AXIAL ADJUSTMENT METHOD FOR PRECESSIONAL TRANSMISSIONS

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Abstract: *Axial adjustment method for precessional transmissions includes the compensation error calculation and the determination compensator groups, achieved in the form of base and auxiliary rings. The compensator has on the base ring axial canals in which clamping bolts can be placed but the auxiliary ring has axial holes for the screws. The auxiliary ring is formed from increasing sectors – the distance between auxiliary ring stairs and front side of body, from decreasing sectors – the distance between base ring and bottom place, and the closure element – the clearance between gear body and the front surface of the base ring. According to the method of group interchangeability, the deviation value of the upper and lower group tolerance and the clearance between lid and body are determined. Then, rotating one of the rings, it should be ensured that the dimension of the compensator will match the value of compensation clearance, and the compensator is adjusted to the required value.*

Keywords: *compensator, precessional, clearance, gear.*

1. Introduction

This method of adjustment of axial movements without thread can be used to adjust the clearance in gear, especially in gearboxes.

According to [Berezovskii, 1983, p.259-260] the adjustment process of axial clearance is the one, in which the value of compensation from the chains of dimensions, the number of fixed compensators steps and their size are determined. Then in the assembling process the axial clearance between the front surface of the lid and the bearing is measured, the compensation gaskets size is chosen and installed on the closure element of the chain.

The disadvantage of this method of clearance compensation is high workmanship of assembling; because of the collecting complexity for the required compensation rings and also the execution complexity of the rings (less than 0.1mm). This method has a disadvantage, namely, it cannot be used to adjust conic gear. The purpose of this method is to decrease the assembling costs of the frontal surfaces of machine nodes, which contain precessional gearing, and to increase the adjustment precision for axial clearance.

2. Compensator for axial adjustment

The intended purpose can be achieved if the axial adjustment method for precessional transmissions include the calculation of compensation error, determination of compensator groups achieved in the form of ring formed as a minimum of four places and auxiliary ring (Fig.11), which has on the front side steps places diametrically opposed. The compensator is characterized by the fact that the base ring has axial canals in which clamping bolts can be placed but the auxiliary ring has axial holes for the passage of screws. The auxiliary ring is formed from increasing the sectors – the distance between auxiliary ring steps and front side of body, from decreasing the sectors – the distance between base ring and the bottom place, and the closure element – the clearance between gear body and the front surface of the base ring. According to the method of group interchangeability it is determined the deviation value of the upper and lower group tolerance and the clearance between gear lid and gear body. Then rotating one of the rings the dimension of the compensator, which must match to the compensation clearance value, is ensured and then the compensator is adjusted to the required value.

Also the process of axial adjustment can be achieved using another compensator. The process of axial adjustment consists of auxiliary ring of compensator which has axial channels and the base ring with axial holes.

The technical positive result ensured by all the characteristics of the process consist of decreasing the assembling costs of the frontal surfaces of machines nodes, which contain precessional gearing, and increasing of adjustment precision for axial clearance.

The reducer has the following components: shell 1, lid 2, compensator 3, driving shaft 4, fixed wheel, satellite 6 with crowns 7 and 8, driven shaft 10, bearing 11, bushing 12, bearing 13 and lid 14 [Bostan, 1991], [Bostan, 2011], [Bostan, 2013], [Bostan, 2017]. As a rule the gearbox, before final assembly, has two subassemblies: the one on the right (Fig.1) and the one on the left (Fig. 2). In the left subassembly we have the body parts 1, mobile wheel 9, driven shaft 10, bearings 11 and 13, bushing 12 and the lid 14. The right subassembly has lid 2, compensator 3, driving shaft, the fixed wheel, satellite 6 and crowns 7 and 8. The assembly is made by insertion of the left side in the right side. When assembling these two parts by moving in the axial direction the left side is ensured by centering the right bearing of driving shaft in the cylindrical seat of the driven shaft. The displacement in axial direction ends when mobile wheel 9 come in contact with crown 8 of the satellite 6. It is also necessary to center the body 1 with the lid 2 during the axial displacement of the left side to the right. Finally it is necessary to adjust the clearance between crown 7 and gear wheel 2.

