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LONG DISTANCE HEAVY DUTY OVERLAND BELT CONVEYORS - "TRANSP_2" COMPUTER PROGRAM BASED ON ITERATIVE CALCULATION METHOD

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Abstract

Overland belt conveyors used in surface mines are often very long and have extremely high capacities. There very large electro motors (more than two) are needed to overcome working resistances. The main resistances are primary, secondary and special. Working resistances and belt tensions should be calculated in steady regime (stationary work), and unsteady regime (start and stopping of the conveyor. It is necessary to use properly disposing power on the conveyor drive pulleys, with secure soft start of the electro motors. In this work the main iterative principle in the algorithm of computer program TRANSP_2 [7] are explained. This C/C++ program was used for calculation of six long conveyors (overall length 9,7 km, and nominal capacity of 3800 t/h) located in the surface coal mine Suvodol - Republic of Macedonia.

***Key words**: belt conveyors, pulley, motors, mine, computer calculation*

1 INTRODUCTION

Long overland belt conveyors usually overcome numerous up-hills or down-hills. The transitions between them are concave or convex curves. DIN 22101 [2],[1], and other standards offer procedures for calculation [3],[4],[5].
So, the entire length of the conveyor should be divided into small partitions (sections). For any of the sections calculation according to the calculation procedures will be performed.

Any arc with its constant Radius, begins after a strait section (Point A), then the arc is divided on segments (max five).The arc ends with point B.

(There the beginning of the concave arc is point A ≅ 72, and the end is point B ≅ 76 - and also the other concave arc is point A≅ 77, and the end of arc is point B ≅ 79).
So, six belt conveyors in surface coal mine REK-Bitola - Macedonia, are with overall length over 9,2 km:
Because of the complexity of the terrain and big distances, some conveyors should be divided into many segments, sometimes more than hundreds.
All conveyors use steel cord belts St630 or St1250. Almost never they work with nominal capacities.

