Dragutin Georgijević, Zijah Burzić

UTICAJ KOROZIJE ELEMENATA PRIČVRSNOG PRIBORA ŠINE NA INTEGRITET SPOJA

CORROSION EFFECTS OF RAIL FASTENING DEVICE ELEMENTS ON JOINT INTEGRITY

Originalni naučni rad / Original scientific paper
UDK /UDC: 620.193: 625.143.4
Rad primljen / Paper received: 15.08.2008.

Adresa autora / Author's address:
Vojnotehnički institut, Beograd, Ranka Ristanovića 1
zijah_burzic@vektor.net

Ključne reči
- ispitivanje
- železnička šina
- korozija
- moment pritezanja
- trenje

Izvod

U radu je ukazano na uticaj korozije elemenata pričvrsnog pribora, tirfona i opruge, na silu pritezanja šine. Ispitivanjem u laboratoriji i na terenu je pokazano da korozija povećava koeficijent trenja zbog čega se za ostvarenje potrebne sile pritezanja u tirfonu zahteva veći moment. Razlabavljeni spoj šine i praga remeti integritet pričvrsnog pribora i smanjuje vek elemenata u spoju.

UVOD

Jedan od problema uočenih u okviru opsežnih ispitivanja u laboratoriji i na terenu ponašanja i integriteta kontinualnih železničkih šina na pruzi Beograd–Bar, pričvršćenih za betonske pragove elastičnim priborom W14, je devijacija geometrije koloseka, što je uglavnom posledica nedovoljne pričvršćenosti šine za prag. Propisana sila pritezanja tirfona, vijaka koji pritiskom na oprugu pritežu šinu za prag, se pokazala nedovoljnom kada se koriste korodirani vijci i kopče (opruge). Cilj eksperimentalnih istraživanja je bio da se odredi, za date uslove, potrebna sila pritezanja.

PRIČVRŠĆIVANJE ŠINE ZA BETONSKI PRAG

Elementi pričvrsnog pribora za šinu i prednapregnuti betonski prag su prikazani na sl. 1. To su tirfon (1), šina (2), kopča – opruga (3), ugaona vodeća ploča (4), elastična šinska podloška (5), plastični tipl za vijak u pragu (6).

Opšti izgled pričvrsnog sistema u montiranom stanju je prikazan na sl. 2, a konstrukcijski oblik kopče za pritezanje u vidu elastične opruge je dat na sl. 3. Konstrukcijskim rešenjem je obezbeđeno da sila pritiska kopče na šinu zavisi samo od savojno-uvojne krutosti spoljnje petlje kopče.

Propisana sila pritiska šine na prag je 20 do 22 kN, pa na svaku stopu šine deluje radna sila 10 do 11 kN. Ova sila se positže momentom pritezanja tirfona 200 Nm i proporcionalna je sili pritezanja tirfona samo dok srednja petlja kopče (sl. 3) ne dodirne ugaonu vodeću ploču.

Keywords
- testing
- railroad rail
- corrosion
- fastening moment
- friction

Abstract

The paper indicates on the corrosion effects of fastening device elements, sleeper screw and spring, on rail fastening force. Laboratory and in-situ testing shows that corrosion increases the friction coefficient, thus requiring a higher torque on sleeper screw to achieve necessary fastening force. Weak joint of rail and sleeper disarrange fastening device integrity and reduce life of its elements.

INTRODUCTION

One of the problems observed in extensive tests in the laboratory and in-situ on the behaviour and integrity of continuous railroad rails on Beograd–Bar railway, fastened to concrete sleepers by elastic device W14, is the geometry deviation of railway track, mostly caused by insuficiently fastened rail to sleeper. The specified sleeper screw force that fastens rail to sleeper has prooved to be insuficient when corroded screws and clamps (springs) are used. The goal of experimental research is to determine the necessary fastening force for actual conditions.

FASTENING OF RAIL TO CONCRETE SLEEPER

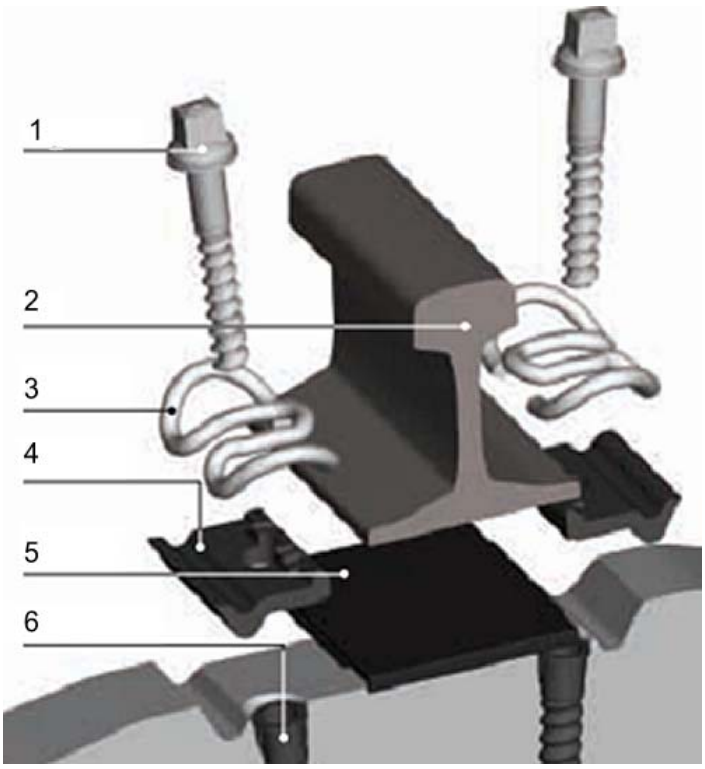
Elements of fastening device for reinforced concrete sleeper are presented in Fig. 1. They are: sleeper screw (1), rail (2), clamp – spring (3), angled guide plate (4), elastic rail pad (5), plastic insert (dowel) for screw in sleeper (6).