3. Dimensional chains calculation

We will examine the realization of the process by the example of precessional gear (Fig.4).

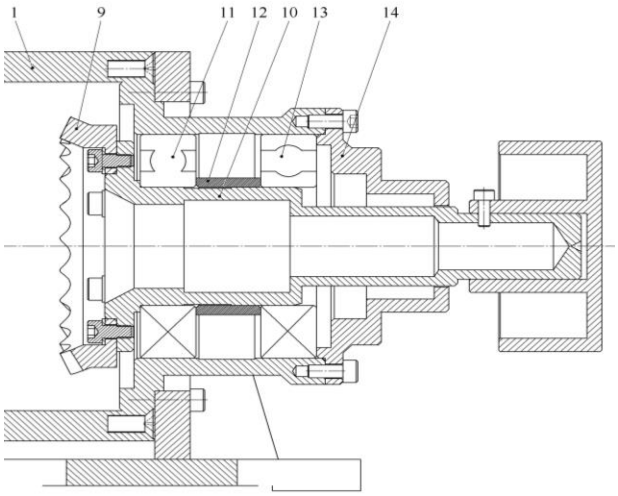


Figure 1: *Right subassembly.*

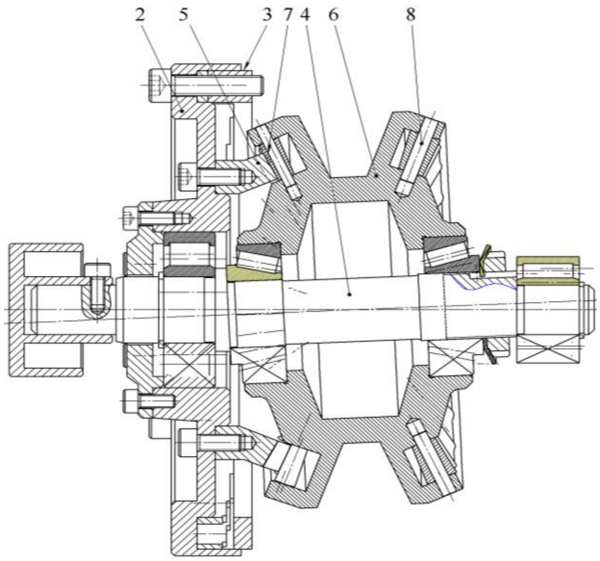


Figure 2: *Left subassembly.*

From dimensional chain (Fig. 5) by method of total interchangeability [Popa, 2006] the value of the closure element is determined

$$A_{\Delta} = \sum_{i=1}^{n} TA_i \ ;$$

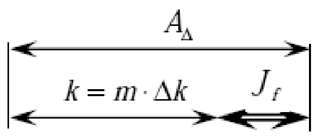


Figure 3: *Dimensional chain of compensator to ensure functional clearance*

The proper functioning of the gear unit is done under a summary functional clearance in the both gear couplings - J_f. From dimensional chain (Fig.3) it is seen that the maximum possible value will be compensated:

