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LENTICULAR EXPANSION COMPENSATORS

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Abstract: *Compensators are used to take over pipes' dilatation due to variations in temperature of the heating agent. Generally the elastic compensators are used for heat networks construction. Especially lenticular or bellows compensators are use for take axial, lateral or angular displacement. The main objective of this paper is to create a presentation of lenticular compensators and to solve dimensioning problem. A part for CNE application refers to lenticular compensators. CNELEN application processes the necessary calculations for lenticular expansion compensators. Every compensator has corresponding formulas, in specific functions for processing compensators database, for calculation all parameters.*

Key words: *axial lenticular compensator, dates, C++ application, pipeline, expansion.*

1. Introduction

Making pipeline routes, auto-compensate or compensate with compensators tubular pipe bent, requires the development of system in three dimensions like pipes in Figure 1. The result will be the increase of the pipes route, appearance bends and high pressure drops.

Fig. 1. *Pipes with compensators*

Compensators are used to take over pipes' dilatation due to variations in temperature of the heating agent. Generally the elastic compensators are used for heat networks construction. Natural elastic compensators are made by changing the direction of the heating pipes layout. These are delimited by fixed arresters on both sides of the direction change, at convenient distances from the angle vertex point.

Expansion compensators are used to retrieve expansion of pipe due to temperature variations of heat. Generally in construction of thermal networks are used especially compensators: curved U, L, Z shape with gasket, naturally elastic and expansion lenticular compensators.

2. Lenticular Expansion Compensators

Difference temperature during installation and operation in the pipeline causes changes

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in length, stretching or shortening.

Often, especially in the path of technological installations on offshore pipelines, taking dilations pipes made using lenticular compensators.

Expansion lenticular compensators (see Figure 2) are composed from connected elements and flexible connecting elements. They allow compensatory thermal dilations and vibration damping.

Fig. 2. *Image of lenticular compensators*

Lenticular compensators can take axial displacement, lateral (perpendicular to their axis) or angular. Everything is based on the bending flexibility of the undulating elements.

Lenticular expansion compensators are used in any industrial area where work with differentials temperature.

Lenticular compensators have the following advantages [1]:

- compensating thermal dilations;
- vibration damping;
- they reduce the reaction forces;
- they reduce maintenance costs;
- increase the reliability and operational safety.

The proper functioning of expansion lenticular compensators depends on:

- the process of implementation;
- geometry of the flexible element for known lenses;
- number of layers and quality of material used for the implementation of lenticular element.

The lenticular compensator design is formed by one or more flexible elements connected to the piping end.

3. Axial Lenticular Compensators

Axial lenticular compensator takes the axial direction after thermal dilations. They are designed to be assembling on pipes and heat exchange equipment. Figure 3 represents schematically a simple lenticular compensator. In order to study these compensators are defined; Max length, Min length, free length, and assembly pretension like figures bellow [2].

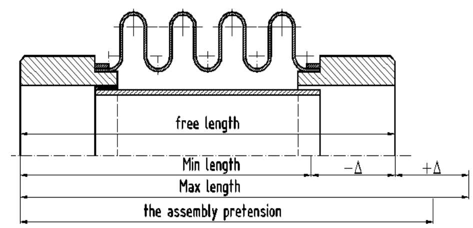
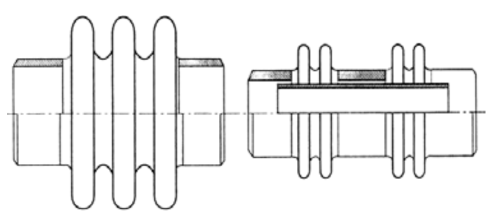


Fig. 3. *Simple axial lenticular compensators*

Figure 4 presents two common shapes of axial lenticular compensators [2], [3].



a) b)

Fig. 4. *Image of axial lenticular compensators*

Axial lenticular compensators are known in several variants:

- Axial lenticular compensators with armoring ring;
- Axial lenticular compensators with a single layer;
- Axial lenticular compensators with multiple layers, for high pressure.