General view of fastening device in assembled state is presented in Fig. 2, and design of fastening clamp in form of an elastic spring is shown in Fig. 3. Design solution assures that clamp fastening force on the rail depends only on flexion-torsional stiffness of clamp outer kink.

Specified fastening force of rail on sleeper is 20 to 22 kN, so on each rail toe the working force 10 to 11 kN is applied. This force is acheved by sleeper screw fastening torque of 200 Nm, and is proportional to fastening force only untill the clamp middle kink and angled guide plate come into contact (Fig. 3).

Daljim povećavanjem momenta pritezanja se ne povećava sila opruge, već samo raste lokalni pritisak na srednju petlju kopče i ugaonu vodeću ploču, praćen dodatnim opterećenjem tirfona i tipla.

A further increase in fastening torque does not increase spring force, but only increases local pressure on clamp middle kink and angled guide plate, followed by additional loading on sleeper screw and insert dowel.



Slika 1. Elementi pričvrsnog sistema: tirfon (1), šina (2), kopča (3), vodeća ploča (4), šinska podloška (5), plastični tipl za vijak (6)
Figure 1. Elements of fastening device: sleeper screw (1), rail (2), clamp (3), guide plate (4), rail pad (5), plastic insert dowel for screw (6).

Slika 2. Opšti izgled pričvrsnog sistema u montiranom stanju
Figure 2. General view of fastening device in assembled state.

Slika 3. Konstrukcijsko rešenje kopče – opruge
Figure 3. Design of tension clamp – spring.

Da bi se ostvarila propisana sila prethodnog pritezanja tirfona koja garantuje silu pritiska kopče na šinu, za montažu je propisana sledeća procedura: prvih nekoliko tirfona se priteže moment ključem sve dok se zazor između srednje petlje kopče i ugaone vodeće ploče ne poništi (maksimalni dozvoljeni zazor je 0,5 mm, sl. 4). Pri tom se meri moment kojim je tirfon pritegnut. Dalje se ostali tirfoni pritežu tim izmerenim momentom.

In order to acieve specified pre-tension force which assures clamp fastening force on rail, the following procedure for assembling is required: the first several sleeper screws are fastened by moment wrench until the gap between clamp middle kink and angular guided plate is annulled (maximum allowed gap is 0.5 mm, Fig. 4). Fastening torque moment is measured. Other sleeper screws are then fastened according to this measured moment.

To, naravno, podrazumeva da su svi tirfoni i kopče u istom stanju. Međutim, kolosečni pribor na ovoj pruzi kod Resnika montiran je sa različitim nivoima korodiranosti elemenata i bez podmazivanja.

SILA PRITEZANJA KORODIRANIH ELEMENATA

Iako uočena korozija praktično nema uticaja na čvrstoću pribora u dužem vremenskom periodu, aksijalna sila u tirfonu je nedovoljna ukoliko se korodirani tirfon priteže istim momentom kao nekorodirani, jer se zbog korozije povećava koeficijent trenja na kontaktnim površinama.

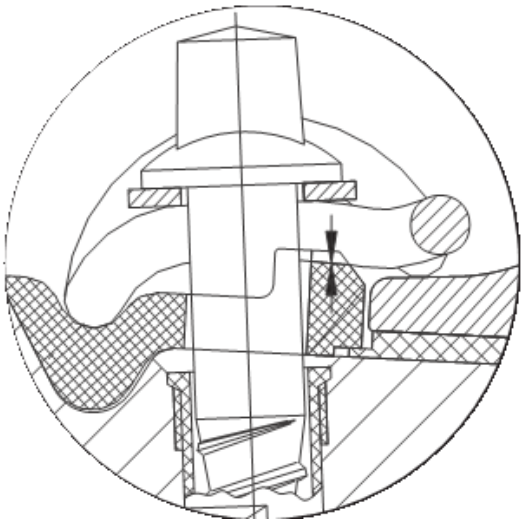
To takođe znači da se merenjem momenta pritezanja na pruzi u eksploataciji ne može odrediti sila pritezanja.

Proverom geometrije, tj. merenjem zazora između srednje petlje kopče i ugaone vodeće ploče, može se ustanoviti da li je ostvarena zadata sila pritezanja, ali je to zametno i praktično neizvodljivo na većem broju pragova.

Osim momenta potrebnog za savladavanje krutosti oprige dodatne dve komponente momenta su potrebne za savladavanje trenja između tirfona i tipla i između glave tirfona (podloške) i kopče.

Sila od pojedinih komponenti momenta pritezanja menja se sa nivoom korozije tirfona i kopče.

Dva tirfona, jedan manje (broj 8), a drugi jako (broj 15) korodiran, su ispitani da bi se odredili koeficijenti trenja, μ_1 i μ_2, i komponente momenta pritezanja.



Slika 4. Opšti izgled pričvrsnog sistema u montiranom stanju
Figure 4. General view of fastening device in assembled state.