$$A_{\max}^{comp} = A_{\Delta} - J_f \, . \qquad (1)$$

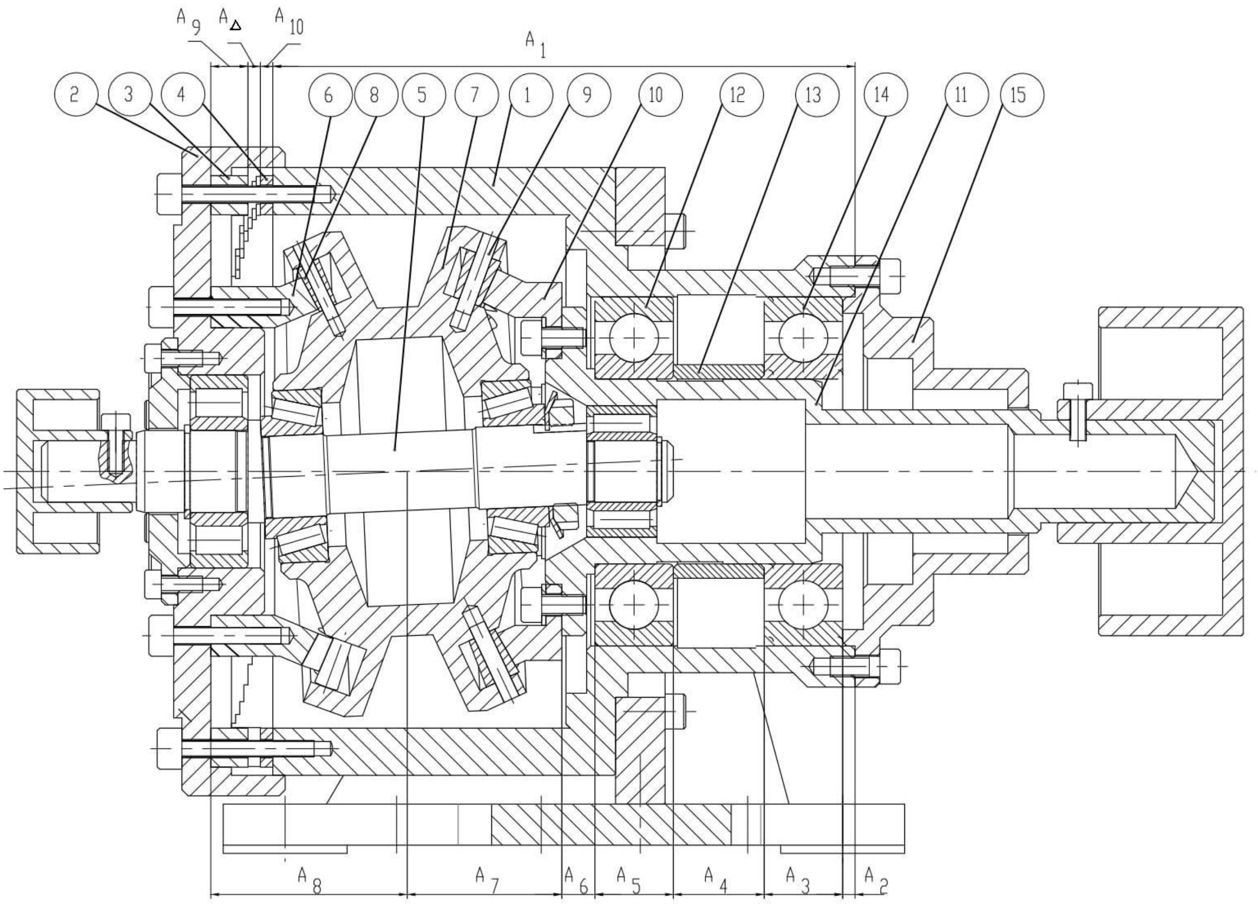


Figure 4: *Axial section for reducer with one compensator*.

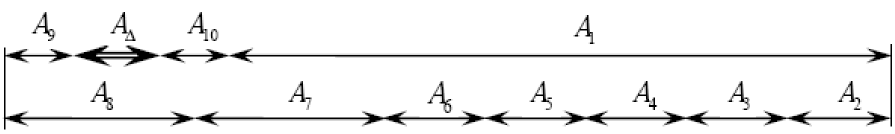


Figure 5: *Dimensional chain for reducer*

Compensation in cases of concrete construction of the reducer is made at the value A^{comp} by selecting the compensator ring steps 3 (Fig.4).

The value $A_{\max}^{comp}$ is divided on the compensator steps with height Δk in number m.

To avoid overcompensation and appearing of tightening in gear couplings, the value Δk should not surpass the functional value of clearance J_f, $\Delta k =< J_f$ [Toca, 2016]. The value Δk depends on the requirements stringency to the values range of the functional clearance J_f and determines the functional clearance variation due to discretized character of compensation in limitations of one step of compensation.

The calculated number of steps:

$$m_c = \frac{A_{\max}^{comp}}{\Delta k} - 1 \qquad (2)$$

(minus 1, because compensation is made using the „body” of compensation ring, i.e. step „zero”).