***Fig.1**. View of a long overland belt conveyor*

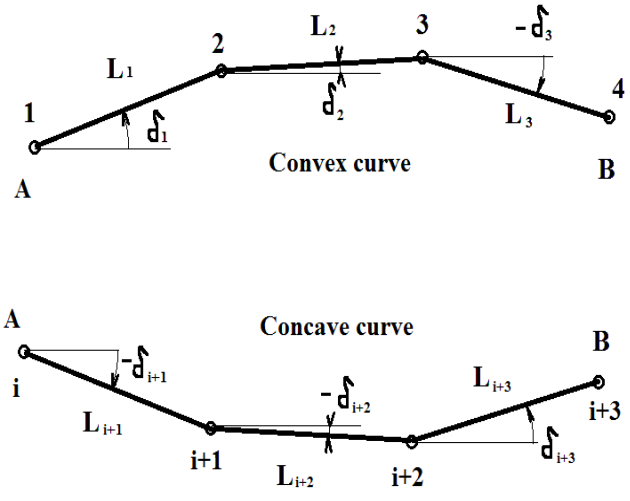

***Fig.2** Convex and concave curves (arcs) of an overland conveyors divided on three sections*

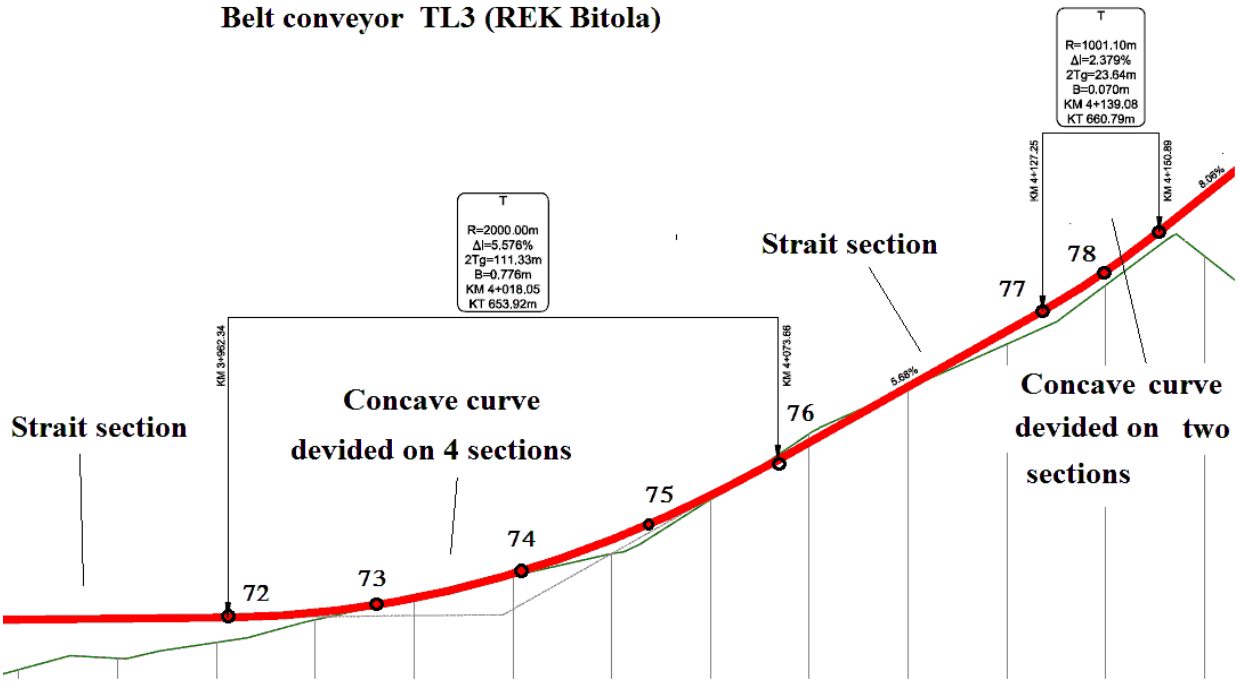

Fig.3*.Example: Sections of the end of the belt conveyor TL3 (Located on surface coal mine REK-Bitola)*

Table 1: Lengths of subsequent belt conveyors with number of arcs and sections, on the mine REK_Bitola

Conveyor	Length [m]	Num. Curves	Num. sections	Motors [kW]	Nom.Capacity [t/h]
TL2	2101,23	18	72	2 x 500	3800
TL3	2097,42	21	79	3x 500	3800
TL4	2135,37	10	40	3x 500	3800
TL5	891,80	7	17	1x500	3800
TL6	733,66	7	23	1x500	3800
TL7	1190,00	2	7	3x400	3800

2. PHASE #1 OF THE PROGRAM TRANSP_2 EXECUTION

File j1*.c concludes data of all start points A of every arc (curve), than end of the curve B, radius in meters, and type of the curve (convex = 1 and concave = 2).

In First phase of program execution, the values which are accomplished:

- Contour points coordinate xK_i [m] and yK_i [m] along the whole length.
- Length L_i [m] and inclination angle δ_i of each segment,
- Masse of a material over the belt segment m_{Li} [kg/m^2]
- Radius of the curves R_i [m]

All of those parameters saves in the same file j1*.c, i the positions below 50-th row.

