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THE DIAMETER OF A STRAND IN STEEL ROPE OPTIMALIZATION

PREČNIK STRUKA U FUNKCIJI OPTIMIZACIJE ČELIČNOG UŽETA

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Abstract: *Problem of determining the optimal diameter of strands with circular section in dependence on the strands winding angle comes forward in designing of rope section geometry. In rope cross-section, which geometry is designed inconveniently, overlapping of wires cross-sectional curves appears. It doesn't enable to observe technological procedure in rope production in practice and rope qualitative parameters ,of course [1]. An original proceeding for strand diameter optimization is proposed in the paper, so that overlapping of cross-sectional curves doesn't appear.*

Key words: steel rope, diameter, optimalization

Apstrakt: *Određivanje optimalnog prečnika strukova kružnog preseka u zavisnosti od ugla upredanja je jedno od najznačajnijih pitanja za definisanje geometrije preseka užadi. Kod nepovoljne geometrije poprečnog preseka užadi, krive koja opisuje poprečni presek žica se preklapaju, što otežava praćenje tehnologije proizvodnje i parametara kvaliteta, [1]. U ovom radu predložen je originalni postupak za optimizaciju prečnika strukova, čime će se izbeći gore pomenuti problemi.*

ključne reči: *čelično uže, prečnik, optimizacija*

1 INTRODUCTION

Various technological problems occure in rope production. One of them is to ensure optimal rope cross-section geometry. The procedure for optimal rope strand diameter determination will be derived from SEAL 6x (1+9+9)+v steel rope sample and It will be then verified by using a mathematical model of the steel rope.

2 OPTIMAL ROPE STRAND DIAMETER DETERMINATION

The strand diameter is formed by the circle diameter, circumscribed to a curve , that is strand section by a plane, vertical to its axis. Our sample

1 UVOD

U proizvodnji užadi srećemo se sa nekoliko problema. Jedan od njih je optimizacija geometrijskih karakteristika poprečnog preseka užeta. Postupak optimizacije prečnika struka dobija se na osnovu SEAL 6x (1+9+9)+v uzorka čeličnog užeta, nakon čega sledi verifikacija primenom matematičkog modela.

2 ODREĐIVANJE OPTIMALNOG PREČNIKA STRUKA U UŽETU

Prečnik struka je kružnog oblika, definisan krivom linijom, odnosno predstavlja presek čija je ravan vertikalna na njegovu osu. Uzorak užeta koji se

rope is produced by winding of six strands with the same diameter in one layer around rope centerline. Each of the strands forms a cyclic screw plane – Archimedean serpentine.

ovde analizira je proizveden upredanjem šest strukova istog prečnika i to u jednom sloju oko jezgra užeta. Svaki struk preden je u formi Arhimedovog zavrtnja

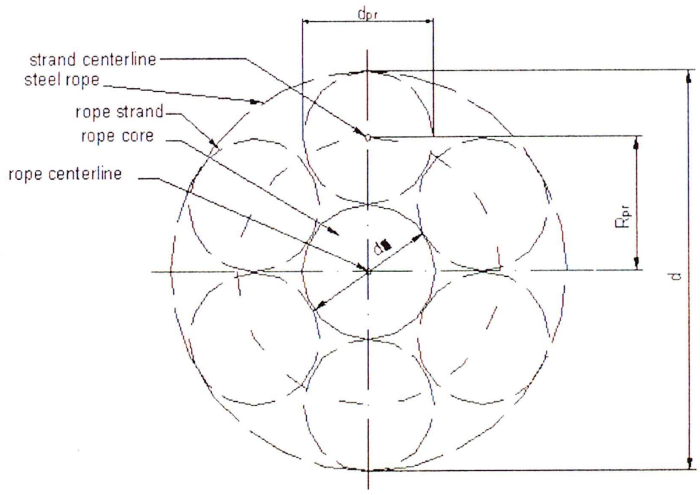


Figure 1 The basic structural rope parameters
slika 1 Osnovni strukturni parametri užeta

The plane is created from a geometric viewpoint by a screw movement of the circle with certain diameter, where the circle plane is the normal one of the screw. Going out of assumption, that strand diameters are equal, sectional curves of appropriate cyclic screw planes by a plane, vertical to the rope axis are identical and in optimal case each two adjacent curves interfere one another, according to [3] it is possible for given rope diameter d and for given strands number n_{pr} with winding angle β_{pr} to determine the **optimal rope strands diameter $d_{pr\,opt}$**.

