STUDY OF STRESS-DEFORMED STATE IN DENTS AREA ON THE WALL OF VERTICAL STEEL TANKS

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During design work strength and stability calculations of vertical steel tanks shall be performed using momentless theory of shells. Herewith the shape of tank wall is considered as an ideal cylinder.

As a result of inspection a considerable number of dents occurred during both erection and operation are found. It is evident that in dents area stressed-deformed state of the wall differs from stress-deformed state in ideal cylinder and can not be calculated using momentless theory of shells.

As a case study for calculation of stress-deformed state vertical steel tank with floating roof has been selected VSTFR-10000 having capacity of 10000 m^3. There are hundreds of such tanks available with various oil and gas producing and transporting companies. Therefore, stress-deformed state calculations of tank wall are crucial for assessment of resource to operate them safely.

The following data was used for calculation:

– radius 17,1 м, wall high – 12 м, designed oil level – 10,48 м, oil density 900 kg/m^3;

– wall yield strength 245 MPa;

– there is dent with length 3 m, high 3 m and maximum tongue 78 mm (fig.1).

Vertical distance to node, mm	Dent tongue, mm Horizontal distance to node, mm															
0	0	0,2	0,4	0,6	0,8	1	1,2	1,4	1,6	1,8	2	2,2	2,4	2,6	2,8	3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0,2	0	0	0	0	1	3	1	3	2	3	0	0	0	0	0	0
0,4	0	0	0	0	3	7	9	12	13	12	9	5	0	0	0	0
0,6	0	0	2	3	6	10	13	26	29	25	18	11	3	2	0	0
0,8	0	1	9	10	15	19	24	37	38	36	27	19	10	8	1	0
1	0	4	15	19	23	27	35	46	49	46	36	28	26	18	4	0
1,2	0	7	21	29	36	35	46	53	59	53	49	45	34	21	7	0
1,4	0	9	26	37	45	52	57	68	69	67	64	55	42	26	13	0
1,6	0	11	27	40	56	61	68	78	78	69	60	57	41	28	12	0
1,8	0	8	23	33	45	53	56	69	69	68	57	49	35	22	9	0
2	0	6	17	26	36	42	46	54	57	59	46	38	24	16	8	0
2,2	0	4	12	18	24	31	32	46	46	48	38	26	16	9	5	0
2,4	0	2	5	11	18	20	27	31	32	33	26	17	11	5	1	0
2,6	0	0	1	7	10	15	16	12	12	15	12	9	8	1	0	0
2,8	0	0	0	2	2	11	9	8	3	4	3	3	2	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

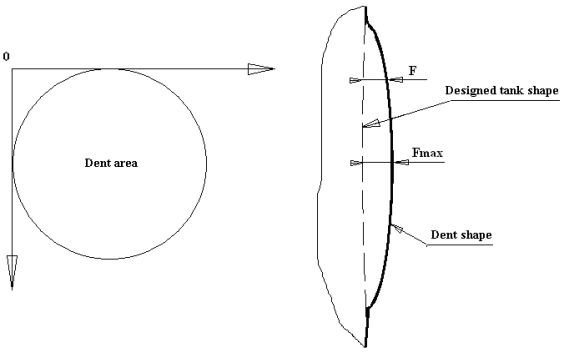


Fig 1. Dent form.

Study of dependence of stressed-deformed state of tank wall from maximum dent tongue has been performed. During calculations the maximum dent tongue (F_{max}) was set from 7,8 mm up to 273 mm with a step of 7,8 мм; all in all 35 dents have been created having equal width, height, shape, same location on the tank wall and different as far as dent tongues were concerned.

Calculation of stressed-deformed state of wall has been performed using finite element method by modeling VST wall with ANSYS. Maximum middle and surface stresses in tank wall in dent area and wall movement values in dent area during tank filling were determined.

The calculations of stress deformed state were made by VST walls modeling using finite elements method in ANSYS. Loads and DOFs was applied to model:

– all DOFs at bottom;

– uniformly distributed load from roof and snow applied to the top of the wall (mantle ring);

– hydrostatic pressure;

– vapor pressure.

Tension curve was set by 2 functions: bilinear and multilinear (fig.2). It was done 70 calculations at all.