Other models by lenticular compensators are [2], [3]:

- Sideways lenticular compensators (see Figure 5);

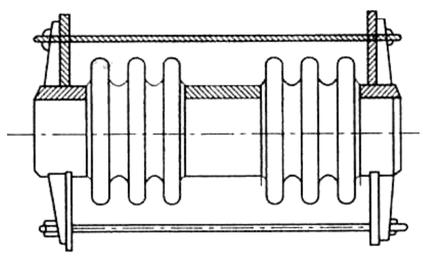


Fig. 5. *Image of sideways lenticular compensators*

- Angular lenticular compensators with rotation joint (see Figure 6);

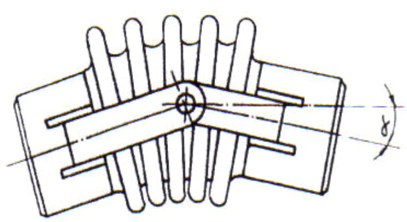


Fig. 6. *Image of angular lenticular compensators*

For curved pipes thermal expansions, the angular expansion lenticular compensators with rotation joint are used.

In the spatial piping systems, when the thermal expansion is on three directions, the angular lenticular compensators with cardan joint couplings are used.

- Angular lenticular compensators with cardan joint couplings (see Figure 7).

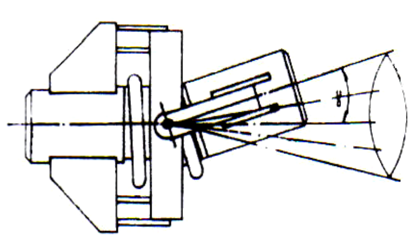


Fig. 7. *Image of angular lenticular compensators with cardan joint couplings*

4. Mechanical Calculation of Axial Lenticular Compensators

This paper refers to axial lenticular compensators.

Mechanical calculation involves the determination of geometric characteristics of lenticular compensators, in conclusion, the calculation of the number of elements [1], [2].

Are defined following data:

ΔL - total expansion taking over;

Δl - total axial deformation of the n elements of a comp ($\Delta l_1 = 10$ mm);

ΔL_1 - pipeline pretensions;

P_1 - unitary stress (Table 1);

Δ - pretension (Table 2);

t_f, t_0 - initial and final temperature;

P_t - reaction stress due to expansion and tension;

n_c - number of compensators ($n_c = 1...6$);

n - expansion elements ($n = 4$);

P_i - force due to internal tensions;

p_i - maximum functioning pressure;

α - linear expansion coefficient (Table 2);

D_n - pipe diameter;

E_1 - modules of elasticity ratio (Table 2);

R - reaction pipe.

Specific unitary stress Table 1

	Specific unitary stress (P_1)				
D_n [mm]	80	100	121	150	175
D_e [mm]	325	350	375	400	440
P_1 [daN/mm]	135	140	140	140	150
D_n [mm]	200	250	300	350	400
D_e [mm]	475	525	575	625	700
P_1 [daN/mm]	165	240	255	260	265

Table 2

Geometric characteristics of compensators

t_f^o	150	200	250	300	350
$\alpha\ 10^{-6}$ [mm/mK]	11.6	12.1	12.5	12.9	13.2
Δ	0.5	0.5	0.52	0.55	0.65
$E_1 = E_t/E_{20}$	0.98	0.96	0.93	0.90	0.86

Figure 8 presents a lenticular element, under internal pressure p_i. Expansion of the pipeline is taken from axial lenticular compensators with **n** expansion elements and $\mathbf{n_c}$ compensators.

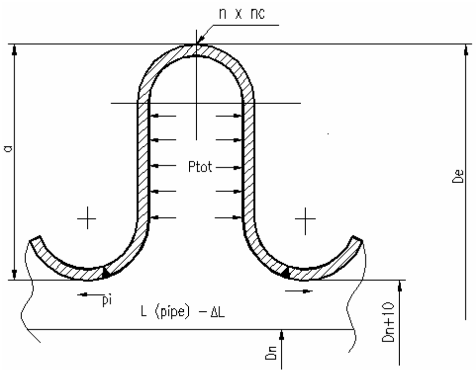


Fig. 8. *Image of lenticular element, pressure p_i*

5. CNELEN Application

The application called CNELEN, written in C++ using Dev C++ compiler, calculate natural elastic configurations for lenticular compensator, according to the specific formula, reading the databases from CNELent.txt like Figure 9.

