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INFLUENCE OF CONJUGATE CAM PAIR RELIEFS ON INDEXING GEARBOX OPERATION

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Abstract: *The company VÚTS, a.s. manufactures KP series indexing gearboxes, which consist of a pair of radial cams and an indexing turret follower fitted with rollers. These indexing cam gearboxes are used to convert the uniform rotary motion of the input camshaft into a unidirectional rotary motion with clearly defined dwell portions of the output shaft. Due to multiple contacts between the rollers and the conjugate cam pair, it is necessary to provide certain reliefs at specific cam areas, both in the profile of the cam pair and the sides of the cams. These reliefs are created to prevent redundant roller/cam connections, thereby avoiding unnecessary impacts in the mechanism, which increase noise during the operation. A test device equipped with the KP series indexing gearbox was designed to evaluate the impact of the size and shape of the reliefs on the working surface and sides of the cams on the operation of the gearbox. The influence of individual parameters of the relief of the conjugate cam pair on the dynamic properties of the indexing gearbox operation was evaluated using the RMS acceleration value in relation to the camshaft revolutions.*

Keywords: Indexing gearbox, Cam mechanism, Conjugate cams, Cam reliefs, RMS acceleration value

1. Introduction

The company VÚTS, a.s. (VÚTS, a.s., 2025) manufactures *KP* series indexing gearboxes (Indexing Gearboxes, 2025), which consist of a pair of radial cams and an indexing turret follower fitted with rollers, see Fig. 1. These cam gearboxes are typically used to convert the uniform rotary motion of the input camshaft into unidirectional rotary motion with clearly defined dwell portions of the output shaft (intermittent rotary motion). The dwell interval and subsequent rise interval occur with a period of 2π. The transition between the dwell intervals is governed by a movement function with a constant rise (index). The shape of the movement function dependency directly affects the dynamic behaviour and properties of the mechanical system. These are widely used in production and handling devices with so-called hard automation.

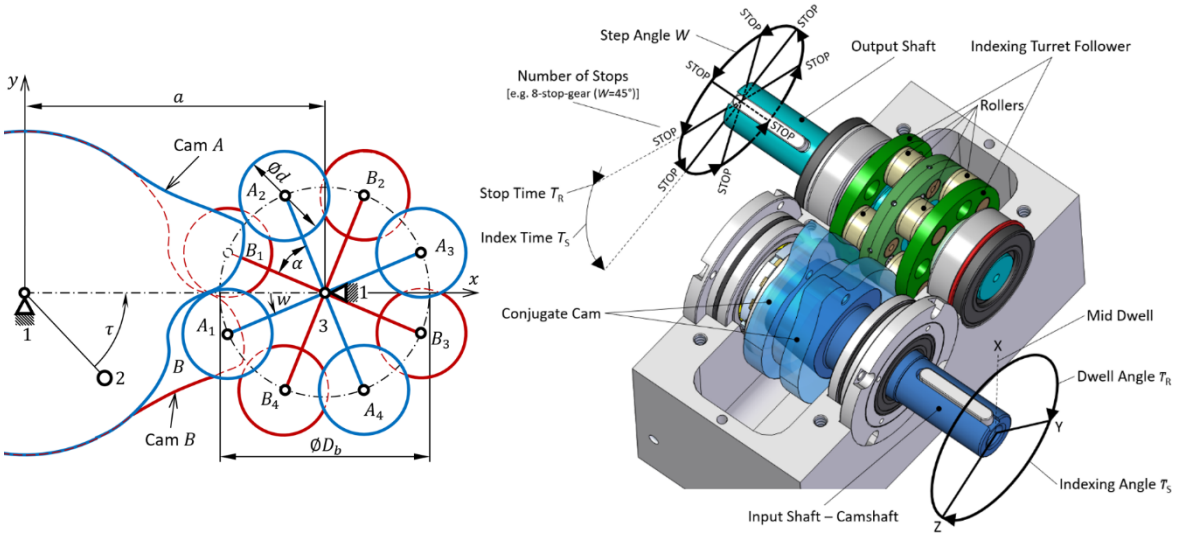

Fig. 1: Indexing gearbox with conjugate cams.

