SAFETY AGAINST SLIPS AND ANALYSIS OF TWO-SIDE SELF-TIGHTENING CABLE CONNECTION DEVICES FOR EXTRACTION VESSELS

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Abstract: Winding installations have the role of transporting, between underground and surface, useful minerals, materials, equipment, and people, with extraction vessels. Cable connecting devices connect winding installation cables to extraction vessels. Depending on their design, connecting cables can be: with loop and core, self-tightening with wedged core on one or both sides; with hinged jaw; with cone-shaped friction wedges; with wedges and bridles. The paper presents an analysis of circular self-tightening metal cable connecting devices wedged on both sides, meeting the requirements of STAS 12519/87.

Key words: cable connection device

INTRODUCTION

Connecting devices (Fig.1) are mechanical devices linking cables and extraction vessels [1], [2]. Cable connecting devices are designed so that cable is able to wind around a metal core, provided with a groove, or can be tightened between two metal wedges, also provided with grooves for the cable. From a construction point of view, the device is made up of two shields and two grips, and therein the core in the shape of a wedge can slide and press the cable winded on it.

The cable is tightened between the core and the a grip, and the end of the cable is caught with two clamps resting on the shields. Both the core and the grip are provided with a cable groove. Its radius varies with the cable diameter. In the lower part, in a coaxial position to the cable, the shields are provided with holes which connect to the extraction vessel.

Due to the load in the cable, the core between the two grips are wedged, normal cable tightening pressures and thus friction efforts being resulted, which when the core angle and the friction coefficient are judiciously chosen, will keep the cable in the device as long as cable tear loads values are not reached.

In case of connecting devices the term "safety against cable slip" is often used.

The safety against cable slip of the cable is the ratio of maximum friction forces that can be generated in the device to keep the cable and the force at which the cable tears.

CONSTRUCTION AND OPERATION OF ALUMINUM BOX BUNDLING PRESS

Fig. 2 shows the design solution of the cable connecting device (CCD) for extraction vessels, made up of: 1 - right shield; 2 - left shield; 3 - main bolt; 4 - metal core; 5 - fixed left grip; 6 - fixed right grip; 7 - core axis; 8 - wedging/de-wedging screw; 9 - safety tube nut; 10 - blocking clamp; 11 - mobile guide; 12 - fixing clamp; 13 - metal cable; 14 - vertical wedge;

15 - arresting plate; 16 - marking plates; 17 - handle; 18 - centering pins; 19 - assembling screws; [2], [6], [7].