Sila u tirfonu

Za ugib kopče f = 13 mm, sila kojom kopča pritiska stopu šine (opterećenje stope) sa jedne strane šine iznosi:

$$\frac{P}{2} \approx 11 \text{ kN}$$

Iz geometrije pričvrsnog pribora (sl. 5) se vidi da je a = 33 mm, L = 72,8 mm, pa je sila u tirfonu

$$P_B = \frac{P}{2}\frac{L}{a} = 11\frac{72,8}{33} = 24,27 \text{ kN} \quad (1)$$

This, of course, comprises that all sleeper screws and clamps are in the same state. Anyhow, rail devices on this railway at Resnik are assembled with elements of different levels of corrosion and without lubrication.

FASTENING FORCE FOR CORRODED ELEMENTS

Although detected corrosion has no effect on device strength in a longer period of time, the axial force in sleeper screw is insufficient if the corroded screws are fastened by the same torque moment as uncorroded ones, since corrosion increases the friction coefficient on contact surfaces.

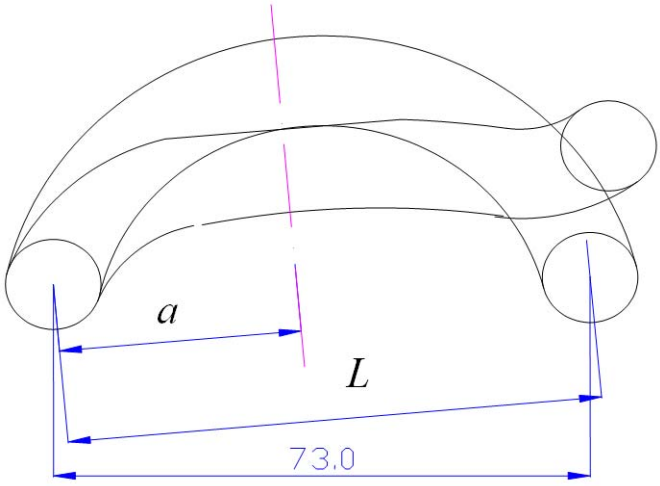
This also means that by measuring the fastening moment on the track is not possible to determine the fastening force in service.

By checking the geometry, i.e. measuring the gap between clamp middle kink and angled guide plate, one can establish wheather the specified fastening force is achieved, but this is time consuming and inapplicable on a lot of sleepers.

Aside to the moment necessary to supress the spring stifness, two additional moment components are required to overome the friction between the sleeper screw and insert, and between screw head (pad) and clamp.

The force caused by individual components of fastening moment changes with screw and clamp corrosion level.

Two sleeper screws, one (No 8) less, the other very corroded (No 15), are tested to determine friction coeffiients, μ_1 and μ_2, and fastening moment components.



Slika 5. Elementi geometrije pričvrsnog pribora
Figure 5. Geometry paramters of fastening device.

Force in sleeper screw

For a clamp deflection f = 13 mm, the force the clamp presses the rail toe (toe load) on one rail side is:

$$\frac{P}{2} \approx 11 \text{ kN}$$

From the fastening device geometry (Fig. 5), it can be seen that a = 33 mm, L = 72.8 mm, so the force in a sleeper screw is

$$P_B = \frac{P}{2}\frac{L}{a} = 11\frac{72.8}{33} = 24.27 \text{ kN} \quad (1)$$

Analiza komponenti momenta pritezanja

Moment T, potreban da se ostvari sila pritezanja P_B, čine tri komponente momenta: T_1 – za uvođenje aksijalne sile, T_2 – da se savlada trenje u navoju, i T_3 – da se savlada trenje između glave tirfona (podloške) i kopče, /1/:

$$T = T_1 + T_2 + T_3 \tag{2}$$

Komponenta momenta T_1

Aksijalna sila u tirfonu, P_B, je komponenta normalne sile između navojaka. Komponenta ove sile normalna na zavojnicu je $P_{N\beta}$, a druga komponenta (obrtna sila), koja se uvodi momentom pritezanja je $P_B \tan\beta$ (sl. 6).

Pretpostavljajući da ova obrtna sila deluje duž srednjeg prečnika navoja, d_2, komponenta momenta T_1, potrebna da se ostvari aksijalna sila je

$$T_1 = P_B \tan\beta \frac{d_2}{2} \tag{3}$$

Zamenom $\tan\beta = l/\pi d_2$ u prethodni izraz dobija se

$$T_1 = P_B \frac{l}{2\pi} \tag{4}$$

Za korak navoja p = 12,7 mm (2 koraka po inču) i srednji prečnik navoja d_2 = 20 mm, postaje

$$\tan\beta = \frac{l}{\pi d_2} = \frac{12.7}{20\pi} = 0.2021 \quad \beta = 11{,}43°, \text{ sledi}$$

$$T_1 = P_B \frac{l}{2\pi} = 24{,}27 \frac{12{,}7}{20\pi} = 49 \text{ kN/mm} = 49 \text{ Nm}$$

Komponenta momenta T_2

Komponenta sile normalna na bokove navoja je $P_{N\alpha}$ (sl. 7). Sa koeficijentom trenja μ_1 između navojaka, sila trenja je $\mu_1 P_{N\alpha}$, ili $\mu_1 P_B/\cos\alpha$. Pretpostavljajući da ova sila deluje duž srednjeg prečnika navoja d_2, komponenta momenta T_2, potrebna da se savlada trenje u navoju iznosi:

$$T_2 = \frac{d_2 \mu_1 P_B}{2\cos\alpha} \tag{5}$$

Kalibracija tirfona

Tirfoni su za kalibraciju opremljeni mernim trakama punog Vitstonovog mosta (sl. 8) i meren je odziv sa mosta u V, a zatezna sila je određena na kidalici u MTS.

