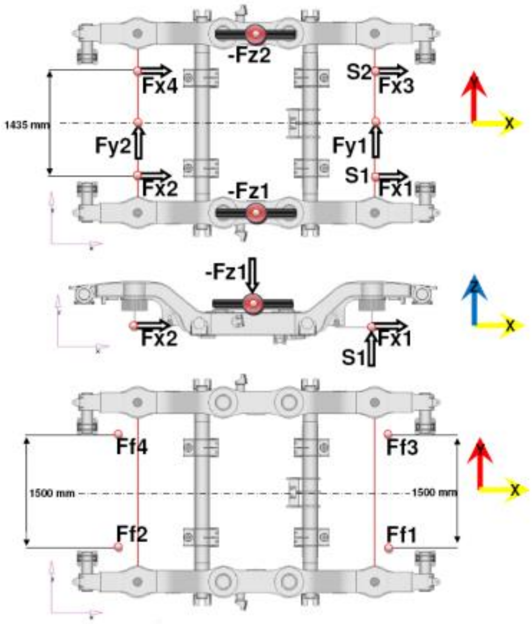

Fig. 2 – Application scheme of static and fatigue loads for the bogie frame

The frequency for the dynamic application of loadings was chosen at 3.5 Hz, after modal identification tests previously undertaken [3]. Thus it has complied to a good practice rule, the test frequency not exceeding the value of 1/3 of the first fundamental frequency of the bogie frame, which has been identified around the value of 18Hz.

For monitoring the evolution of fatigue tests, were performed stresses measurements recorded in the critical points of the bogie frame, previously identified through finite element analysis.

Were applied a total of 44 strain gauges LY11-6/350 manufactured by Hottinger having the base of 6mm and the electrical resistance of 350 Ohm, the factor k=2.09 ±0.7%, transversal sensitivity -0.9%.

Also were acquired and the data relating at the amplitude and frequency of the applied loads to the bogie frame.

Frecventa de aplicare dinamica a sarcinilor a fost aleasa la 3.5 Hz, in urma testelor de identificare modala intreprinse anterior [3]. Astfel s-a respectat o regula de buna practica, frecventa de incercare nedepasind valoarea de 1/3 din prima frecventa fundamentala a ramei de boghiu, care a fost identificata in jurul valorii de 18 Hz.

In scopul urmaririi evolutiei testelor de oboseala, s-au efectuat masuratori ale tensiunilor inregistrate in punctele critice ale ramei de boghiu, identificate anterior prin analiza cu element finit.

Au fost aplicate un numar de 44 de marci tensometrice LY11-6/350, produse de firma Hottinger avand baza de 6mm si rezistenta de 350Ohm, factorul k=2,09 ±0,7%, sensibilitate transversala -0,9%.

De asemenea au fost achizitionate si datele referitoare la amplitudinea si frecventa sarcinilor aplicate ramei de boghiu.

Fig. 3 – Detail of strain gauge application

RESULTS

Product for which the dynamic test was performed was the trailer bogie frame for electrical frames which is shown in Figure 4.

The trailer bogie frame is made of welded steel type S355J2G3-STD01W03 (ERRI B12/RP60) of varying thicknesses (8,10,12mm), with the mechanical breaking effort of 510 MPa and the proportionality elastic limit of 350 MPa for unwelded material, respectively 325 MPa, for welded material.

REZULTATE

Produsul pentru care s-au efectuat incercarile dinamice a fost rama de boghiu purtator pentru rame electrice prezentata in figura 4.

Rama de boghiu purtator este o constructie sudata confectionata din otel tip S355J2G3-STD01W03 (ERRI B12/RP60) de diferite grosimi (8,10,12mm), cu efortul mecanic la rupere de 510 MPa si limita de proportionalitate elastica de 350 MPa pentru material nesudat, respectiv 325 MPa, pentru material sudat.

Fig. 4 – Bogie frame

Accelerated fatigue tests were performed on a specialized stand (fig.5) that simulates the real operating conditions. Installation used for the application of loadings in dynamic regime was the installation of Hydropulse type from the endowment of Testing Department within INMA Bucharest. For the application of vertical loads were used two hydraulic cylinders of 250 kN, one for each longeron. The application of transversal loads was made through two 100 kN hydraulic cylinders, one for each axle. The twisting strains were applied through two hydraulic cylinders of 250 kN.

To succeed in the application of a test frequency of 3.5 Hz, the primary suspension of the bogie frame was artificially stiffened by pre-stressing with a force of 90 kN, the twisting strain being recalculated for this reason.