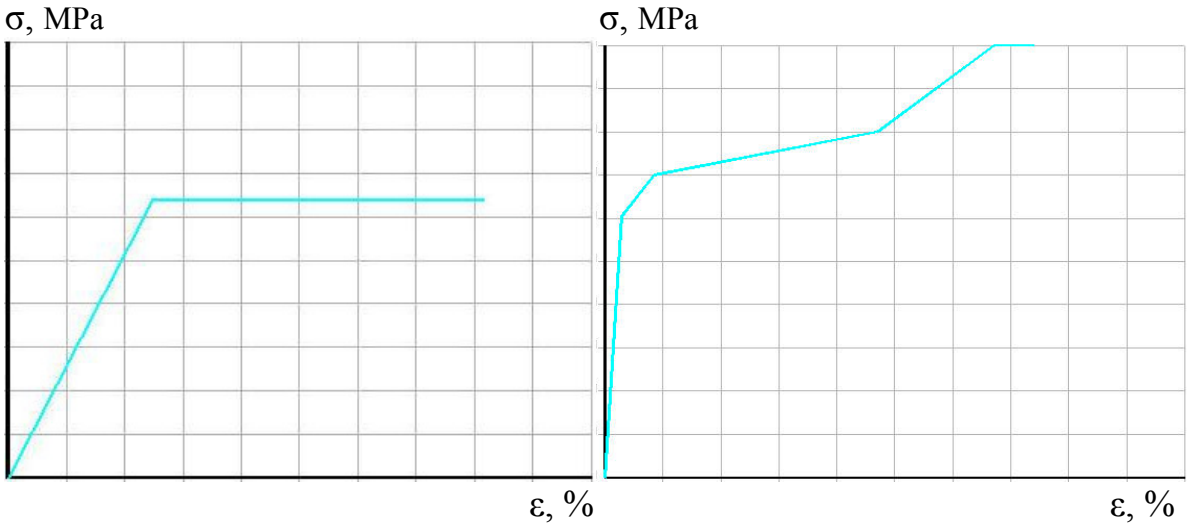
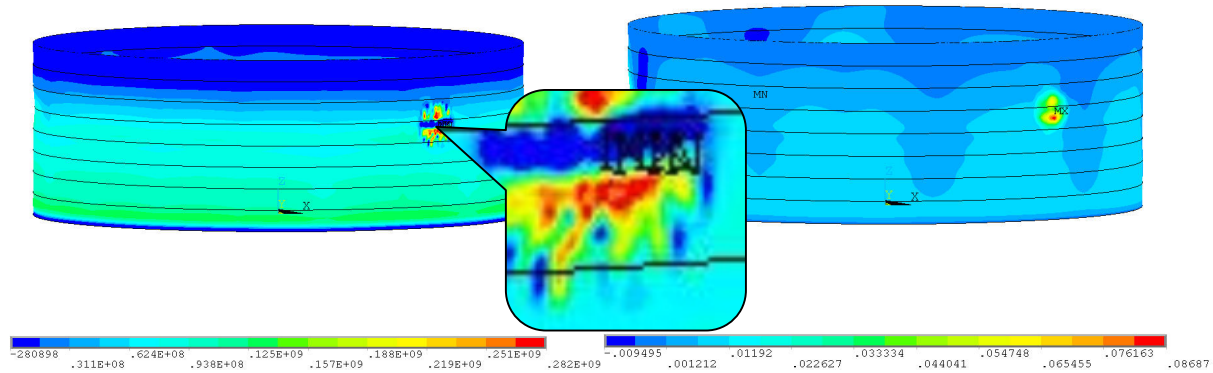
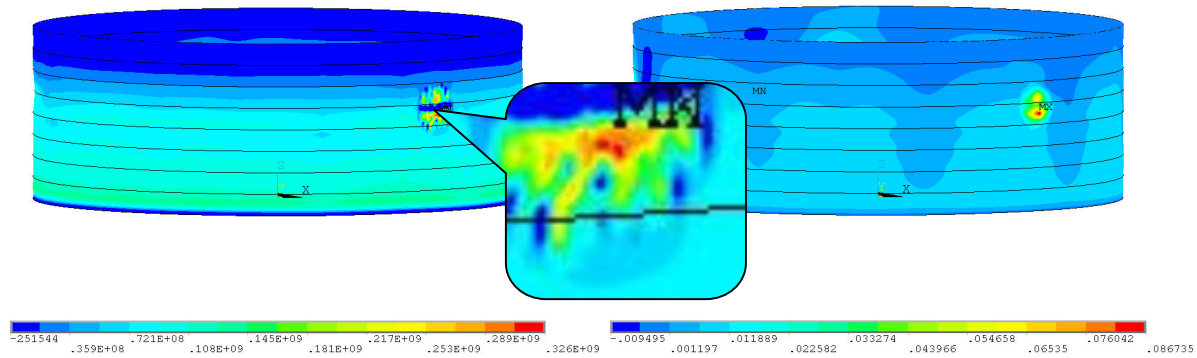