Način kalibracije prikazan je na sl. 9, a dobijeni kalibracioni dijagrami su dati na sl. 10 i 11.

Komponenta momenta T_3

Sila trenja između glave tirfona (podloške) i kopče je $\mu_2 P_B$, gde je μ_2 koeficijent trenja između te dve površine. Uzimajući da ova sila deluje duž srednjeg prečnika d_m, kontaktne površine između glave tirfona (podloške) i kopče, komponenta momenta potrebna da se savlada trenje je:

$$T_3 = \left(\frac{d_m}{2}\right) \mu_2 P_B \tag{6}$$

Komponenta momenta T_3 određena je ispitivanjem dva tirfona: malo korodiranog, br. 8, i jako korodiranog, br. 15.

Tirfon se pri ispitivanju oslanja na kopču postavljenu na ugaonu vodeću ploču. Aksijalna sila se uvodi sa donje strane. Rotacija omogućava aksi-radijalni ležaj, a deluje samo trenje između glave tirfona (podloške) i kopče (sl. 12).

Analisys of fastening torque moment components

Moment T, required to achieve fastening force P_B, consists of three moment components: T_1 – to involve axial force, T_2 – to overcome friction on thread, and T_3 – to overcome friction between screw head (pad) and clamp, /1/:

$$T = T_1 + T_2 + T_3 \tag{2}$$

Moment component T_1

Axial force in sleeper screw P_B, is the component of normal force between threads. Normal component of this force is $P_{N\beta}$, and the second component (rotating force), introduced by fastening torque moment is $P_B \tan\beta$ (Fig. 6).

Assuming that this rotating force acts along thread pitch diameter d_2, moment component T_1 necessary to involve axial force is

$$T_1 = P_B \tan\beta \frac{d_2}{2} \tag{3}$$

Replacing $\tan\beta = l/\pi d_2$ in previous expression gives

$$T_1 = P_B \frac{l}{2\pi} \tag{4}$$

For single thread p = 12.7 mm (2 threads per inch) and pitch diameter d_2 = 20 mm, one reads

$$\tan\beta = \frac{l}{\pi d_2} = \frac{12.7}{20\pi} = 0.2021 \quad \beta = 11.43°, \text{ it follows}$$

$$T_1 = P_B \frac{l}{2\pi} = 24{,}27 \frac{12{,}7}{20\pi} = 49 \text{ kN/mm} = 49 \text{ Nm}$$

Moment component T_2

Force component normal on thread flank is $P_{N\alpha}$ (Fig. 7). With friction coefficient μ_1 between threads, friction force is $\mu_1 P_{N\alpha}$, or $\mu_1 P_B/\cos\alpha$. Assuming that this force acts along thread pitch diameter, d_2, moment component T_2, necessary to overcome friction in threads amounts to

$$T_2 = \frac{d_2 \mu_1 P_B}{2\cos\alpha} \tag{5}$$

Sleeper screw calibration

Sleeper screws for calibration are instrumented by strain gauges in full Wheatstone bridge (Fig. 8), its response is measured in V, and tensile force is read on MTS device.

Calibration procedure is presented in Fig. 9, and obtained calibration diagrams are given in Figs. 10 and 11.

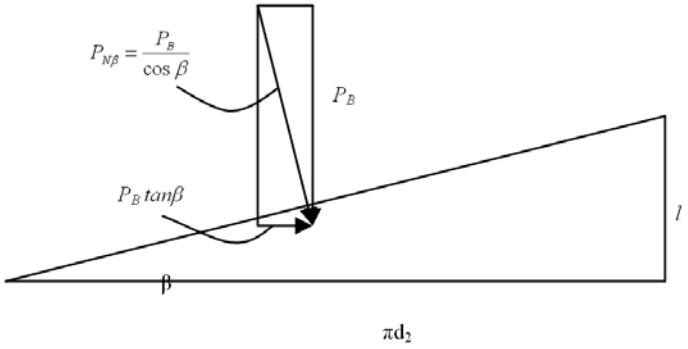
Moment component T_3

Friction force between screw head (pad) and clamp is $\mu_2 P_B$, where μ_2 is friction coefficient between these two surfaces. Assuming that this force acts along pitch diameter d_m, of contact surface between screw head (pad) and clamp, moment component necessary to overcome this friction is

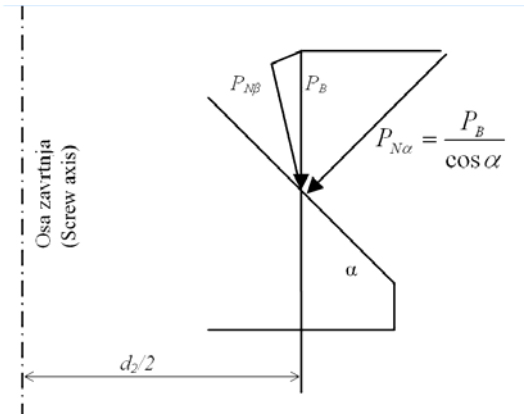
$$T_3 = \left(\frac{d_m}{2}\right) \mu_2 P_B \tag{6}$$

Moment component T_3 is determined by testing two sleeper screws: less corroded, No 8, and very corroded, No 15.

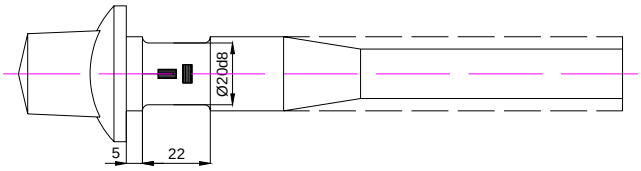
The tested screw reclines on clamp, positioned on angled guide plate. Axial force is involved on bottom side. Axial-radial bearing enables rotation, so the only acting friction is between screw head (pad) and clamp (Fig. 12).