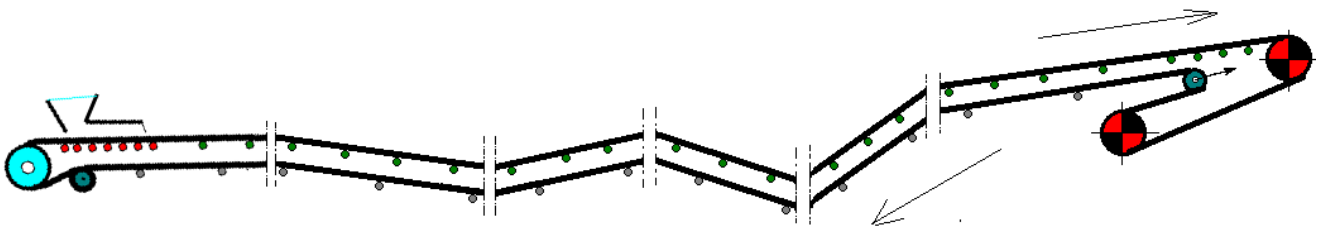

Fig.4. *View of a main screen of TRANSP_2 computer program(C/C++)[7]*

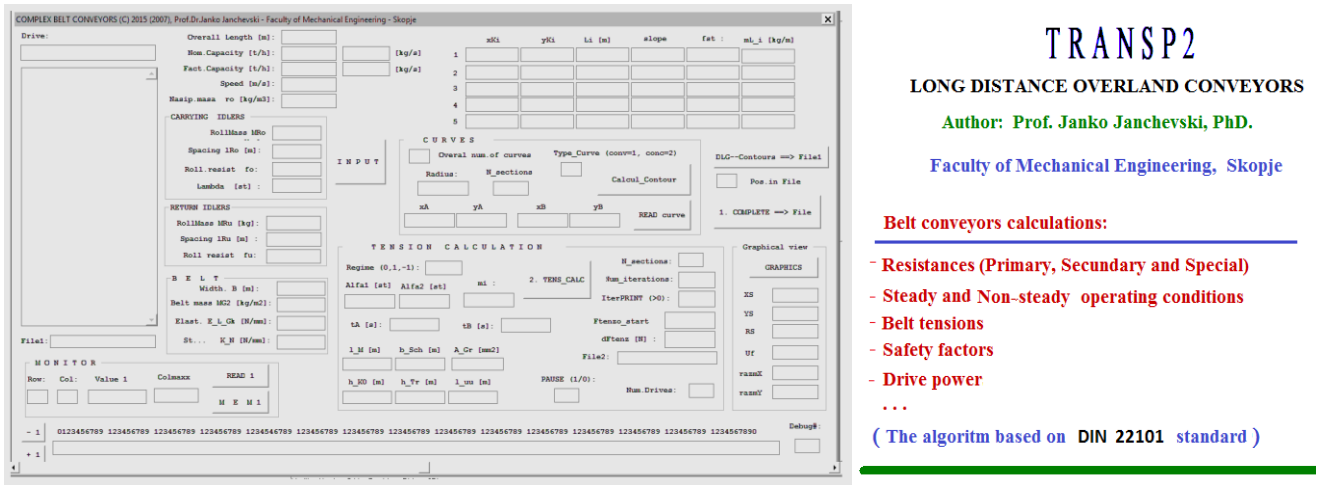

Fig.5. *The main Dialog box for input data*

Belt conveyor TL4

170	xA	yA	xB	yB	Radius	N_arcs	Type
1	4210.59	661.1	4235.44	661.4	1001.1	2	2
2	4243.75	661.6	4390.21	658.0	1500.	4	1
3	4420.73	655.7	4509.90	653.1	1001.1	3	2
4	4573.56	654.2	4582.06	654.3	1500.	2	1
5	4615.02	654.6	4648.20	655.5	1001.1	2	2
6	4657.53	656.0	4724.50	655.9	750.0	3	1
7	4742.69	655.1	4942.05	659.4	1500.0	4	2
8	5112.71	674.5	5121.41	675.3	1500.0	2	1
9	5236.49	684.4	5643.02	701.3	5000.0	4	1
10	6223.94	701.4	6304.11	704.8	1001.1	3	2
11							0
12							

Fig.6. *View of the j1TL4.c file with parameters for beginning A, and end B of the arcs (curves) on the conveyor TL4*