The integer number of steps m is obtained by rounding to the higher integer number (to ensure $\Delta k =< J_f$);

The value of one step:

$$\Delta k_c = \frac{A_{\max}^{comp}}{m+1}. \qquad (3)$$

The number of step, on which the compensation TR is made, represents the integer part of calculated number of step:

$$TR_c = \frac{A^{comp} - j_f}{\Delta k_c}. \qquad (4)$$

Functional clearance after compensation:

$$J_{fc} = A^{comp} - TR \cdot \Delta k_c \qquad (5)$$

Deviation of functional clearance:

$$\Delta J_f = J_{fc} - J_f \qquad (6)$$

Maximum possible clearance:

$$J_{f\max} = J_f + \Delta k \qquad (7)$$

Example. Summary value of clearance in both functional gear couplings $J_f = 0.1\,mm$:

$$A_\Delta = \sum_{i=1}^{n} TA_i = 0.78\,mm; \qquad (8)$$

$$A_{\max}^{comp} = 0.78 - 0.1 = 0.68\,mm \qquad (9)$$

we choose the option $\Delta k = J_f = 0.1\,mm$. The compensator steps number $m = 6$ that is the integer part of:

$$m_c = \frac{A_{\max}^{comp}}{\Delta k} - 1 = \frac{0.68}{0.1} - 1 = 5.8. \qquad (10)$$

The results of the calculations are given in the Table 1, and for the case $\Delta k = 0.07\ mm$.

The schema of compensator steps executed to IT9 is shown in Fig. 6.

Table 1.

$J_{fc} = 0.1\ mm\quad \Delta k = 0.1\,mm$				
Compensated clearance	Step of compensation		Functional clearance	
	Calc.	Adopt.	Value	Dev.
A^{comp}	TR_c	TR	J_{fc}	ΔJ_f
0.1	0	0	0.1	0
0.11	0.1	0	0.11	0.01
0.19	0.9	0	0.19	0.09
0.2	1	1	0.1	0
0.21	1.1	1	0.11	0.01
0.29	1.9	1	0.19	0.09
0.3	2	2	0.1	0
0.31	2.1	2	0.11	0.01
0.39	2.9	2	0.19	0.09
0.4	3	3	0.1	0
0.41	3.1	3	0.11	0.01
0.49	3.9	3	0.19	0.09
0.5	4	4	0.1	0
0.51	4.1	4	0.11	0.01
0.59	4.9	4	0.19	0.09
0.6	5	5	0.1	0
0.61	5.1	5	0.11	0.01
0.68	5.8	5	0.18	0.08
$J_{fc} = 0.1\ mm\quad \Delta k = 0.07\ mm$				
Compensated clearance	Step of compensation		Functional clearance	
	Calc.	Adopt.	Val.	Dev.
A^{comp}	TR_c	TR	J_{fc}	ΔJ_f
0.1	0.00	0	0.1	0
0.11	0.14	0	0.11	0.01
0.19	1.29	1	0.12	0.02
0.2	1.43	1	0.13	0.03
0.21	1.57	1	0.14	0.04
0.29	2.71	2	0.15	0.05
0.3	2.86	2	0.16	0.06
0.31	3.00	3	0.1	0
0.39	4.14	4	0.11	0.01
0.4	4.29	4	0.12	0.02
0.41	4.43	4	0.13	0.03
0.49	5.57	5	0.14	0.04
0.5	5.71	5	0.15	0.05
0.51	5.86	5	0.16	0.06
0.59	7.00	7	0.1	0
0.6	7.14	7	0.11	0.01
0.61	7.29	7	0.12	0.02
0.68	8.29	8	0.12	0.02

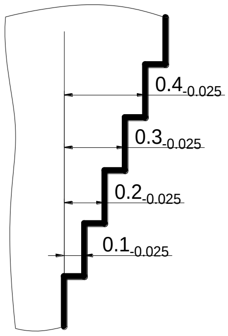


Figure 6: *Schema with compensator steps (example)*

In precessional reducers, especially with two gear couplings, the elements number in dimensional chain is high, so the total clearance $A_\Delta = \sum_{i=1}^{n} TA_i$ and the maximum compensation $A_{\max}^{comp}$ get to the values of a few millimeters. Therefore, the number of compensation steps becomes very high. The number of steps becomes big and in case when the requirements for the precision of functional clearance are high, i.e. $\Delta k < J_f$.