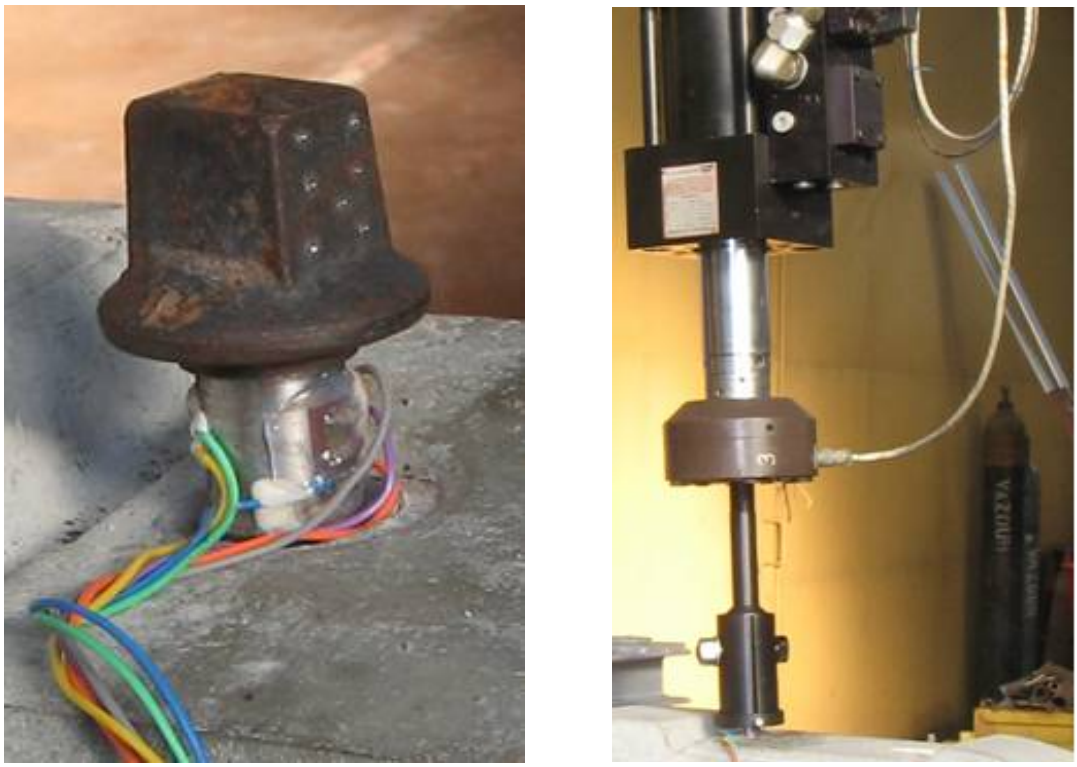
Slika 6. Komponente sila na zavojnici
Figure 6. Force components on the thread.



Slika 7. Komponente sile na navojku
Figure 7. Force components on one thread.



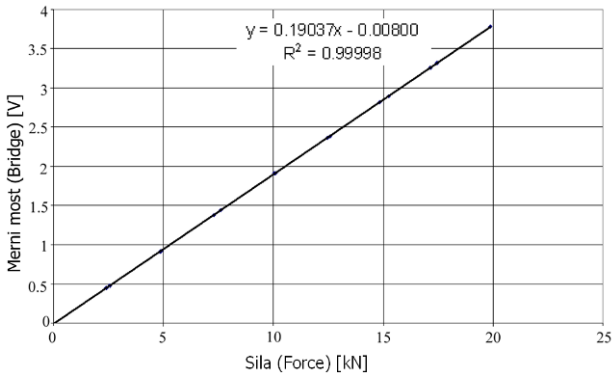
Slika 8. Tirfon opremljen mernim trakama
Figure 8. Sleeper screw instrumented by strain gauges.



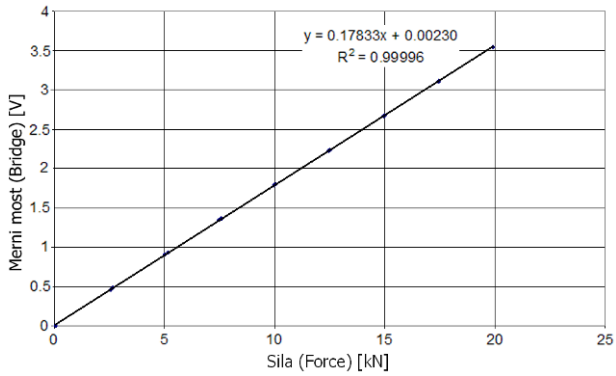
Slika 9. Kalibracija tirfona
Figure 9. Sleeper screw calibration.

Tirfon je zatezan stepenasto silom do 20 kN. Na svakoj sili meren je moment trenja u oba smera moment ključem. Rezultati su sledeći:
– za tirfon br. 8 se može uzeti $T_3 = 4{,}85\ P_B$ i
– za tirfon br. 15 se može uzeti $T_3 = 8{,}84\ P_B$.