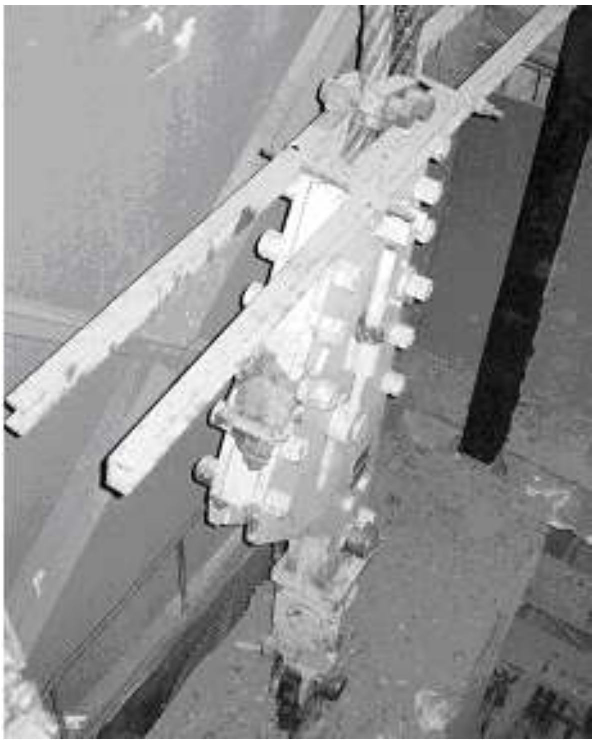

Fig.1. Cable connecting device

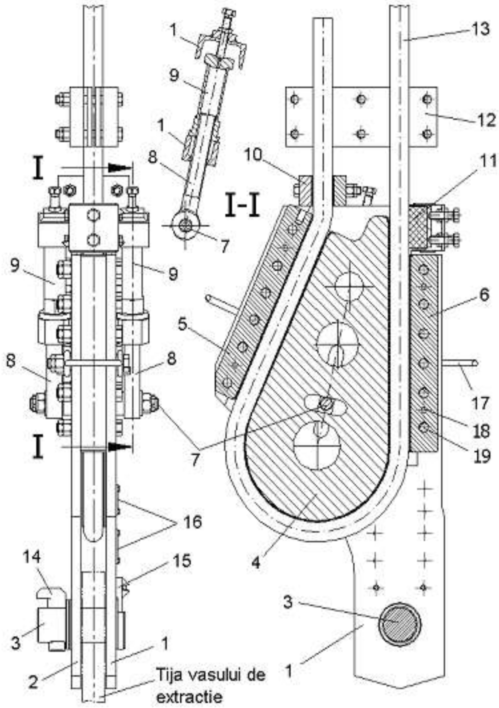

Fig.2. Cable connecting device design

To fix the cable in the device, the metal core 4 is moved with the help of the screws 8, so that the end of the cable might enter between the core and the left grip 6. Then a loop is bended at the end of the 1 - 1.3 m cable inserted between the core and the right grip 5, so that the length of the cable end coming out of the device would be of at least 500 mm.

When the cable is in the metal core groove, it is wedged between the fixed grips 5 and 6 with the help of screws 8, and blocking clamps 10 are fixed at the end of the cable, then the device is coupled to the extraction vessel rod by bolt 3, and the extraction vessel is lifted 150 - 200 mm off its blocking support with the help of the winding installation.

The cable and metal core position is then checked between shields and grips, then mobile guide 11 and fixing clamps 12 are mounted. Cable connecting devices will provide interchangeability of components, so that the cable will not deteriorate and slip.

For this, fixed shields and metal core surfaces coming into contact with the metal cable, are covered with an Y-Sn10 STAS 202-86 anti-friction 3,5 - 4 mm thick alloy layer. The main bolt and its sleeves in the shields will not show plastic deformations in the contact areas, as a result of operation.

The main elements (right shield, left shield, main bolt, metal core, fixed grips) should not be sized in such a manner as to show a higher safety coefficient than 10 for maximum static load.

FORCES AND TIGHTENING CAPACITY

In these devices, safety against slip depends only on the device construction and friction coefficients between the cable and the items taking part in tightening. Safety against slip is the same, irrespective of the force generated in the cable. Equilibrium of forces, if there is any, is the same limit, for $c_a < 1$ the cable slips. For connecting device with wedged core and tightening on two faces, the calculation methodology of the tightening capacity (safety against slip) is given below (fig.3) [4], [5], [6], [7]. The loose end of the cable applies R_1 force to the housing of the device, (with the F_1 friction component and N_1 normal component) , angle φ being made with the normal line (maximum value of the friction angle was taken, considering the relative original movement of the core to the housing); the free end of the cable exerts R_2 force to the housing (with F_2 friction component and N_2 normal component), angle $\varepsilon \leq \varphi$ being made with the normal line (any unknown value ε of the friction angle, lower than the maximum possible value) and the linking bolt exerts principal P force (static load (traction force)).