Incercarile accelerate de oboseala s-au efectuat pe un stand specializat (figura 5) care simuleaza conditiile reale de exploatare. Instalatia folosita pentru aplicarea sarcinilor in regim dinamic a fost instalatia de tip Hidropuls din dotarea Departamentului de Incercari din cadrul INMA Bucuresti. Pentru aplicarea sarcinilor verticale s-au folosit doi cilindri hidraulici de 250 kN, cate unul pentru fiecare lonjeron. Aplicarea sarcinilor transversale s-a facut prin intermediul a doi cilindrii hidraulici de 100 kN, cate unul pentru fiecare osie. Solicitarile de răsucire au fost aplicate prin intermediul a doi cilindrii hidraulici de 250 kN.

Pentru a se reusi aplicarea unei frecvente de incercare de 3.5 Hz suspensia primara a ramei de boghiu a fost rigidizata artificial prin precomprimare cu o forta de 90 kN, solicitarea de răsucire fiind recalculata din acest motiv.

Fig. 5 – Mounting made on the Hydropulse type installation for carrying out the dynamic fatigue tests

Figure 6 shows the diagram of forces applied to the bogie frame in dynamic regime for the first 6 million dynamic load cycles. Looking at the chart we can identify the static, quasi-static and dynamic characteristic of each applied force or displacement. Also it should be noticed the correlation between the reference signal (fig.2) and the real signal acquired (fig.6).

Diagrams are associated with color displays placed in the bottom of each graphics. In the displays, the represented parameters mean values are transmitted at selected time points in the second race of red and blue. The corresponding values of the first red cursor are transmitted among superior and inferior displays or are transmitted among corresponding values of the second blue cursor.

For all types of strains are available the following rules for reading and interpretation:

In figura 6 se prezinta diagrama fortelor aplicate ramei de boghiu in regim dinamic, pentru primele 6 milioane cicluri de incarcare dinamica. Analizand diagrama se pot identifica componentele statica, cvasi-statica si dinamica caracteristice fiecarei forte sau deplasari aplicate. De asemenea se observa corelarea intre semnalul de referinta (fig.2) si semnalul real achizitionat (fig.6).

Diagramele sunt asociate prin culoare cu display-uri plasate in partea inferioara a fiecarei reprezentari grafice. In display-uri sunt transmise valorile parametrilor reprezentati, la momente de timp selectate prin cele doua cursoare de culoare rosu si albastru. Valorile corespunzatoare primului cursor, rosu, sunt transmise in randul superior de display-uri, iar in randul inferior sunt transmise valorile corespunzatoare celui de al doilea cursor, cel albastru.

Pentru toate tipurile de solicitari sunt valabile urmatoarele reguli de citire si de interpretare:

Forces applied vertically FZ1 and FZ2 are reported in right ordinate. Forces applied horizontally FY1 and FY2 are ordered relative to the left. Twisting sites S1 (DTw1) and S2 (DTw2) are relative to the middle ordinate.

In the diagram in Figure 7 is observed a part of the strains measured in the critical points of the bogie frame during the 10 million cycles of dynamic load. Mechanical stresses were obtained by multiplying the measured specific deformation modulus E = 206000 MPa which is specific for the steel from which the bogie frame is built. It can be seen that the shape of the mechanical stresses complies with the profile of the strains applied to bogie frame.

Fortele aplicate pe directia verticala, Fz1 si Fz2, sunt raportate la ordonata din dreapta. Fortele aplicate pe directia orizontala, Fy1 si Fy2, sunt raportate la ordonata din partea stanga. Răsucire-urile S1 (DTw1) si S2 (DTw2) sunt raportate la ordonata din mijloc.

In diagrama din figura 7 se observa o parte din tensiunile masurate in punctele critice ale ramei de boghiu pe durata celor 10 milioane de cicluri de incarcare dinamica. Tensiunile mecanice au fost obtinute prin inmultirea valorii deformatiei specifice masurate cu modulul de elasticitate E=206000 MPa specific otelului din care a fost construita rama de boghiu. Se poate observa ca forma tensiunilor mecanice respecta profilul solicitarilor aplicate ramei de boghiu.

