LEVERING IN THE TOOTHED CLAMP GEAR – INITIAL INVESTIGATIONS

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1. Introduction

The toothed clamp is a new generation of gear for reducing force acting in Hold Down and Release Mechanisms (HDRM-s). The toothed clamp gear is patented by Astronika company.

HDRM holds down a rod despite the large forces acting on the rod and releases the rod after the activation of the release module. Mechanisms of this type are widely used in space industry - HDRM protect moving parts and payloads of a spacecraft during launch of the rocket.

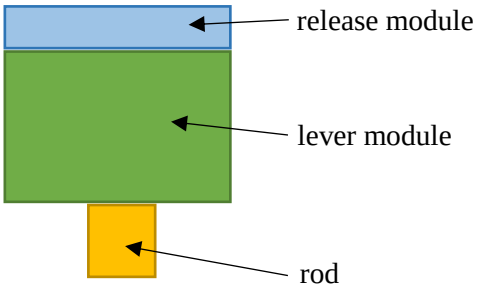

Fig. 1. General construction of the HDRM.

The lever module can be built based on various simple machines. The tooted clamp gear is a kind of inclined plane, which was repeated 8 times on Archimedes' spiral. The toothed clamp is characterized by a large gear ratio and the ability to easily deployment - in addition, it takes up little space and has a small mass compared to other existing solutions. The high gear ratio allows to build the small release module that consumes little energy during release.

In the present study a strain gages were used for to measure strains. Then, based on the strains, the gear ratio was determined. Comparison with the gear ratio theory for toothed clamp has been carried out.

2. Theoretical levering in the toothed clamp gear

Fig. 2. shows an example of HDRM based on the toothed clamp gear.

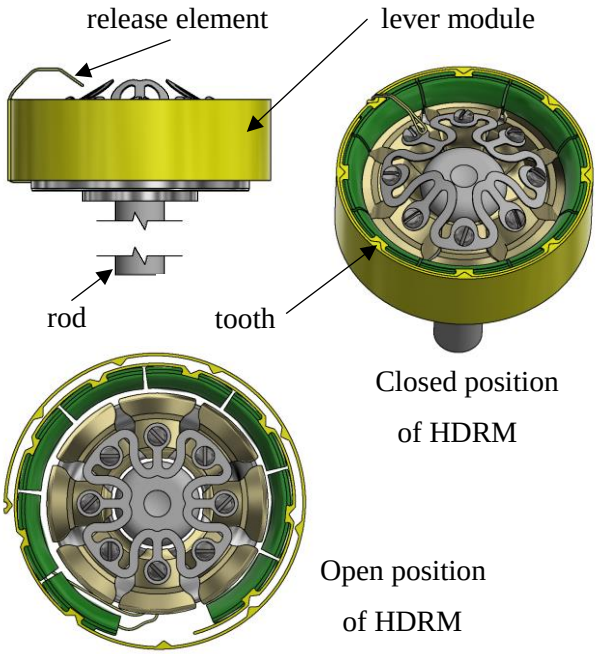

Fig. 2. General construction of the HDRM based on the toothed clamp gear.

The gear ratio has been introduced for one tooth based on general mechanics:

$$R2 = \frac{R1}{\cos\theta + \mu * \sin\theta + \frac{\sin\theta * \sin\gamma}{\cos\gamma} + \frac{\mu * \cos\theta * \sin\gamma}{\cos\gamma}} \quad (1)$$

$$R3 = \frac{R2 * \sin\theta - T2 * \cos\theta}{\cos\gamma} \quad (2)$$

$$\gamma = \frac{360}{n} \quad (3)$$

$$i4 = \left(\frac{R1}{R3}\right)^{7} \quad (4)$$

where:

$R1$ $[N]$ – force before the tooth

$R2$ $[N]$ – reaction for the tooth

$R3$ $[N]$ – force after the tooth

$\theta = 30$ $[deg]$ – angle of tooth inclination

$n = 8$ [1] – number of all teeth

μ [1] – coefficient of friction (variable)

$i4$ [1] – gear ratio for 7 teeth

For last tooth gear ratio $i5$ have other value (calculation are not show).