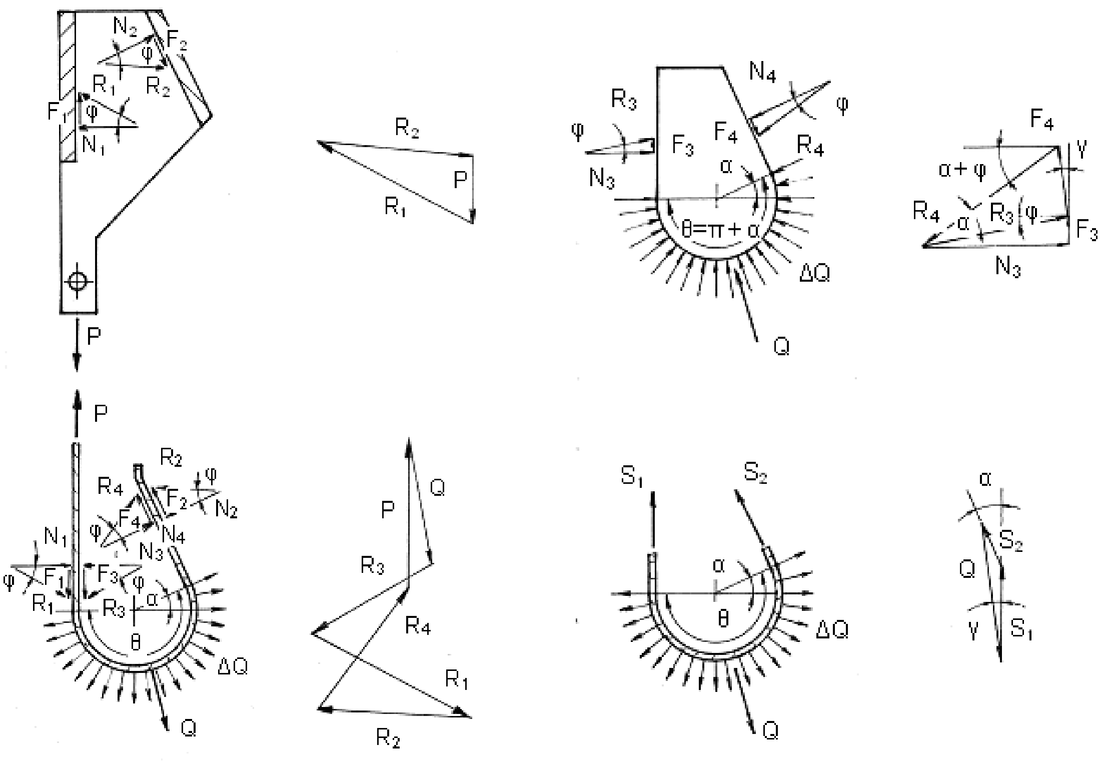

Fig.3. Calculation scheme for cable not slipping

The winding engine exerts a force equal to static load P from the housing to the tightening section at the entry in the device from the loose end of the cable, force R_1 (with F_1 friction component and N_1 normal component) from the housing to the free end of the cable (to the tightening of the free end) force R_2 (with F_2 friction component and N_2 normal component), angle $\varepsilon \leq \varphi$ being made with the normal line (any unknown value ε of the friction angle lower than the maximum possible value), from the core to the tightening section at the entry in the device force R_3 (with F_3 friction component and N_3 normal component), inclined to the normal line with angle φ (maximum value of the friction angle was considered , taking into account the original relative movement of the core to the cable), from the core tp the tightening section of the free end force R_4 (with F_4 friction component and N_4 normal component) inclined to the normal line with angle φ, and from the core to the winding section of the cable to the arc θ ($\theta = \alpha + \pi$) pressure resultant , force Q.

To the core from the cable to the tightening section at the entry in the device force R_3 (with friction component F_3 and normal component N_3) angle φ being made to the normal line (maximum value of the friction angle considering the relative original movement of the core to the housing), from the cable to the tightening section of the free end force R_4 (with F_4 friction component and N_4 normal component) inclined to the normal line with angle φ and fro m the cable to the winding section of the cable to the arc θ ($\theta = \alpha + \pi$) resultant of pressure, force Q.

Unlike the connecting device with wedged core on one side, in case of the connecting device with wedged core on two sides, at the entry in the winding arc θ ($\theta = \alpha + \pi$)

The tension is no longer P, but a lower tension, due to friction of the cable on the tightening section at the entry in the device.

This tension, unknown so far, will be noted S_1.

Taking apart the cable section corresponding to the winding over arc $\theta = \alpha + \pi$, it is seen that over this section S_1 and S_2 forces apply which stay Q after the winding.

Tension S_1 is lower than force P, namely by the sum of friction forces at the tightening section at the cable entry in the device.

Table 1 gives the values of the other forces for P load values of 130.000N, 160.000N, 300.000N, 320.000N and values of friction coefficient μ of 0,10, 0,15, 0,20, 0,25 şi 0,30.

Table 1. Values of the other forces for P load values of 130.000N, 160.000N, 300.000N, 320.000N and values of friction coefficient μ of 0,10, 0,15, 0,20, 0,25 and 0,30.

CCD TYPE	P [N]	μ	$R_1 = R_3$ [N]	$N_1 = N_3$ [N]	$F_1 = F_3$ [N]	$R_2 = R_4$ [N]	$N_2 = N_4$ [N]	$F_2 = F_4$ [N]
CCD-13	130.000	0,10	135542,95	134870,27	13487,027	143732,62	143019,3	14301,93
		0,15	140722,24	139165,34	20874,801	153686,73	151986,4	22797,96
		0,20	147955,27	145082,08	29016,416	166443,47	163211,25	32642,25
		0,25	157811,18	153099,33	38274,833	182905,68	177444,58	44361,145
		0,30	171188,29	163968,65	49190,594	204470,4	195847,12	58754,137
CCD-16	160.000	0,10	166822,09	165994,18	16599,418	176901,69	176023,76	17602,376
		0,15	173196,61	171280,42	25692,063	189152,9	187060,18	28059,027
		0,20	182098,8	178562,56	35712,512	204853,5	200875,39	40175,077
		0,25	194229,14	188429,95	47107,487	225114,69	218393,33	54598,332
		0,30	210693,28	201807,56	60542,269	251655,88	241042,61	72312,784
CCD-30	300.000	0,10	312791,41	311239,09	31123,909	331690,67	330044,55	33004,455