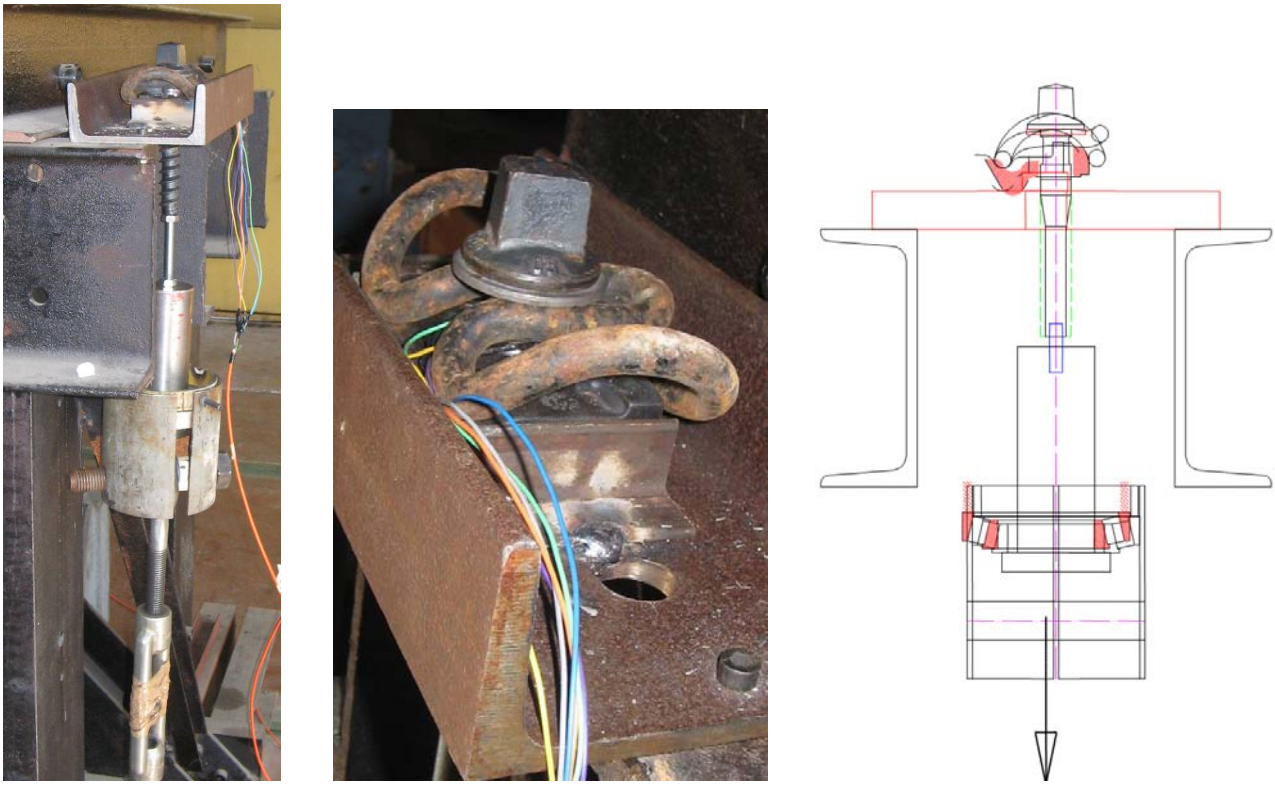
Sleeper screw is stepwise loaded by force to 20 kN. At each force, friction moment is measured at both directions by moment wrench. The results are as follows:
– for screw No. 8, one can apply $T_3 = 4.85\ P_B$ and
– for screw No. 15 one can apply $T_3 = 8{,}84\ P_B$.



Slika 10. Kalibracioni dijagram za tirfon br. 8
Figure 10. Calibration diagram for sleeper screw No 8.



Slika 11. Kalibracioni dijagram za tirfon br. 15
Figure 11. Calibration diagram for sleeper screw No 15.



Slika 12. Određivanje komponente momenta T_3
Figure 12. Determinatioon of moment component T_3

Rezultati merenja prikazani su dijagramom na sl. 13.

Za zahtevanu silu pritiska kopče $P/2 \approx 11$ kN, tj. za aksijalnu silu u tirfonu $P_B = 24{,}27$ kN, za savladavanja trenja između glave tirfona (podloške) i kopče, potrebna je komponenta momenta T_3:

– za tirfon br. 8, $T_3 = 4{,}85 \cdot 24{,}27 \approx 118$ Nm
– za tirfon br. 15, $T_3 = 8{,}84 \cdot 24{,}27 \approx 215$ Nm

Pretpostavljajući da je srednji prečnik površine kontakta glave tirfona (podloške) i kopče $d_m = 34$ mm, iz izraza (6) koeficijent trenja μ_2 je za

tirfon br. 8 $$\mu_2 = \frac{T_3}{\frac{d_m}{2} P_B} = \frac{118}{17 \cdot 24{,}27} = 0{,}29$$

tirfon br. 15 $$\mu_2 = \frac{T_3}{\frac{d_m}{2} P_B} = \frac{215}{17 \cdot 24{,}27} = 0{,}52$$

Measured results are presented by diagram in Fig. 13.