Is appropriate to use two compensators, one at major steps and another one to small increments that depends on the functional clearance value (Fig.7). Dimensional chains for the case with two compensators are shown in Fig. 8.

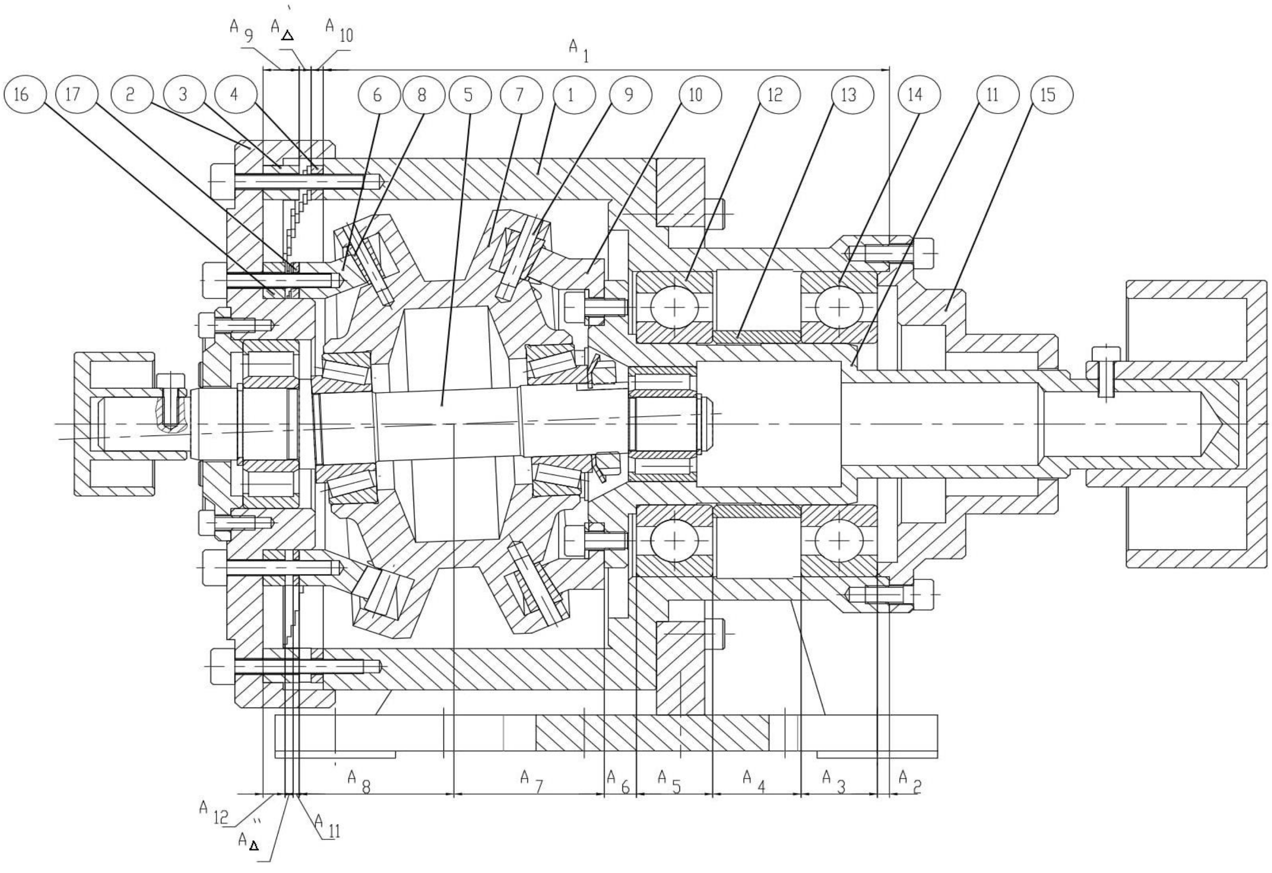


Figure 7: *Axial section for reducer with two compensators.*

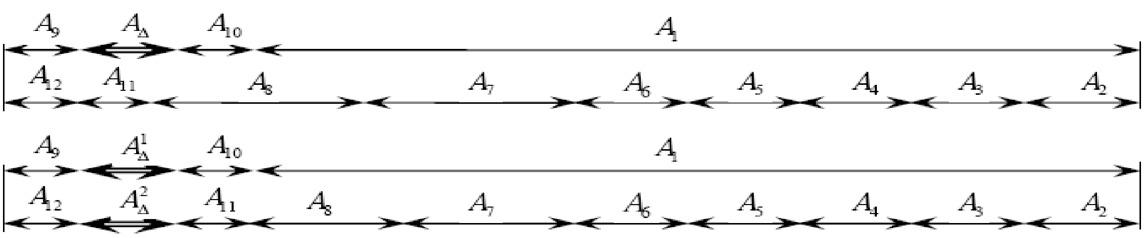
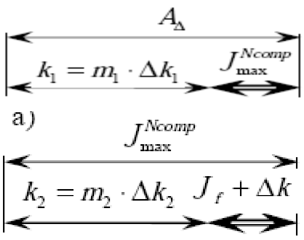


Figure 8: *Dimensional chains for the reducer with two compensators*



a)

b)

Figure 9: *Dimensional chains of the compensators to ensure functional clearance*

We will examine the realization of the process by example of precessional reducer (Fig.7).

We admit, for example, that:

$$A_\Delta = \sum_{i=1}^{n} TA_i = 3.4 \cdot mm. \quad (11)$$

From dimensional chain (Fig. 9b) using the method of total interchangeability the maximum value of clearance is determined uncompensated by the previously compensator:

$$J_{\max}^{Ncomp} = m_2 \cdot \Delta k_2 + J_{f\,\max} = m_2 \cdot \Delta k_2 + + (J_f + \Delta k_2) = (m_2 + 1) \cdot \Delta k_2 + J_f \quad (12)$$

for various values of the steps number m_2 and value $\Delta k_2 < J_f$. The value Δk_2 is expressed by J_f:

$$r = \Delta k_2 / J_f\,, \quad (13)$$

then:

$$J_{\max}^{Ncomp} = (m_2 + 1) \cdot \Delta k_2 + J_f = J_f \cdot [(r \cdot (m_2 + 1) + 1] \quad (14)$$

Table 2.

$r = 1$		$r = 0.7$	
m_2	$J_{\max}^{Ncomp}$	m_2	$J_{\max}^{Ncomp}$