Fig. 2. Bilinear (left) and multilinear (right) tension curve

Walls stress and displacements were established after calculation. Samples of the calculation result are shown on fig.3.



a)



b)

Fig. 3. Walls stress (left) and displacements (right) - a) bilinear b) multilinear

The results of 70 calculations have been summarized on charts given in Fig. 4 and 5.

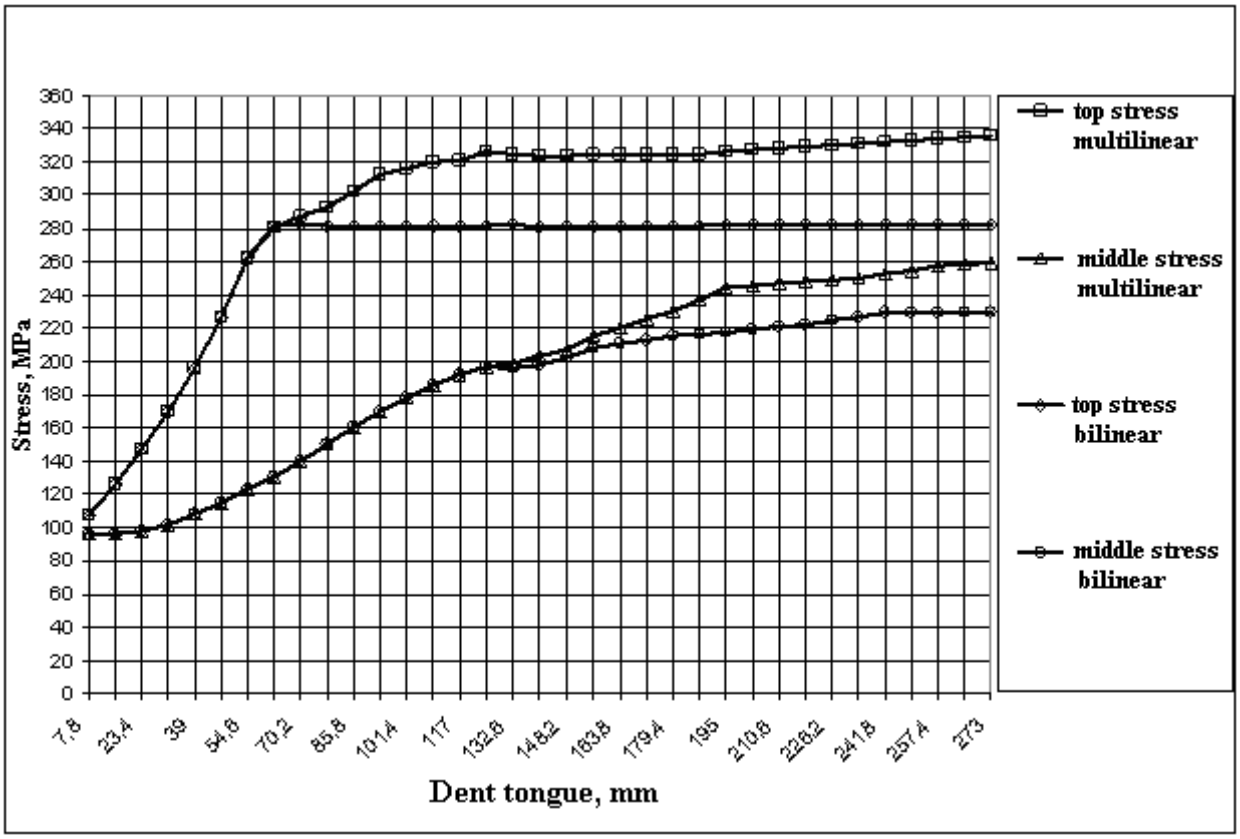


Fig.4 Dependence of maximum stresses in dent area on dent tongue

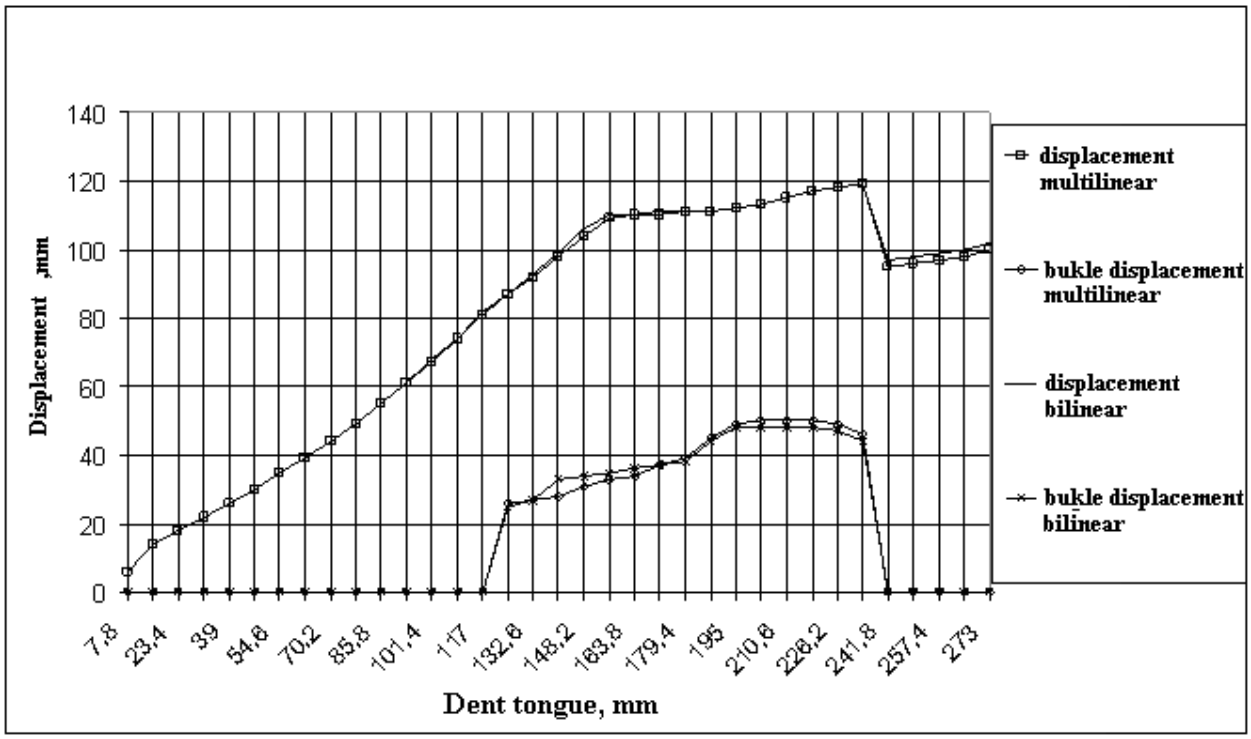


Fig. 5. Dependence displacement (higher curve), buckle displacement (lower curve) and dent tongue

As shown on fig. 4, top and middle stress rising with rise dent tongue. Top stress is equal to yield strength when dent tongue is 50,9 mm. Future rising dent tongue cause plastic deformation on the metal surface (top stress) in central dent zone. Plastic zone in bilinear model is bigger than in multilinear model (insertion on fig.3) because in bilinear model steel has zero young's modulus after yield strength. Middle stress (fig.4) is less than yield strength in bilinear model and more than yield strength in multilinear model. The stress difference between bilinear and multilinear model occur when dent tongue is equal 124,8 mm.

The dependences «displacement; buckle (fig.6) displacement – dent tongue» are shown on fig. 5. This dependence was established based on 70 buckle displacement curve (sample is shown on fig.6).