S geometrijske tačke gledišta ravan se formira zavojnim pomeranjem kruga određenog prečnika, pri čemu je kružna ravan normalna, odnosno vertikalna u odnosu na zavoj. Polazeći od pretpostavke da su prečnici struka jednaki, da su krive koje opisuju presek zavojnih ravni identične i da se, u optmalnom slučaju, susedne krive ponašaju u skladu sa [3] moguće je za određeni prečnik užeta d za dati broj strukova n_{pr} a pod uglom upredanja β_{pr} odrediti **optimalni prečnik strukova u užetu $d_{pr\,opt}$**.

3 SOLUTION

Going out of assumption, that winding angle of rope strands β_{pr}, strands number in the rope n_{pr} and winding radius of rope strands R_p. is being given, let's apply the procedure, listed in [3].

1. Calculation of the angle φ (an angle, which contain a tangent line to the sectional curve of the optimal strand, being leaded through the rope midpoint) by convenient numerical method e.g. the bisection method ,from the expression:

$$arctg\left(tg\varphi.\cos\beta_{pr}\right)+\frac{\sin\varphi\cos\varphi\sin^2\beta_{pr}}{\left(1-\sin^2\varphi\right)\cos\beta_{pr}}=\frac{\pi}{n_{pr}}. \quad (1)$$

3 REŠENJE

Polazeći od pretpostavke da je dat ugao upredanja strukova β_{pr}, broj strukova u užetu n_{pr} i poluprečnik upredanja R_p, primenićemo postupak naveden u [3].

1. Izračunaćemo ugao φ (ugao koji čine tangenta krive koja opisuje presek optimalnog struka i linije koja prolazi kroz središte struka) primenjujući odgovarajuću numeričku metodu, tj. odnosno metodu preseka ili bisekcije iz izraza:

$$arctg\left(tg\varphi.\cos\beta_{pr}\right)+\frac{\sin\varphi\cos\varphi\sin^2\beta_{pr}}{\left(1-\sin^2\varphi\right)\cos\beta_{pr}}=\frac{\pi}{n_{pr}}. \quad (1)$$

2. According to [3] from the formula for determination of optimal strand $\frac{d_{pr\,opt}}{2}$ after substitution and editing the following expression can be obtained:

2. U skladu sa [3] iz fomule za optimizaciju struka $\frac{d_{pr\,opt}}{2}$ nakon supstitucije dobija se sledeći izraz:

$$\frac{d_{pr\,opt}}{2} = R_{pr}\sqrt{1+\left(\frac{\frac{\pi}{n_{pr}} - arctg(tg\varphi\cos\beta_{pr})}{\sin\varphi\sin\beta_{pr}tg\beta_{pr}}\right)^2 - 2\left(\frac{\frac{\pi}{n_{pr}} - arctg(tg\varphi\cos\beta_{pr})}{\sin\varphi\sin\beta_{pr}tg\beta_{pr}}\right)\cos\varphi}\ . \quad (2)$$

Likewise we can proceed in designing of the optimal diameter of wires in the first layer of the rope strand $\delta_{dr1\ opt}$ and next in designing of optimal diameter of wires in the second layer $\delta_{dr2\ opt}$ on the assumption that are being given α_{v1} - wires winding angle of the first layer in the rope strand and α_{v2}- wires winding angle of the second layer in the rope strand.

Na isti način vrši se i optimizacija prečnika žica u prvom sloju struka $\delta_{dr1\ opt}$, a zatim i optimizacija prečnika žica u drugom sloju $\delta_{dr2\ opt}$ pod pretpostavkom da je α_{v1} -ugao upredanja žica u prvom sloju struka, a α_{v2}-ugao upredanja žica u drugom sloju struka.