Calculated values for Contour Points

50 No	xKi	yKi	Li	delta	fii	mLi	Curve	Re i Ra
51 1	4198.650	660.150	11.978	4.549	0.987	57.133	0	
52 2	4210.590	661.100	12.426	0.336	1.000	57.870	2	1001.1
53 3	4223.016	661.173	12.426	1.047	1.000	57.870	2	1001.1
54 4	4235.440	661.400	8.312	1.379	1.000	57.870	0	
55 5	4243.750	661.600	36.640	0.691	1.000	57.870	1	1500.
56 6	4280.387	662.042	36.640	-0.708	1.000	57.870	1	1500.
57 7	4317.024	661.589	36.640	-2.108	0.999	57.839	1	1500.
58 8	4353.639	660.242	36.640	-3.507	0.992	57.434	1	1500.
59 9	4390.210	658.000	30.607	-4.310	0.988	57.202	0	
60 10	4420.730	655.700	29.745	-3.373	0.993	57.473	2	1001.1
61 11	4450.423	653.950	29.745	-1.670	1.000	57.870	2	1001.1
62 12	4480.155	653.083	29.745	0.032	1.000	57.870	2	1001.1
63 13	4509.900	653.100	63.670	0.990	1.000	57.870	0	
64 14	4573.560	654.200	4.250	0.755	1.000	57.870	1	1500.
65 15	4577.810	654.256	4.250	0.593	1.000	57.870	1	1500.
66 16	4582.060	654.300	32.961	0.521	1.000	57.870	0	
67 17	4615.020	654.600	16.597	1.079	1.000	57.870	2	1001.1
68 18	4631.614	654.912	16.597	2.029	1.000	57.862	2	1001.1
69 19	4648.200	655.500	9.343	3.068	0.995	57.561	0	
70 20	4657.530	656.000	22.330	1.620	1.000	57.870	1	750.
71 21	4679.851	656.631	22.330	-0.086	1.000	57.870	1	750.
72 22	4702.181	656.598	22.330	-1.792	1.000	57.870	1	750.
73 23	4724.500	655.900	18.208	-2.518	0.997	57.720	0	
74 24	4742.690	655.100	49.886	-1.623	1.000	57.870	2	1500.
75 25	4792.556	653.687	49.886	0.283	1.000	57.870	2	1500.
76 26	4842.442	653.934	49.886	2.188	0.999	57.816	2	1500.
77 27	4892.291	655.838	49.886	4.094	0.990	57.264	2	1500.
78 28	4942.050	659.400	171.327	5.056	0.985	56.986	0	
79 29	5112.710	674.500	4.368	5.337	0.983	56.905	1	1500.
80 30	5117.059	674.906	4.368	5.170	0.984	56.953	1	1500.
81 31	5121.410	675.300	115.439	4.521	0.987	57.141	0	
82 32	5236.490	684.400	101.747	4.129	0.989	57.254	1	5000.
83 33	5337.972	691.727	101.747	2.963	0.995	57.592	1	5000.
84 34	5439.583	696.987	101.747	1.798	1.000	57.870	1	5000.
85 35	5541.280	700.178	101.747	0.632	1.000	57.870	1	5000.
86 36	5643.020	701.300	580.920	0.010	1.000	57.870	0	
87 37	6223.940	701.400	26.754	0.897	1.000	57.870	2	1001.1
88 38	6250.690	701.819	26.754	2.428	0.998	57.746	2	1001.1
89 39	6277.420	702.953	26.754	3.960	0.990	57.303	2	1001.1
90 40	6304.110	704.800	27.749	4.600	0.987	57.118	0.	
91 41								

Fig.7. *Example: Calculated parameters of TL4 conveyor after First-phase of program execution for all 40 contour points (positions in the file are positioned from row 50 to the row 90 in the file* ***j1TL4.c)***

3. PHASE #2 OF THE PROGRAM EXECUTION

Calculations of the tension forces in any contour point, sags, power, safety factors, in any conditions (winter- snow, summer high temperature, during steady operation, in starting or breaking etc.), according to the DIN 22101 standard, it is very important to start the calculation of the first point, Point 0, with a initial value $F_{tens}[0]$. This value should be between 0 kN to 20 kN depending on the capacity and transport distance [6]. Calculation of the six conveyors for REK Bitola, used start value $F_{tens}[0]$=10 kN. All segments are calculated and during the calculation some conditions must be accomplished:

1. Belt sags between all neighboring carrying and return idlers must be less than 1%-2%. (DIN 22101 recommends 1%).

In the files **j1*.c** below the row 29 to 41 are input parameters for the conveyors which are necessary for second phase of calculation.