$i5$ [1] – gear ratio for 8 tooth

Theoretical levering for different coefficient of friction in the toothed clamp gear is presented in Table 1.

Table 1. Theoretical levering in the toothed clamp gear.

	μ [1]		
	0.00	**0.053**	**0.16**
R1/R3 [1]	1.932	2.242	3.100
i4 [1]	100.4	284.7	2751.6
i5 [1]	1.732	1.965	2.617

3. Experiment description

During the test, the strain during closing of the toothed clamp and caused by applying force to the rod were measured. Strain gages were glued before each subsequent tooth. The strain gages from Hottering Baldwin Messtechnik GmbH were used (k-Faktor 2.08 ± 1.0%, resistance 120.0Ω ± 0.2%). During the test, the mechanism was loaded until it was destroyed. Data for calculations was taken for the moment just before plasticization.

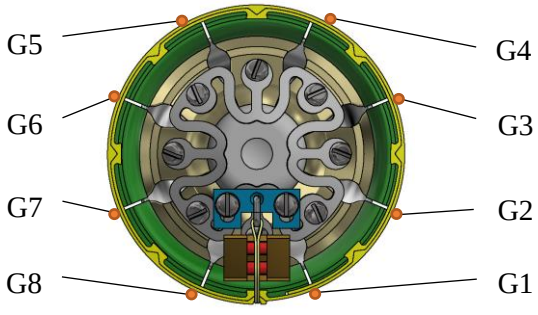

Fig. 3. Position of the strain gages.

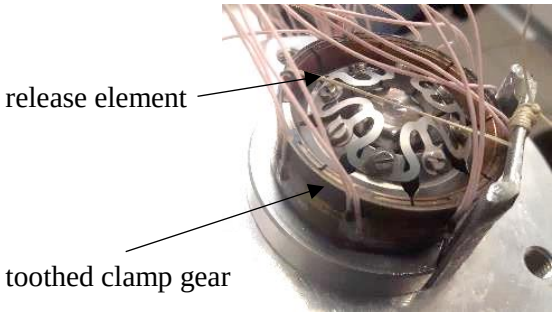

Fig. 4. HDRM before applying the force to the rod.

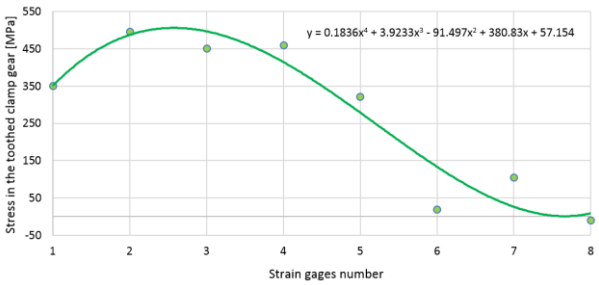

Fig. 5. Stress distribution in the toothed clamp gear.

The calculated levering in the toothed clamp gear based on test data is shown in Table 2.

Table 2. Stress and levering in the toothed clamp gear.

No. of strain gages	**Stress in the toothed clamp gear [MPa]***	**Levering for each tooth [1]**
G1	351	0.720
G2	487	0.980
G3	497	1.199
G4	415	1.486
G5	279	2.088
G6	134	5.114
G7	26	2.989
G8	9	n/a
	Average levering:	**2.082**
*Stress were calculated based on the curve from Fig. 5		

4. Conclusions

Measurements have shown that the teeth produce the levering. The levering is slightly different from the theoretical predictions – the levering is not constant for each tooth (Table 2). Stress distribution in the toothed clamp gear is very similar to the stress distribution for a typical thread connection (Fig. 5).

References

[1] Hendzel, Z., Żylski, W.: Determination of the theoretical levering in the toothed clamp, *Mechanika Ogólna, Statyka*, Rzeszów, 2000.

[2] Gasiak, G.: *Analysis of thread coil effort in the screw – nut joint*, http://sjsutst.polsl.pl/archives/2014/vol82/87_ZN82_2014_Gasiak.pdf, 2014.