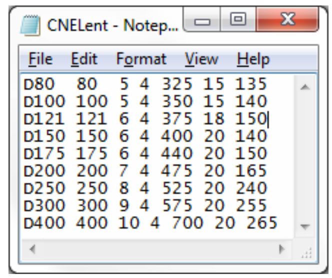


Fig. 9. *Image of CNELEN.txt file*

CNE application processes the data, lists the data and checks the maximum bending tensile stress for the elastic configuration under observation for 4 compensators shape [4], [5].

The structure of CNELEN application for axial lenticular compensators is schematically presented by captures from Figures 10. Dev C++ Compiler has the interface below.

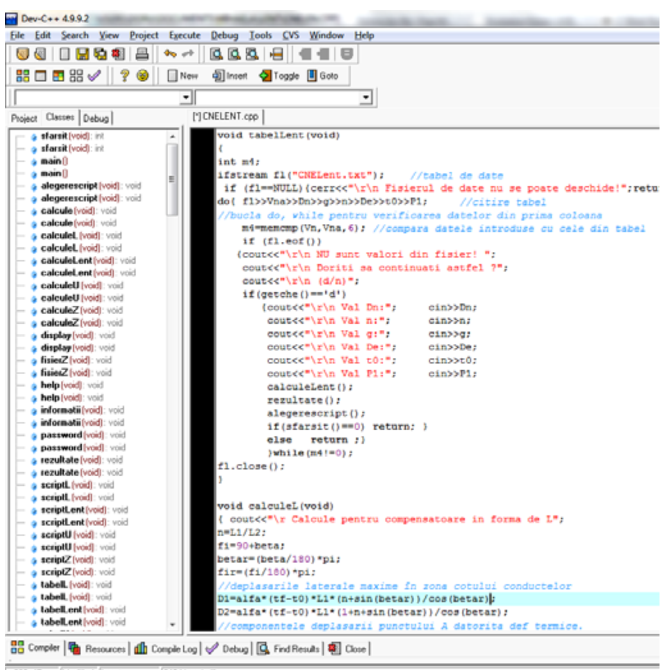


Fig. 10. *Image of tableLent function*

This application manages the databases with *TableLent* function:

```
void tabelLent(void)
{int m4;
ifstream fl("CNELent.txt");
if (fl==NULL){cerr<<"\r\n
Could not open!"; return;}
do{ fl>>Vna>>Dn>>g>>n>>De
>>t0>>P1;
m4=memcmp(Vn,Vna,6);
if (fl.eof())
{cout<<"\r\n No values ";
cout<<"\r\n Do you want to continue
this?";
cout<<"\r\n (y/n)";
if(getche()=='y')
{cout<<"\r\n Val Dn:";cin>>Dn;
cout<<"\r\n Val n:"; cin>>n;
cout<<"\r\n Val g:"; cin>>g;
cout<<"\r\n Val De:"; cin>>De;
cout<<"\r\n Val t0:"; cin>>t0;
cout<<"\r\n Val P1:"; cin>>P1;
calculeLent(); rezults ();
scriptfile();
if(end()==0) return; }
else return ;} }while(m4!=0);
fl.close();}
```

The input dates for lenticular compensators, known by the user, or declared in the program are presented below: D_n = 250 mm, g = 8 mm, L =100 m, t_f = 140 °C, t_0 = 20 °C, p_i = 2 daN/cm^2, $E = 2 \cdot 10^6$ daN/cm^2, E_1, Δl_1 = 10…12, n, Δ, α.

For maximum internal pressure 4 daN/cm^2, maximum item expansion could be 10-12 mm. Expansion compensator involves the following calculations; data processing is made in order to develop a computer program:

$$\Delta t = t_f - t_0, \quad (1)$$

$$\Delta L = \alpha \cdot L \cdot \Delta t, \quad (2)$$

$$\Delta l = \mathrm{n} \cdot \Delta l_1/(0.9 + 0.1\, n), \quad (3)$$

$$\Delta l_1 = 10...12, \quad (4)$$

$$n_c = \Delta L/\Delta l, \quad (5)$$

$$P_t = \Delta L \cdot E_1 \cdot (1 - \Delta) \cdot P_1/n \text{ [daN]}, \quad (6)$$

$$E_1 = E_t/E_{20}, \quad (7)$$

$$d_m = (D_e + D_n + 10)/2 \quad (8)$$

$$P_i = p_i \cdot \pi \cdot (d_m^{\,2} - d_i^2) \text{ [daN]}, \quad (9)$$

$$\Delta L_1 = \Delta L \cdot 0.7, \quad (10)$$

$$P_{tot} = P_i + P_t, \quad (11)$$

$$R = \alpha \cdot E \cdot A_c \cdot \Delta t, \quad (12)$$

$$A_c = \pi \cdot D_n^{\,2}. \quad (13)$$

This application includes also the following activities:

- implementation of a schematically drawing for the calculated compensator;
- a pattern drawing was generated in AutoCAD, representing a lenticular element, valid for several dimensions. In this drawing a layer TEXT and a text style ISO were created;
- at running the application results: the calculated values and a script file;
- completing the drawing template with variable dimensions, processed in CNELEN application by opening the script file;
- the CNELENT application allows to expansion these calculations to other compensators for example U-shaped, L-shaped, Z-shaped compensators using special switch. Figure 11 refers to the first part of listing for compensator symbolized D250;
- all calculated values, related to compensators, can be read in the second part of the listing (see Figure 12);
- this program allows entry data outside the database. In this case is formed a new data table named newdata.txt.

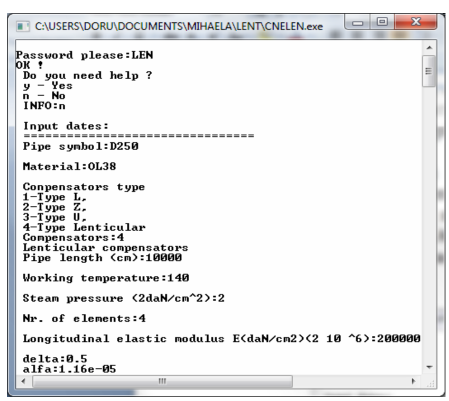


Fig. 11. *Image of first listing*

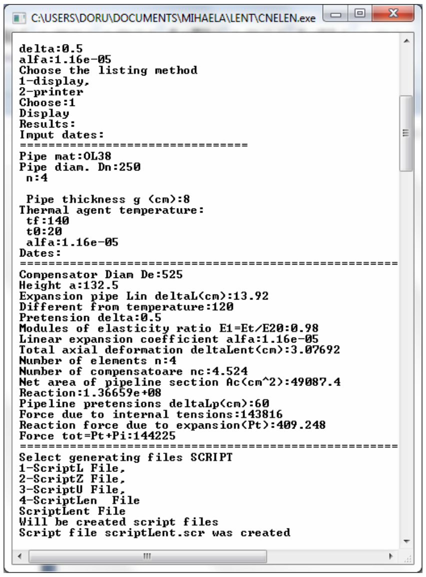


Fig. 12. *Image of final listing*

In the flowing drawing the values are according to Figure 8. The values are the result of script file loading, for $D_n = 250$.

The drawing values from Figure 13 are the result of script file loading.

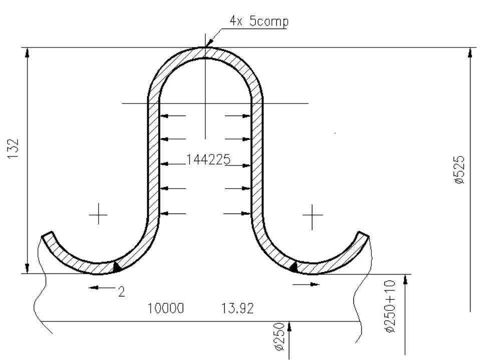


Fig. 13. *Final drawing with script file*

6. Conclusions

This paper presents an original method for designing axial lenticular compensators. The pipe expansion is taken by elastic compensators. Compensators, several forms, are designed according to the size, shape and temperature of the fluid pipeline.

The central and original result of the work is CNELEN C++ application written in C++ language. This application processes all database, by calculating the compensators dimension, the reaction force due to expansion, the total axial deformation. This application also calculates number of compensators and elements, force due to internal tensions and the total forces.

This application compiled with Dev C++, generate script files for axial lentricular compensators drawing, for the databases developed for users.

The CNE application allows to expansion the calculations to other compensators for example U-shaped, L-shaped, Z-shaped compensators.

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