2. Friction condition: $$F_{T2} \geq \frac{F_{Tr,\max}}{e^{\mu\cdot\alpha}-1} \qquad (1)$$

Where $\boldsymbol{F_{T2}}$ is belt tension of the belt running off a pulley, and $F_{Tr,max}$ is a maximal total pulley peripheral force. In many cases, to be able to accomplish those two condition is possible with a big tension forces. So, the initial force $F_{tens}[0]$ must increase with, for example, dF=1 kN in all iterations. After calculation, when both conditions are accomplished, iterations ended, and program TRANSP_2 delivers results. Sometimes, more than hundred iterations are needed. However, complete calculation Phase#2 of TRANSP_2 takes less than minute time.

The results are shown in a Dialog box, Fig..8.

```
28    |
29  |--------- INPUT DATA FOR TL4 Conveyor ----------------------------------------------100-----------------------------------------------150--------JJ  |
30      kapac t/h  ro kg/m3  v m/s     Lvk m     B mm     MRo kg     lRo m     MRu kg     lRu m     l_th1    mG2 kg/m2 lambda     fo         fu        Q_fakt t/h Nsekc |
31       3800.       800       4.8      2133.12   1.4        30.       1.5       22.8       6.0         913       21.5      45.       0.025     0.024     1000.    40   |
32  | ---|---------|---------|---------|---------|---------|---------|--m/s ---|--- m ---|--- m ---|---------|---------|---------|---------|-- mm2 --|-- N/mm2-|------|
33      Auf1 Auf2  Bort      Cist1     Cist2     Cist3     Cist4        v_0       l_M     b_Sch     mi_1      mi_2      C_Schb    mi_4      A_Gr      p_Gr                  |
34        1   0      1         1        40        40        40          0.0      0.53      0.90       0.6       0.6        1.0      0.65     14000.      0.07                  |
35  | ---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----  |
36      Alfa1 [st]  Alfa2     mi        tA [s]    tB [s]    GD2rot     Gsp N     Pogoni    PemVk     n_em      i_red     SumGbar   Rbar  m   Eta_ges   Dsp m                 |
37       170.       180.0     0.35      28.0      41.0      1300.      4000.      12       1500.     1500       16.75     141700.   0.512     0.95      0.35                  |
38  | ---|---------|---------|-- N/m --|---------|---------|---------|-- m  ---|-- m  ---|--N/mm --|-- m ----|---------|---------|---------|-- N/mm--|---------|-----  |
39      ho_rel      hu_rel    Sigma_kin                       c_uu      h_K0      h_Tr      E_L_Gk    l_uu       S0        S1        K_t_rel   K_N                   |
40      0.01        0.01      1250.                            14       0.35      0.01      100000.   5.0        1.2       1.9       .45       1250.                 |
41  | ---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----  |
42
```