4	0.6	4	0.45
5	0.7	5	0.52
6	0.8	6	0.59
7	0.9	7	0.66
8	1	8	0.73
9	1.1	9	0.8
10	1.2	10	0.87

It is chosen one of the plausible obtained variants, for example: $m_2 = 7$, $J_{\max}^{Ncomp} = 0.66$ for $r = 0.7$;

From dimensional chain (Fig. 9a) the value of compensation step Δk_1 and the number of compensation steps are determined, considering the fact that:

$$J_{\max}^{Ncomp} = 2 \cdot \Delta k_1\,; \quad (15)$$

$$m_1 \cdot \Delta k_1 + J_{\max}^{Ncomp} = A_\Delta;\ (m_1 + 2) \cdot \Delta k_1 = A_\Delta \quad (16)$$

$$\Delta k_1 = \frac{J_{\max}^{Ncomp}}{2} = 0.33 \quad (17)$$

$$m_1 = \frac{A_\Delta}{\Delta k_1} - 2 = \frac{3.4}{0.33} - 2 = 8.3 \quad (18)$$

It is chosen $m_1 = 9$ and the values are recalculated (Fig. 10):

$$\Delta k_1 = \frac{3.4}{9 + 2} = 0.31\,, \quad (19)$$

$$J_{\max}^{Ncomp} = 2 \cdot 0.31 = 0.62 \quad (20)$$

The value of functional clearance ensured by the second compensator is recalculated:

$$J_f = \frac{J_{\max}^{Ncomp}}{[(r \cdot (m_2 + 1) + 1]} = \frac{0.62}{0.7 \cdot (7 + 1) + 1} = \frac{0.62}{6.6} = 0.094 \quad (21)$$

The insured clearance is practically equal to the requested value $0.094 \approx 0.1$.

For each compensator according to compensated clearance the steps of compensation, uncompensated clearances and clearance deviations are determined (see Table 1).

If technical solution is not acceptable, recourse to another iteration operating with number of steps.