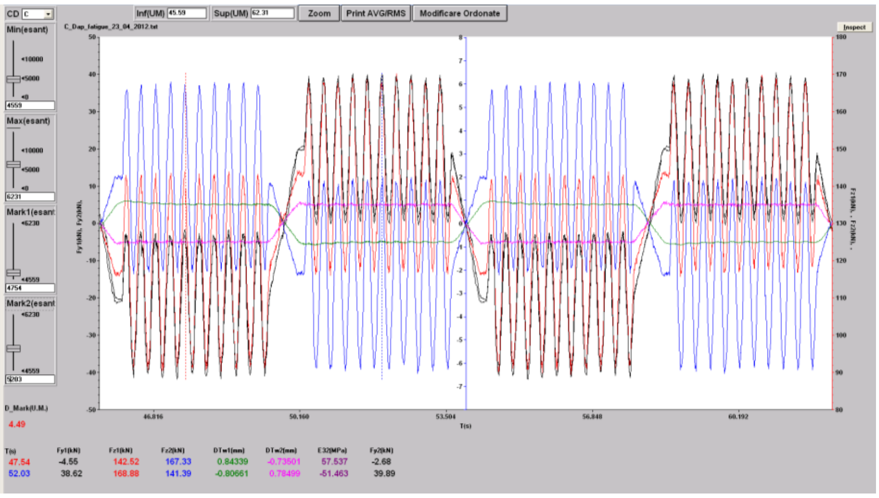

Fig. 6 – Applied forces diagram / *Diagrama forte aplicate*

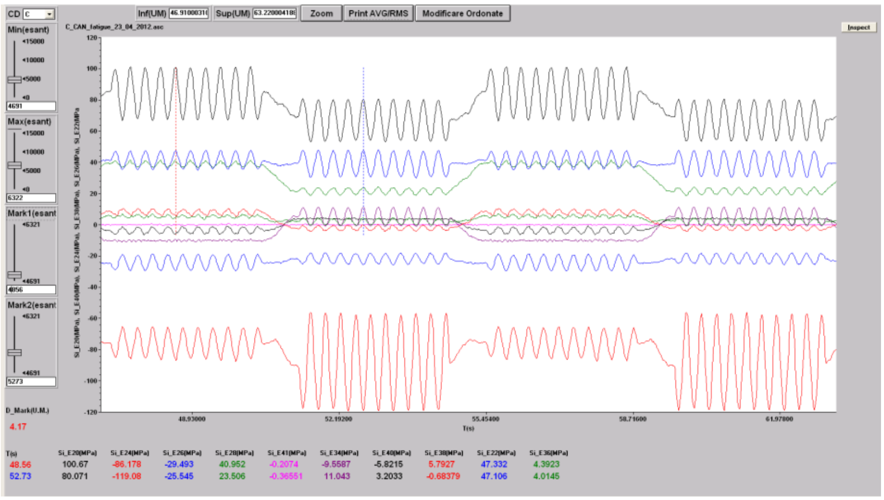

Fig.7 – Mechanical tensions diagram

Figure 8 shows the framing into the Goodman-Smith stress diagram σ_m and σ_a calculated for each specific deformation measured in the critical points of the bogie frame. It can be seen that all the points of coordinates (σ_m, σ_a) are within the chart except one, which is on the border. Framing points within the chart predicts a value of strains below the limit of fatigue. The point from the boundary suggests possible fatigue limit reaching in the critical area which it represents. This area was observed until the end of tests, and have not presented the appearance of cracks or fractures caused by fatigue.

In figura 8 se prezinta incadrarea in diagrama Goodman-Smith a tensiunilor σ_m si σ_a calculate pentru fiecare deformatie specifica masurata in puntele critice ale ramei de boghiu. Se poate observa ca toate punctele de coordonate (σ_m, σ_a) se afla in interiorul diagramei cu exceptia unuia singur, care se afla pe frontiera. Incadrarea punctelor in interiorul diagramei previzioneaza o valoare a tensiunilor sub limita de oboseala. Punctul de pe frontiera sugera o eventuala atingere a limitei de oboseala in zona critica pe care o reprezinta. Aceasta zona a fost tinuta sub observatie pana la finalul testelor si nu a prezentat aparitia unor fisuri sau rupturi datorate oboselii.

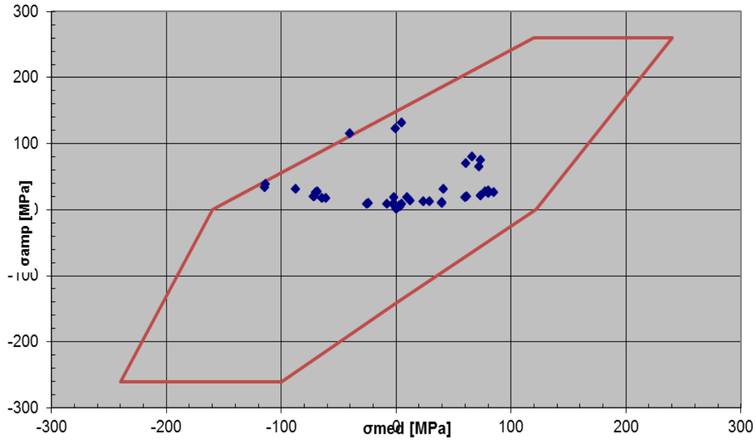

Fig. 8 – Goodman-Smith diagram and framing of the blue marked points representing the calculated tensions σ_m and σ_a

CONCLUSIONS

Testing in simulated and accelerated regime of the bogie frames is done in order to verify the structure from the perspective of the resistance to fatigue.