Fig.8. *View on the j1TL4.c file - Input data for the TL4 conveyor*

i70	#i	L m	h m	FHo kN	FNo	Fsto	Ftenzo	Sag o mm	FHu	FNu	Fstu	Ftenzu	Sag u mm
1		11.98	0.95	0.314	1.335	0.813	117.000	2.04	0.095	0.637	0.281	112.500	11.74
2		12.43	0.07	0.329	0.000	0.063	119.678	2.03	0.099	0.000	0.022	111.418	11.93
3		12.43	0.23	0.329	0.000	0.196	120.296	2.02	0.099	0.000	0.067	111.226	11.94
4		8.31	0.20	0.220	0.000	0.173	121.047	2.00	0.066	0.000	0.059	110.989	11.97
5		36.64	0.44	0.970	0.000	0.381	121.590	2.00	0.292	0.000	0.130	110.815	11.99
6		36.64	-0.45	0.970	0.000	-0.391	123.607	1.96	0.292	0.000	-0.134	110.182	12.06
7		36.64	-1.35	0.969	0.000	-1.163	124.852	1.94	0.292	0.000	-0.398	109.813	12.08
8		36.64	-2.24	0.965	0.000	-1.925	125.325	1.92	0.292	0.000	-0.662	109.708	12.07
9		30.61	-2.30	0.804	0.000	-1.970	125.028	1.92	0.244	0.000	-0.679	109.867	12.03
10		29.75	-1.75	0.784	0.000	-1.503	124.414	1.94	0.237	0.000	-0.517	110.127	12.02
11		29.75	-0.87	0.787	0.000	-0.748	124.232	1.95	0.237	0.000	-0.256	110.236	12.04
12		29.75	0.02	0.788	0.000	0.014	124.812	1.94	0.237	0.000	0.005	110.083	12.07
13		63.67	1.10	1.686	0.000	0.949	126.154	1.92	0.508	0.000	0.325	109.670	12.11
14		4.25	0.06	0.113	0.000	0.048	129.946	1.87	0.034	0.000	0.017	108.471	12.25
15		4.25	0.04	0.113	0.000	0.038	130.184	1.86	0.034	0.000	0.013	108.396	12.26
16		32.96	0.30	0.873	0.000	0.259	130.412	1.86	0.263	0.000	0.089	108.325	12.27
17		16.60	0.31	0.439	0.000	0.270	132.142	1.84	0.132	0.000	0.092	107.784	12.32
18		16.60	0.59	0.439	0.000	0.507	133.153	1.82	0.132	0.000	0.174	107.464	12.35
19		9.34	0.50	0.246	0.000	0.430	134.400	1.79	0.074	0.000	0.148	107.063	12.38
20		22.33	0.63	0.591	0.000	0.545	135.246	1.79	0.178	0.000	0.186	106.787	12.43
21		22.33	-0.03	0.591	0.000	-0.029	136.788	1.77	0.178	0.000	-0.010	106.294	12.50
22		22.33	-0.70	0.591	0.000	-0.603	137.756	1.76	0.178	0.000	-0.206	105.997	12.52
23		18.21	-0.80	0.481	0.000	-0.689	138.150	1.75	0.145	0.000	-0.236	105.897	12.52
24		49.89	-1.41	1.321	0.000	-1.219	138.272	1.75	0.398	0.000	-0.417	105.884	12.54
25		49.89	0.25	1.321	0.000	0.213	139.279	1.74	0.398	0.000	0.073	105.616	12.58
26		49.89	1.90	1.320	0.000	1.643	141.719	1.71	0.398	0.000	0.562	104.859	12.65
27		49.89	3.56	1.311	0.000	3.052	145.587	1.65	0.397	0.000	1.052	103.612	12.76
28		171.33	15.10	4.485	0.000	12.899	150.851	1.58	1.363	0.000	4.458	101.876	12.94
29		4.37	0.41	0.114	0.000	0.347	171.322	1.39	0.035	0.000	0.120	95.070	13.86
30		4.37	0.39	0.114	0.000	0.336	171.862	1.39	0.035	0.000	0.116	94.891	13.89
31		115.44	9.10	3.028	0.000	7.788	172.391	1.39	0.919	0.000	2.687	94.715	13.94
32		101.75	7.33	2.673	0.000	6.278	185.290	1.29	0.810	0.000	2.163	90.445	14.62
33		101.75	5.26	2.684	0.000	4.524	196.079	1.23	0.811	0.000	1.553	86.887	15.25
34		101.75	3.19	2.693	0.000	2.755	205.131	1.18	0.812	0.000	0.943	83.939	15.81
35		101.75	1.12	2.694	0.000	0.969	212.427	1.14	0.812	0.000	0.331	81.599	16.28
36		580.92	0.10	15.383	0.000	0.087	217.938	1.11	4.637	0.000	0.030	79.871	16.64
37		26.75	0.42	0.708	0.000	0.361	243.962	0.99	0.214	0.000	0.124	71.867	18.48
38		26.75	1.13	0.707	0.000	0.977	245.517	0.99	0.213	0.000	0.335	71.376	18.58
39		26.75	1.85	0.703	0.000	1.584	247.687	0.97	0.213	0.000	0.546	70.674	18.71
40		27.75	2.23	0.728	0.000	1.904	250.458	0.95	0.221	1.911	0.657	69.762	18.92