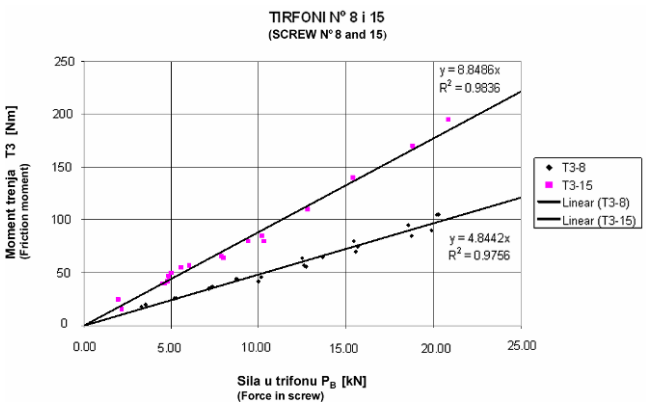
For specified clamp pressure force $P/2 \approx 11$ kN, i.e. for axial force in screw $P_B = 24.27$ kN, to overcome friction between screw head (pad) and clamp, the necessary moment component T_3 is:

– for screw No. 8, $T_3 = 4.85 \cdot 24.27 \approx 118$ Nm
– for screw No. 15, $T_3 = 8.84 \cdot 24.27 \approx 215$ Nm

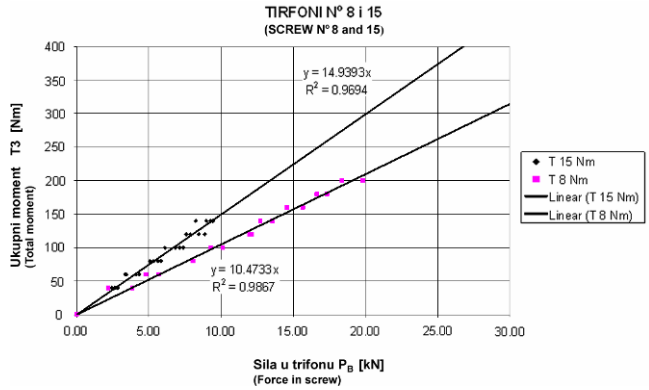
Assuming that at contact surface, between screw head (pad) and clamp, mid-diameter $d_m = 34$ mm, the friction coefficient μ_2 from expression (6) is

for sleeper screw No. 8 $$\mu_2 = \frac{T_3}{\frac{d_m}{2} P_B} = \frac{118}{17 \cdot 24.27} = 0.29$$

for sleeper screw No 15 $$\mu_2 = \frac{T_3}{\frac{d_m}{2} P_B} = \frac{215}{17 \cdot 24.27} = 0.52$$



Slika 13. Veličina komponente momenta T_3
Figure 13. The values of moment component T_3.



Slika 14. Dijagram za određivanje ukupnog momenta T
Figure 14. Diagram for determination of total moment T.

Ukupni moment T

Prema jedn. (2), ukupni moment T, potreban da se ostvari aksijalna sila prethodnog pritezanja tirfona P_B, je:

$$T = P_B\left(\frac{l}{2\pi} + \frac{d_2\mu_1}{2\cos\alpha} + \frac{d_m\mu_2}{2}\right) \tag{7}$$

Ukupni moment T je određen ispitivanjem istih tirfona (br. 8 i 15). Moment je stepenasto uvođen moment ključem i za svaki moment, merena je sila u tirfonu. Rezultati su prikazani dijagramski na sl. 14. Oni su:

– za tirfon br. 8 može se računati sa $T = 10{,}47 \cdot P_B$
– za tirfon br. 15 može se računati sa $T = 14{,}94 \cdot P_B$.

To znači da, za zahtevanu silu pritiska kopče tj. aksijalnu silu u tirfonu $P_B = 24{,}27$ kN, potreban je moment T:

– za tirfon br. 8, $T = 10{,}47 \cdot 24{,}27 \approx 254$ Nm
– za tirfon br. 15, $T = 14{,}94 \cdot 24{,}27 \approx 363$ Nm.

Ove relacije važe sve dok srednja petlja kopče ne ostvari kontakt sa ugaonom vodećom pločom; pri daljem porastu sile u tirfonu, sila pritiska kopče na šinu se ne menja.

Komponenta momenta T_2

Iz jedn. (2) se može izračunati komponenta momenta T_2 potrebna da se savlada trenje u navoju, pa je

– za tirfon 8, $T_2 = T - T_1 - T_3 = 254 - 49 - 118 = 87$ Nm,
– za tirfon 15, $T_2 = T - T_1 - T_3 = 363 - 49 - 215 = 99$ Nm.

Koeficijent trenja u navoju sledi iz jedn. (5) u vidu:

$$\mu_1 = \frac{T_2\cos\alpha}{\frac{d_2}{2}P_B} \tag{5a}$$

tako da je za tirfon br. 8, $\mu_1 = 0{,}25$, a za tirfon br. 15 je $\mu_1 = 0{,}29$.

Tirfoni su montirani sa kompletnim pričvrsnim priborom W14, koji pričvršćuje segment šine S 49 na armirano-betonski prag, opremljen tiplovima Sdü 9a (kopče Skl 14, ugaone vodeće ploče Wfp 14 K-12, šinska podloška Zw 123/165/7 yu) (sl. 15).

PREPORUKA

Moment pritezanja, potreban da se ostvari aksijalna sila zatezanja u tirfonu $P_B = 24{,}27$ kN, kojom se ostvaruje sila pritiska kopče na šinu od 11 kN, je:

– za tirfon 8, $T = T_1 + T_2 + T_3 = 49 + 87 + 118 = 254$ Nm
– za tirfon 15, $T = T_1 + T_2 + T_3 = 49 + 99 + 215 = 363$ Nm.

Total moment T

According to Eq. (2), total moment T, necessary to attain axial pre-tension force of sleeper screw P_B, is:

$$T = P_B\left(\frac{l}{2\pi} + \frac{d_2\mu_1}{2\cos\alpha} + \frac{d_m\mu_2}{2}\right) \tag{7}$$

Total moment T is determined by testing the same screws (No 8 and 15). The moment is stepwise applied by wrench and the force in screw is measured for each moment. Results are given in a diagram, Fig. 14. They are:

– for screw No 8, one can account with $T = 10.47 \cdot P_B$
– for screw No 15, one can account with $T = 14.94 \cdot P_B$.

