1. Introduction

During the last decades of last century, majority of manufacturers of distribution transformers introduced corrugated tanks. The main reasons were automated and cheaper production and possibility of transformer construction without conservator. Lack of conservator means cheaper and more reliable maintenance.

Ribs of corrugated walls and tank are constantly exposed to stresses due to oil temperature dilatation. Increase and decrease in oil volume induces increase and decrease of pressure in transformer tank. Proper design of ribs and tank is crucial for safe and reliable operation.

Therefore, to properly design transformer tank, it is vital that relation between oil volume increase / decrease and pressure increase / decrease is determined.

2. Experimental testing

In order to measure pressure change in relation to change in oil volume, special test equipment is designed and produced. Equipment, together with one transformer during testing is shown in Fig. 1. Test equipment has capability to measure oil flow (change in volume of oil), and pressure and temperature in tank.

During the test pressure levels varied between -0.2 bar and 0.2 bar. These pressure levels are proved not to induce stress levels high enough to cause tank failure.

Experimental testing consists of pumping oil into the tank up to the level at which point pressure in the tank reached 0.2 bar, and draining oil from tank up to the level at which point pressure in the tank reached -0.2 bar, in small increments. At each increment pressure and oil volume are recorded.

Test was conducted on 5 transformers, ranging in power from 50 kVA to 630 kVA.

3. FEM Analysis

FEM analysis provides very fast and accurate way to calculate deformation (change in volume) of ribs and tank for any pressure level. 46 models of ribs were made, ranging in rib depth from 100 mm to 300 mm, and ranging in rib height from 500 mm to 1000 mm. Rib dimensions are standardized, and designer made a choice from standard dimensions during designing. Fig. 2 shows one rib FEM model.

However, ribs are not the only construction part of transformer that deforms under pressure. Tank as a structure also deforms, that includes tank bottom, cover and side walls. Therefore...
transformer tanks were modelled, and models were made same as tanks used in experimental testing to obtain best coincidence between experimental and numerical testing.

FEM analysis showed that dependence between change in oil volume and pressure is linear

\[ V = x \cdot p \] (1)

where \( x \) is tank elasticity coefficient and is calculated:

\[ x = \sum_{i=1}^{4} n_i \cdot x_i + x_k \] (2)

where \( i \) - number of tank walls (i=1, 2, 3, 4), \( n_i \) - number of ribs on tank wall, \( x_i \) - rib elasticity coefficient, \( x_k \) - tank structure elasticity coefficient.

### 4. Comparative results

Fig. 3 shows results calculated by FEM analysis (red) and experimental results (blue) for 250 kVA transformer.

<table>
<thead>
<tr>
<th>Rib deformation</th>
<th>p=0.15 bar</th>
<th>p=0.25 bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>1.50 mm</td>
<td>2.45 mm</td>
</tr>
<tr>
<td>FEM Analysis</td>
<td>1.55 mm</td>
<td>2.59 mm</td>
</tr>
</tbody>
</table>

**Tab. 1: Results comparison for 250 kVA transformer**

Some of transformers used for testing were also used for endurance test according to EN 50464-4 [1]. That made great opportunity to measure p-V chart before and after endurance test. Fig. 4 shows results calculated by FEM analysis (red) and experimental results (blue and yellow) for 100 kVA transformer.

Endurance test induces high stress levels that cause low cycle fatigue. Even if transformer passes endurance test and low cycle fatigue do not provoke transformer failure, its impact on transformer is clearly visible on p-V chart.

### 5. References