		0,15	324743,64	321150,79	48172,618	354661,7	350737,84	52610,677
		0,20	341435,24	334804,8	66960,96	384100,32	376641,35	75328,27
		0,25	364179,64	353306,15	88326,538	422090,04	409487,49	102371,87
		0,30	395049,91	378389,18	113516,76	471854,77	451954,9	135586,47
CCD-32	320.000	0,10	333644,17	331988,36	33198,836	353803,38	352047,52	35204,752
		0,15	346393,21	342560,84	51384,126	378305,81	374120,37	56118,055
		0,20	364197,59	357125,12	71425,025	409707,01	401750,77	80350,154
		0,25	388458,29	376859,89	94214,974	450229,38	436786,65	109196,66
		0,30	421386,57	403615,13	121084,54	503311,75	482085,22	144625,57

Table 2 shows tightening values (safety against cable slip) depending on the friction coefficient for μ de 0,10, 0,15, 0,20, 0,25, and 0,30 values of the friction coefficient, for $\alpha = 24^0$ wedging angle.

Table 2. Tightening values

μ	0,10	0,15	0,20	0,25	0,30
c_a	1,0633	1,2685	1,4072	1,5089	1,5879

Figure 4. shows the tightening capacity(safety against slip) variation function of the core wedging angle for μ 0,15, 0,20, 0,25, şi 0,30. Fig.5. shows the variation of the tightening capacity (safety against cable slip) function of the friction coefficent for α wedging angle of 16^0, 18^0, 20^0, 22^0, 24^0, 26^0, 28^0 şi 30^0.

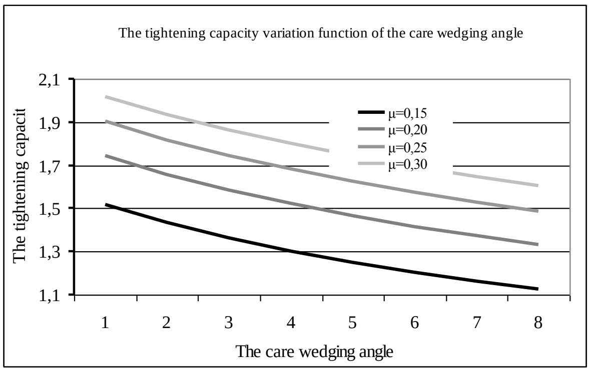

Fig.4. Variation of tightening capacity (safety against cable slip) function of core wedging angle

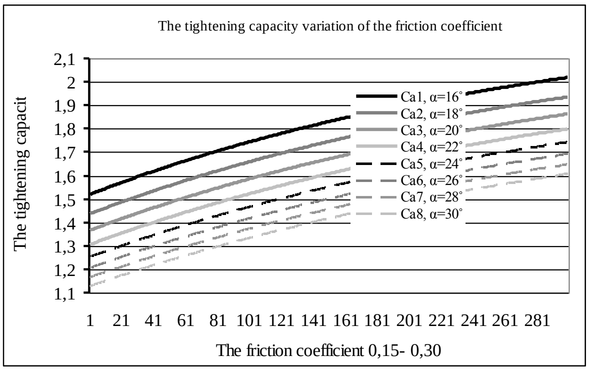

Fig.5. Variation of tightening capacity (Safety H against cable slip) function of friction coefficient

NUMERIC ANALYSIS OF CCD

Due to the high safety coefficient to be applied to these devices, an as accurate determination as possible of tensions in their elements is required.

To be able to carry out an analysis with finite element for the metal cable connecting device, a 3D geometric modeling of the device was necessary [3]. The device elements modeling was carried out with the help of Solid Edge Soft, and the analysis with finite elements was carried out with COSMOS Design STAR SOFT. The analysis was made only at the principal bolt, which is the most strained element. In the execution document of the devices, the calculation of the bolt verification was made according to Navier (pure bend), with a simple beam model resting with concentrated force on the middle of the beam, its length being equal to the distance between the two shields plus the width of a shield. The condition d/l ≥ 1/4 makes the bolt to be strained at simple bend (Juravski) where tangent tension given by the shear force occurs.