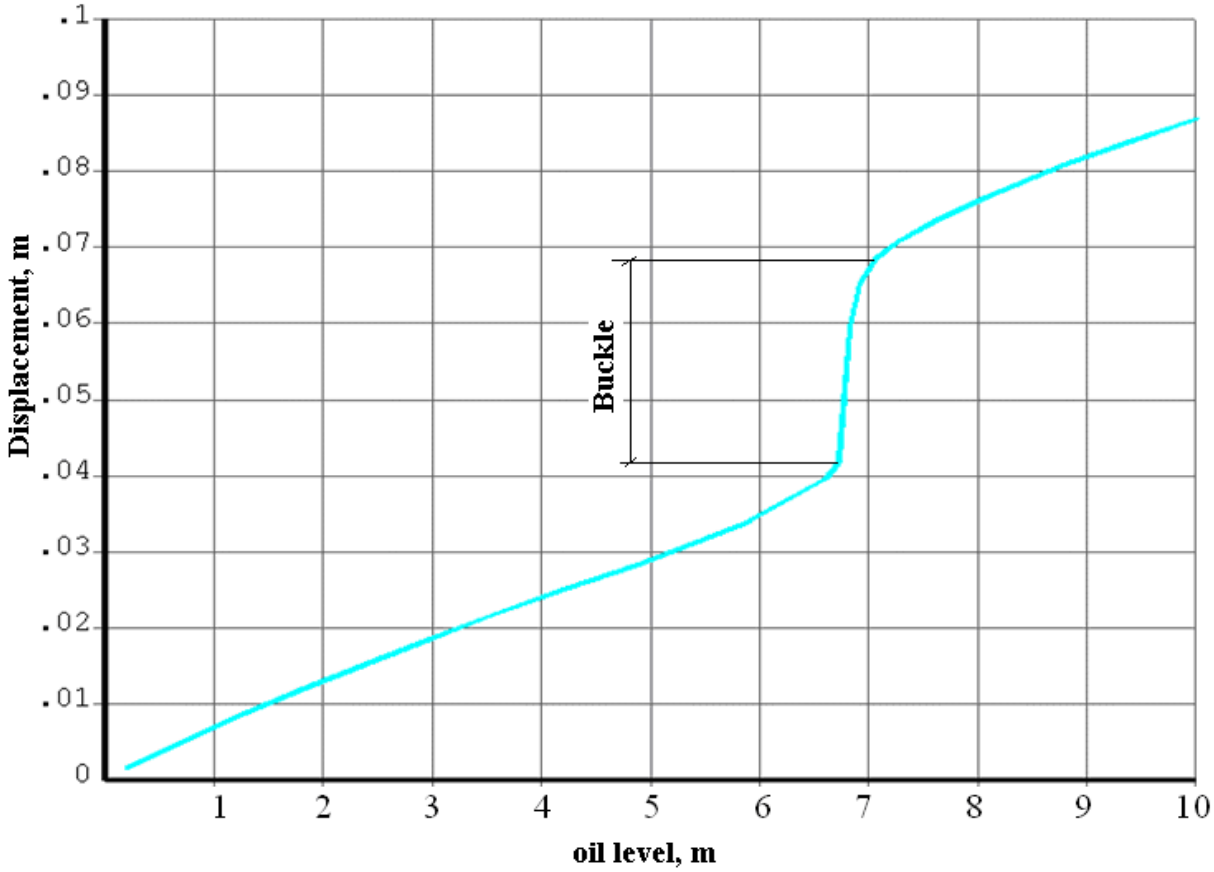


Fig. 6. Dependence buckle displacement in dent zone and oil level

On the curve (Fig. 5) one can emphasize 3 sections:

- 1st section – dent tongue value from 0 up to 117 mm – buckling in dent area does not occur;
- 2nd section – dent tongue value from 124,8 mm up to 241,8 mm – the dent “buckles”, i.e. local wall stability loss occurs in the dent area, higher oil level case higher buckle displacement;
- 3rd section – dent tongue value 241,8 mm and more – bucking in the dent area does not occur at design filling level.

Conclusion:

Therefore as a result of stressed-deformed state calculation influence of dent depth on tank wall stressed-deformed state variation and occurrence of local stability loss has been determined. In order to continue operation stresses on tank wall should not exceed ultimate ones and tank stability has to be ensured. Based on the calculations performed expert organization may extend operation of a tank having dent using design or reduced operation parameters.