Fig.9. *View on the File j2TL4.c Results after Phase#2 with TRANSP_2 program (Conveyor TL4)*

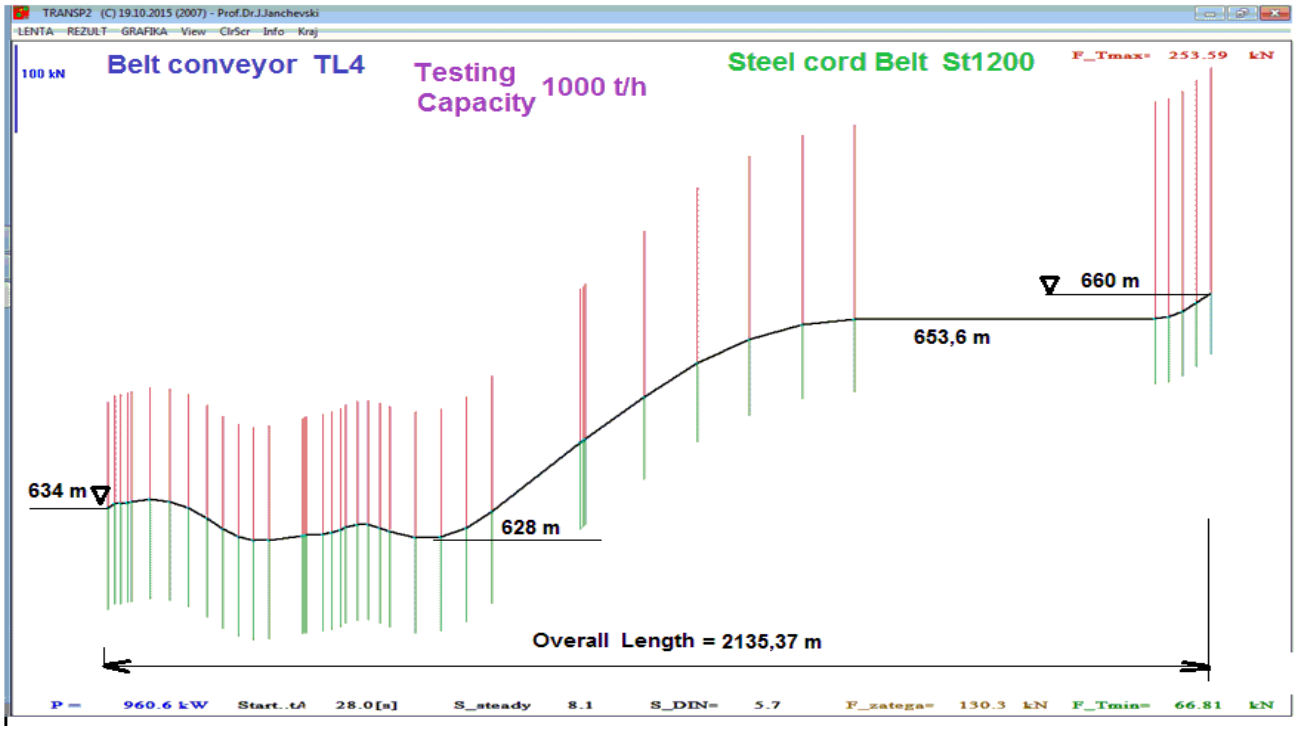

Fig.10. *Graphical presentation of the results of TL4 conveyor in Starting regime with 1000 t/h*