Within the dynamic tests to fatigue the assessment of fatigue strength using the fatigue diagrams GOODMAN - SMITH only allows assessing of a compliance with the limits imposed by diagrams [4]. It can assess the fatigue resistance using the approach of accumulation of flaws, based on summation of effects of stresses due to all load cases and including them into the Wohler curve for the material in which is constructed the structure. Then, using a hypothesis for damages accumulation due to the fatigue (Palmer-Miner for example) can be estimated the total degree of fatigue that will be accumulated during the active period of life of the structure [2]. However, this method requires complex calculations and definition of the complete spectrum of stresses to which may be subjected the structure.

The groups of stresses to which was subjected the structure are based on waveforms experimentally established on the railways and accelerated from the perspective of increasing the testing frequency and the amplitudes of the strains in order to obtain results as correlated with reality in good time.

Acknowlegement

The paper is realized within contract PN II-PCCA, no. 192/2012.

REFERENCES

[1]. Escobar L.A., Meeker W.Q. (2006) - *A Review of Accelerated Test Models*, Statistical Science, Vol. 21, No. 4, 552–577;

[2]. Mancini G., Cera Al. (2006) – *Design of railway bogies in compliance with new EN 13749 European Standard,* http://www.uic.org/cdrom/2006/wcrr2006/pdf/609.pdf;

[3]. Manea I., Gîrniță I., Matache M. s.a. (2012) - *Research for modal analysis utilization as a tool for fatigue and structural change assessment of mechanical structures*, International Symposium ISBINMATEH 2012;

[4]. Tănăsoiu A., Copaci I. (2011) – *On the span life of the carrying structures of railway vehicles*, AIR Bulletin no.3, July-September;

[5]. ***- EN13749:2011 - *Railway Applications- Wheelsets and bogies- Method of specifying the structural requirements of bogie frames*.

CONCLUZII

Testarea in regim simulat si accelerat a ramelor de boghiu se face in scopul verificarii structurii din punctul de vedere al rezistentei la oboseala.

În cadrul încercărilor dinamice la oboseala aprecierea rezistenţei la oboseală folosind diagramele de oboseală GOODMAN – SMITH permite doar evaluarea unei încadrări în limitele impuse de diagrame [4]. Se poate evalua rezistenta la obosela folosind abordarea cumulului de defecte, prin insumarea efectelor tensiunilor datorate tuturor cazurilor de incarcare si incadrarea acestora in curba lui Wohler pentru materialul din care este construita structura. Apoi folosind o ipoteza pentru acumularea stricaciunilor datorita oboselii (Palmer-Miner de exemplu) se poate estima gradul total de oboseala care va fi acumulat pe parcursul duratei active de viata a structurii [2]. Totusi aceasta metoda presupune calcule complexe si definirea spectrului complet de sarcini la care poate fi supusa structura.

Colectivele de solicitare la care a fost supusa structura au la baza forme de unda stabilite experimental pe calea ferata si accelerate din punctul de vedere al cresterii frecventei de testare si a amplitudinilor solicitarilor in scopul obtinerii unor rezultate cat mai corelate cu realitatea în timp util.

Recunoaştere

Lucrarea este realizata in cadrul contractului PN II-PCCA, nr. 192/2012.

BIBLIOGRAFIE

[1]. Escobar L.A., Meeker W.Q. (2006) – *Un review asupra modelelor de testare accelerata*, Statistical Science, Vol. 21, No. 4, 552–577;

[2]. Mancini G., Cera Al. (2006) – *Proiectarea boghiurilor de cale ferata in conformitate cu noul standard european EN 13749,* http://www.uic.org/cdrom/2006/wcrr2006/pdf/609.pdf;

[3]. Manea I., Gîrniță I., Matache M. ş.a. (2012) - *Cercetări privind utilizarea analizei modale ca instrument pentru evaluarea stării de oboseală si a modificărilor structurale ale structurilor mecanice*, Simpozion International ISBINMATEH 2012;

[4]. Tănăsoiu A., Copaci I. (2011) – *Asupra duratei de viaţă a structurilor portante ale vehiculelor feroviare*, Buletinul AIR nr.3, iulie-septembrie;

[5]. ***- EN13749:2011 - *Aplicatii Feroviare, Osii montate si boghiuri, Metode pentru specificarea cerintelor referitoare la rezistenta structurilor cadrelor de boghiuri.*