Table 1 Optimal wires diameters and diameters of the rope strand SEAL 6x(1+9+9)+v
tabela 1 Optimalni prečnici žica i prečnici strukova užeta SEAL 6x(1+9+9)+v

φ_{av1} [°]	19,8531	φ_{av2} [°]	19,5735	$\Phi_{\beta pr}$ [°]	29,0246
δ_{dr1} [mm]	0,71	δ_{dr2} [mm]	1,25	d_{pr} [mm]	5,250
$\delta_{dr1\ opt}$ [mm]	0,7913	$\delta_{dr2\ opt}$ [mm]	1,3402	$d_{pr\ opt}$ [mm]	5,2359

The calculation was realised and verified for the rope cross-section geometry with the equal gap – 0,01 mm among wires in strand layers (fig. 2) with optimal parameters, which are documented in Table 1.

Proračun koji je izvršen i verifikovan odnosi se na geometriju poprečnog preseka užeta jednakih koeficijenata ispune, odnosno sa međuprostorom između žica u struku od 0,01mm (fig. 2) i optimalnih parametara koji su dati u tabeli 1.

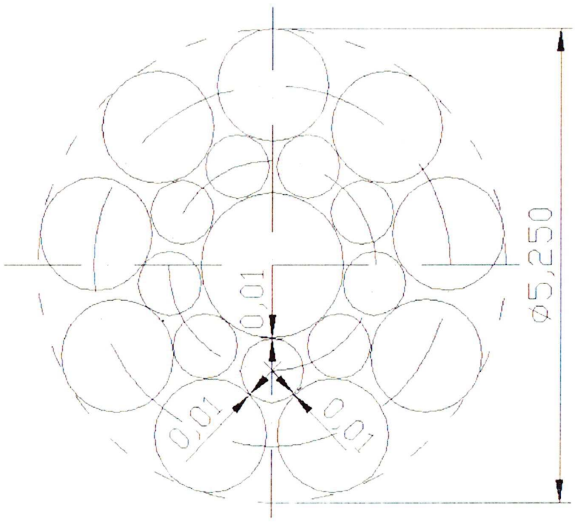


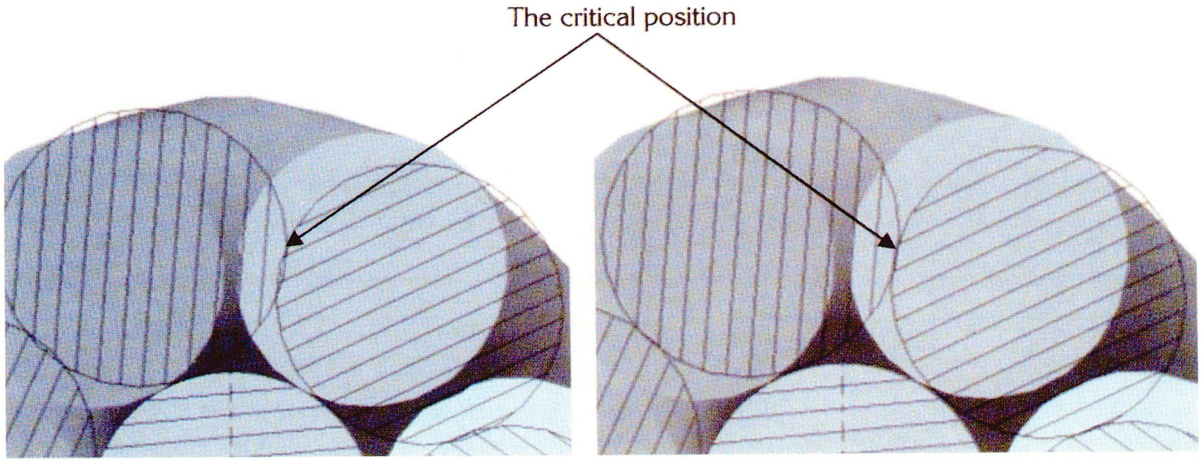
Figure 2 The layout of wires in strand layers
slika 2 Raspored žica u slojevima struka

The rope section is shown in fig.3a, which geometry is designed inconveniently, because overlapping of wires cross-sectional curves appears. It doesn't enable to observe technological procedure in rope production in practice and rope qualitative parameters ,of course.