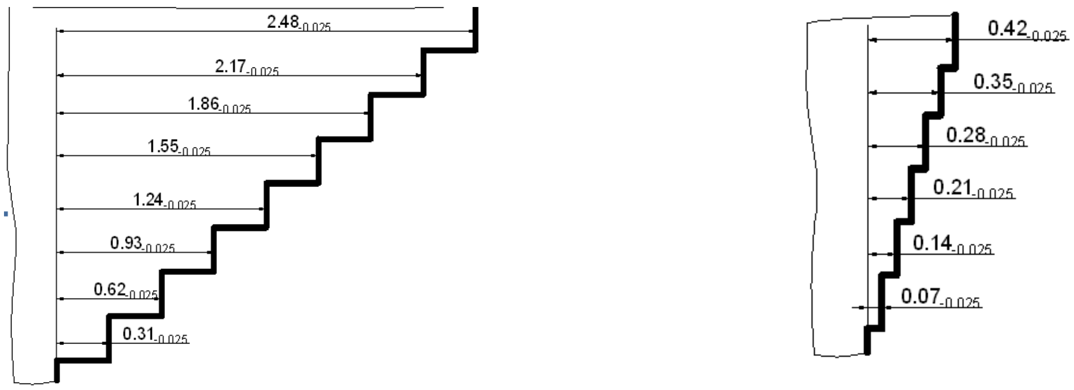


Figure 10: *Schemas with compensators steps (example).*

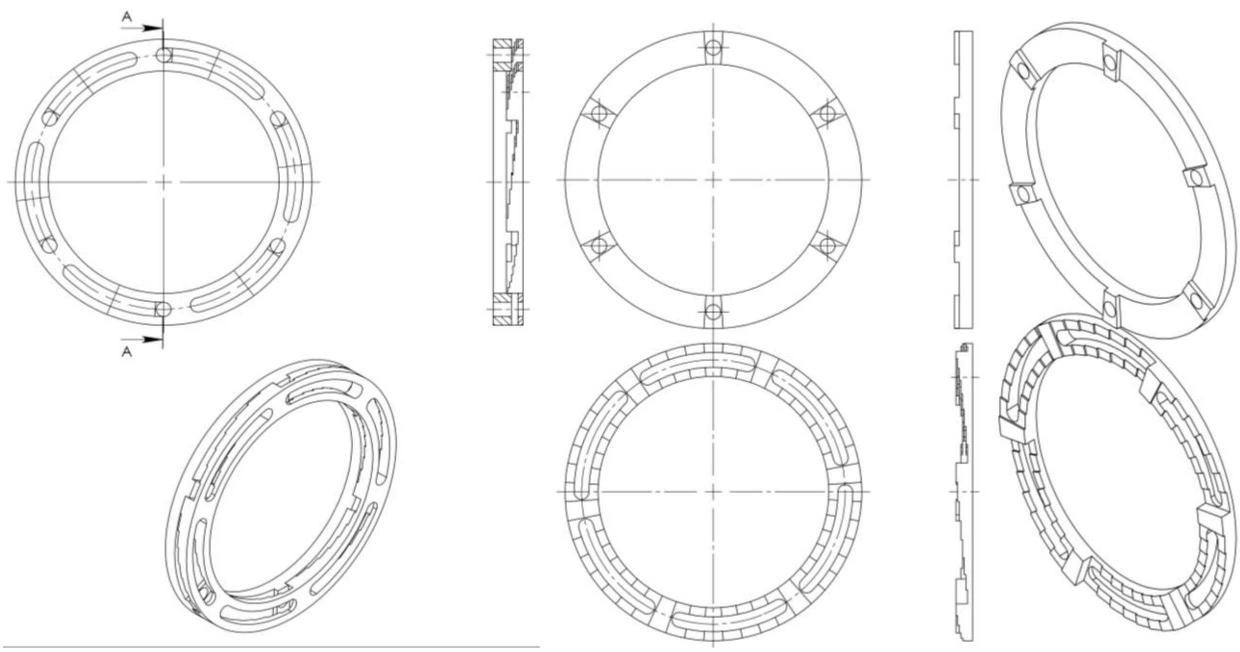


Figure 11: *3D model of the compensator.*

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