That means that for specified clamp pressure force, i.e. screw axial force $P_B = 24.27$ kN, necessary moment is T:

– for screw No 8, $T = 10.47 \cdot 24.27 \approx 254$ Nm
– for screw No 15, $T = 14.94 \cdot 24.27 \approx 363$ Nm.

The relations are valid until clamp middle kink touches angled guide plate; further force increase in screw does not cause the change of clamp pressure force on rail.

Moment component T_2

It is possible to calculate the necessary moment component T_2 to overcome friction in thread from Eq. (2), so it is

– for screw 8, $T_2 = T - T_1 - T_3 = 254 - 49 - 118 = 87$ Nm,
– for screw 15, $T_2 = T - T_1 - T_3 = 363 - 49 - 215 = 99$ Nm.

Friction coefficient in thread follows from Eq. (5) as:

$$\mu_1 = \frac{T_2\cos\alpha}{\frac{d_2}{2}P_B} \tag{5a}$$

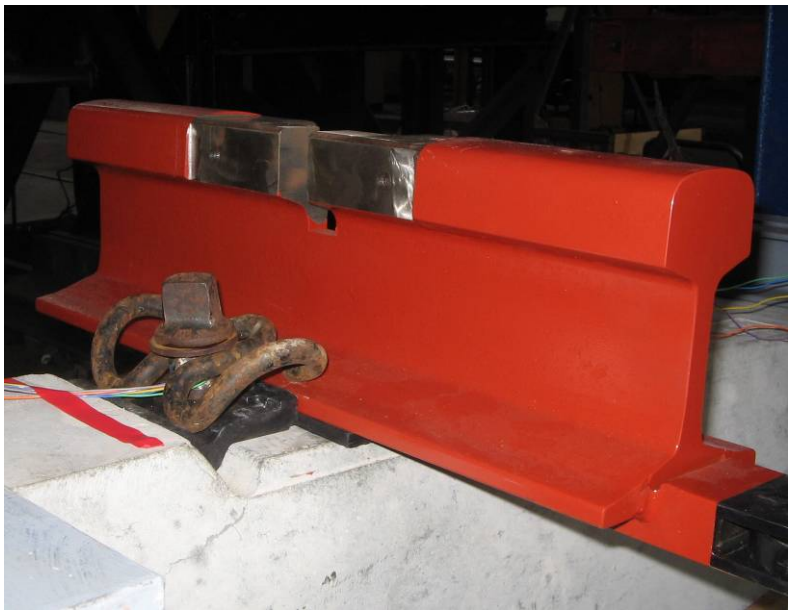
so that for screw No. 8 $\mu_1 = 0.25$, and for screw No. 15 $\mu_1 = 0.29$.

Sleeper screws are assembled by complete fastening device W14 that fastens rail segment S 49 on reinforced concrete sleeper fit-up by inserts dowel Sdü 9a (clamps Skl 14, angled guide plate Wfp 14 K-12, rail pad Zw 123/165/7 yu) (Fig. 15).

RECOMMENDATION

Fastening moment, necessary to realize axial tension force in sleeper screw $P_B = 24.27$ kN that produces clamp pressure force on rail of 11 kN is:

– for screw 8, $T = T_1 + T_2 + T_3 = 49 + 87 + 118 = 254$ Nm
– for screw 15, $T = T_1 + T_2 + T_3 = 49 + 99 + 215 = 363$ Nm.



Slika 15. Sistem ispitivanja radi određivanja ukupnog momenta *T*
Figure 15. Testing set-up for determining total moment *T*.

ZAKLJUČAK

Uočena nedovoljna sila pritezanja šine za prag posledica je ugradnje korodiranih tirfona i kopči. Da bi se ostvarila zadata sila pritezanja, u tom slučaju je potreban veći moment zbog povećanja koeficijenta trenja.

Proverom geometrije, tj. merenjem zazora između srednje petlje kopče i ugaone vodeće ploče, može se ustanoviti da li je ostvarena zadata sila pritezanja, ali je to vrlo zametno i praktično neizvodljivo na većem broju pragova.

Ostvarivanje zahtevane sile prethodnog pritezanja, tj. sile pritiska kopče na stopu šine, jednim određenim momentom pritezanja, može se postići bez velike disperzije rezultata podmazivanjem mašću svih kontaktnih površina.

Održavanje propisane sile pritiska kopče na šinu i na prag u toku eksploatacije je preduslov pouzdanog rada u dužem vremenskom intervalu i sa korodiranim elementima pričvrsnog pribora.

CONCLUSION

Unsufficient rail to sleeper fastenning force is a consequence of applying corroded screws and clamps. To achieve specified fastening force, a higher moment is necessary in this case because of higher friction coefficient.

By controlling the geometry, i.e. measuring the gap between clamp middle kink and angled guide plate, it is possible to establish whether the specified fastening force is attained, but this is time consuming and not practical for plenty of sleepers.

It is possible to realise a specified pre-tension force, i.e. the pressure clamp force on rail toe, by pre-determined fastening moment, without significant scattering of results, by applying lubricating grease on all contact surfaces.

Preserving the specified clamp tension force on rail and on sleeper during service is a precondition for safe operation in long term intervals, also with corroded elements of the fastening device.

LITERATURA – REFERENCES

1. Erik Oberg, et al., *Machinery's Handbook*, Industrial Press Inc. New York, p. 1486, Torque and Tension in Fasteners.