An optimal design for a rope geometry by optimal rope strand diameter $d_{pr\,opt}$ calculation is shown in fig.3b.

Na slici 3 prikazan je presek užeta nepovoljnih geometrijskih karakteristika zbog preklapanja krivih koje opisuju poprečni presek žice kod kojih je onemogućeno praćenje tehnologije i kvalitativnih parametara.

Geometrijske karakteristike užeta sa obračunom optimalnog prečnika strukova $d_{pr\,opt}$ prikazane su na slici 3b.

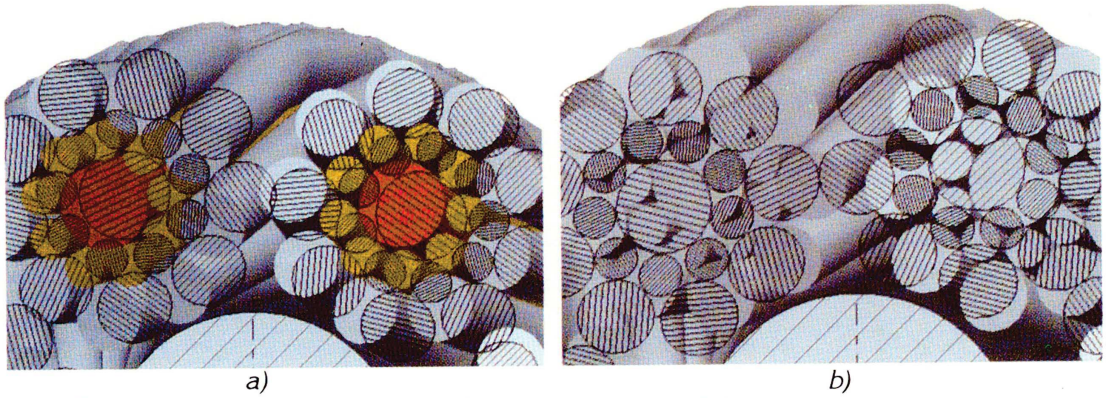


a) b)

Figure 3 The strands cross-sectional curves of the right contrary six strands steel rope SEAL 6x(1+9+9)+v
a - a rope with inconveniently designed geometry , b –a rope with calculated optimal strand diameter $d_{pr\,opt}$
slika 3 Poprečni presek šestostrukog čeličnog užeta sa kontra desnom pređom SEAL 6x(1+9+9)+v
a - a uže nepovoljnih geometrijskih karakteristika, b –a uže sa strukom optimiziranog prečnikom $d_{pr\,opt}$

The cross-sectional curves of individual wires in layers of the right contrary six strands steel rope SEAL 6x(1+9+9)+v is shown in Fig. 4.

Poprečni presek pojedinačnih žica u slojevima šestostrukog čeličnog užeta sa kontra desnom pređom SEAL 6x(1+9+9)+v prikazan je na slici 4.



a) b)

Figure 4 The cross-sectional curves of individual wires in layers of the right contrary six strands steel rope SEAL 6x(1+9+9)+v
a - a rope with inconveniently designed geometry , b –a rope with calculated optimal strand diameter $d_{pr\,opt}$
slika 4 Poprečni presek pojedinačnih žica u slojevima šestostrukog čeličnog užeta sa kontra desnom pređom SEAL 6x(1+9+9)+v
a - a uže nepovoljnih geometrijskih karakteristika, b –a uže sa strukom optimiziranog prečnika $d_{pr\,opt}$

4 CONCLUSION

A problem area of determination of the optimal strands diameter in a rope cross-section appears in connexion with compliance of technological conditions in rope production. This procedure helps to solve the problem by using available computer support in a quite simple original way.

4 ZAKLJUČAK

Pitanje optimizacije prečnika struka u poprečnom preseku užeta je veoma značajno za proces proizvodnje. Predložena metoda omogućava da se pomenuti problem rešava na veoma lak i originalan način uz pomoć računara.

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