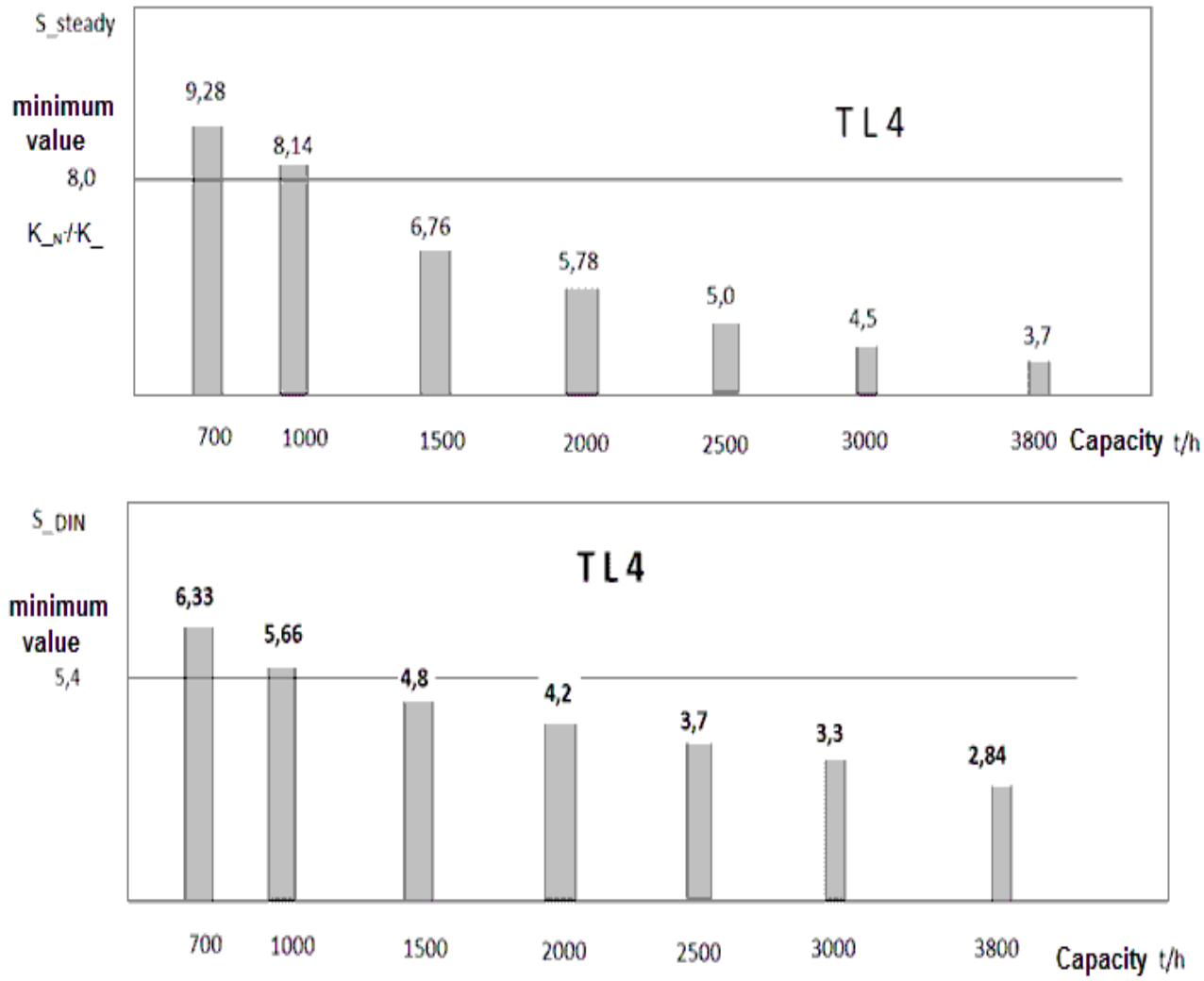

Fig.11. *Steady and dynamical safety factors for conveyor TL4 - different capacities*

4. CONCLUSION

Long distance overland belt conveyors are very complex for calculation. Iterative method used here in algorithm is very fast in calculations. TRANSP_2 is used for practical complex calculation for long belt conveyors, with many curves, up hills, down hills, working in difficult terrains with sharp slopes in wide whether condition in open mines. All parameters in j1*.c files are easy for modification, and results stored in j2*.files can be analyzed. Many calculations should be made for specific regimes, especially Starting, Breaking or Steady operation [5].

Safety factors and other important parameters are completely calculated according to DIN 22101, but compared with other standards, for example Program (TRANSP _1).

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