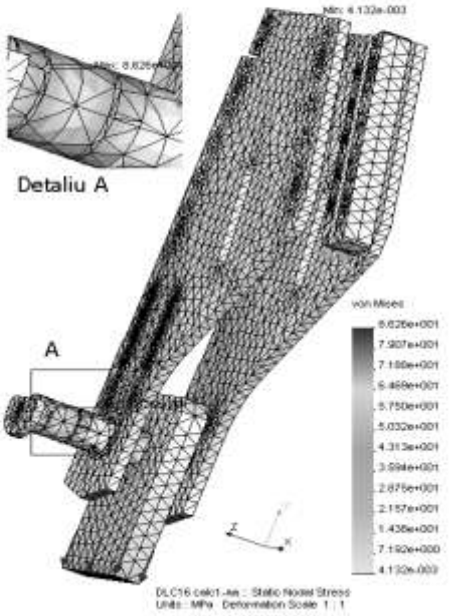

Fig.6. CCD-16 with 4 m distance between shields and rod

Fig. 6 shows the finite element analysis of CCD-16 (16 ton) for54 mm extraction vessel rod thickness, 58 mm distance between shields, 22 mm shield thickness and 80 mm bolt diameter. Maximum tension (σ = 86,26 MPa) is seen to occur in a point of the shear area above the neutral axis. This is explained by the fact that for the dimensional calculation and verification, Juravski's equation should be applied:

$$\sigma_{ech} = \sqrt{\sigma^2 + 4\tau^2} \qquad (1)$$

For the conditions from above σ = a 63,66 MPa, bending tension results in the extreme point on the vertical line, and the shearing force τ = 42,44 MPa, in the extreme points on the horizontal line, resulting that equivalent tension in vertical points σ_{echv} = 63,66 MPa, and horizontal σ_{echo} = 84,88 MPa. Fig.7 shows the finite element analysis of the same device, with rod width less than 10 mm, which occurs in mining, when spacers are used to center the extraction vessel rod. In this case, tension in the shear area is diminished to 71,95 MPa, in a horizontal plane, this is explained by the modality of segmenting space between shield and rod.

The conclusion is that modern CAD softs provides performance for interactive mechanic engineering, in our case it allowed rapid bolt check and suitable choice of material. Allied steel 42 MoCr11/STAS 791-88 is recommended for the bolt, with a flow resistance of $R_{p0,2}$ = 900 MPa, a 10.43 safety coefficient resulting.

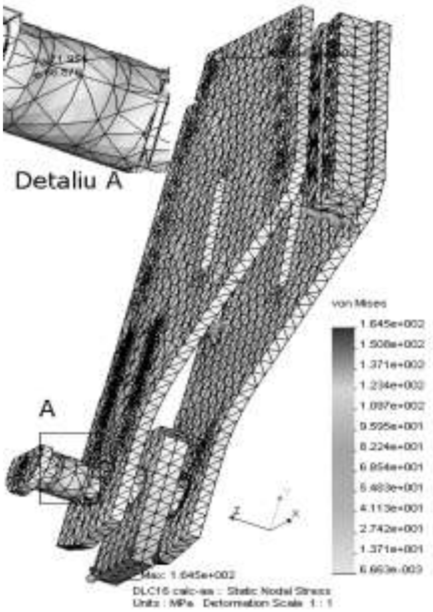

Fig.7. CCD-16 with 14 mm distance between shields and rod

CONCLUSIONS

For wedged core and two side tightening cable connecting devices, for winding engines vessels, safety against slip only depends on the construction of the device and the friction coefficients between the cable and the pieces participating in tightening. Keeping cables in the device is happens only due to tightening forces generated from wedging between core, cable and grips of the device. Any additional safety measures that might be taken (clamps, pressure screws etc) do not influence the self-tightening phenomenon, therefore they are not considered in the calculations.Safety against slip is the same, irrespective of the force generated in the cable. Equilibrium of forces, if there is any, is the same. Safety against slip of the cable is the ratio of. Maximum friction forces that can be generated in the device to retain cable and the force at which the cable is torn. From the point of view of tightening capacity, (Safety to slip), both friction forces tending to retain cable for any given load, and especially maximum friction forces that might be generated in the device, up to maximum friction angle values, are to be considered.

Thus the ratio of maximum friction forces and the value of suspended load, P, can determine the value of device tightening capacity. Connecting devices are especially important in providing safe transportation in shafts.

The paper analyzed forces generated in the connecting device during operation (with numeric application to devices CCD-13, CCD-16, CCD-30 and CCD-32) in view of determining cable retaining safety during operation, as well as determining concrete force values applied to various component parts of the device, in view of ther suitable sizing.

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