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Due to multiple contacts between the rollers and the conjugate cam pair, it is necessary to provide certain reliefs at specific cam areas, both in the profile of the cam pair and the sides of the cams, see Fig. 2. The dashed curves indicate the cam profile without relief. In the case of cams with relief, the coordinates of the relief are subtracted in the given intervals of the polar coordinates of the cam profile, with their course in the given interval defined by mathematical relations. The working surface of the cam is relieved in sections corresponding to the intervals $\varphi \in \langle \varphi_I, \varphi_{II} \rangle$ and $\varphi \in \langle \varphi_{III}, \varphi_{IV} \rangle$, where the length coordinate of the relief runs from zero values at the boundary points of the intervals to the maximum value $\Delta u_{\mathrm{Max}_{12}}$ or $\Delta u_{\mathrm{Max}_{34}}$ in the middle of the intervals. Similarly, this is also the case for the relief of the sides of the cams, which are assigned the intervals $\varphi \in \langle \varphi_A, \varphi_B \rangle$ and $\varphi \in \langle \varphi_C, \varphi_D \rangle$, where the length coordinate of relief $\Delta u_{\mathrm{Max}_{AB}}$ or $\Delta u_{\mathrm{Max}_{CD}}$ reaches maximum values in the middle of the intervals. These reliefs are created to prevent redundant roller/cam connections, thereby avoiding unnecessary impacts in the mechanism, which increase noise during operation.

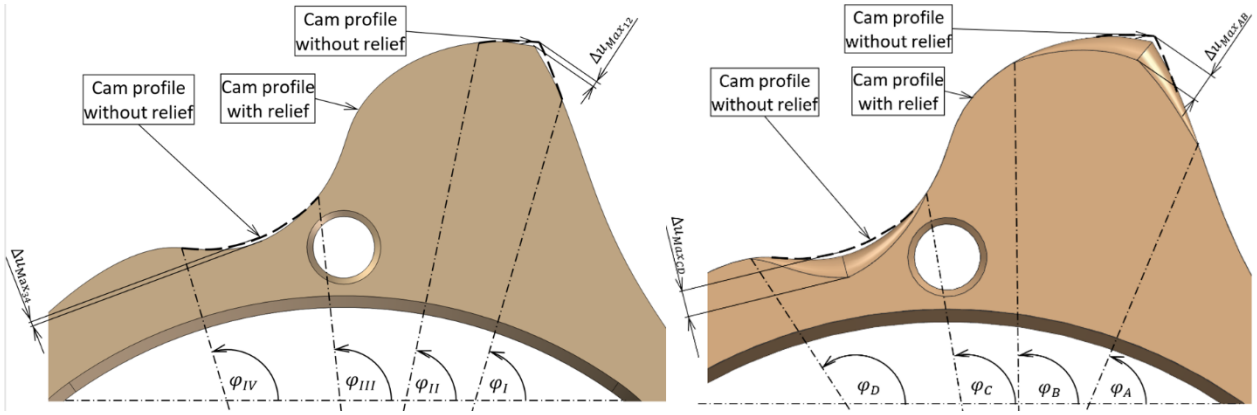

Fig. 2: Reliefs of the cam working surface and Reliefs of the cam sides.

2. A test device

A test device equipped with the *KP* series indexing gearbox was designed to evaluate the impact of the size and shape of the reliefs on the working surface and sides of the cams on the operation of the gearbox, see Fig. 3. Various cam pairs with different sizes and ranges of reliefs were designed and manufactured. The relief parameters of the conjugate cam pair are contained in Tab. 1. Using a test rig, we can measure the required driving torque, the device's vibrations (measured by an acceleration sensor located on the gearbox housing), the amount of generated noise, and the rotation and velocity of the output shaft, depending on the operating frequency of the indexing gearbox and the installed cam pair with the specified reliefs.

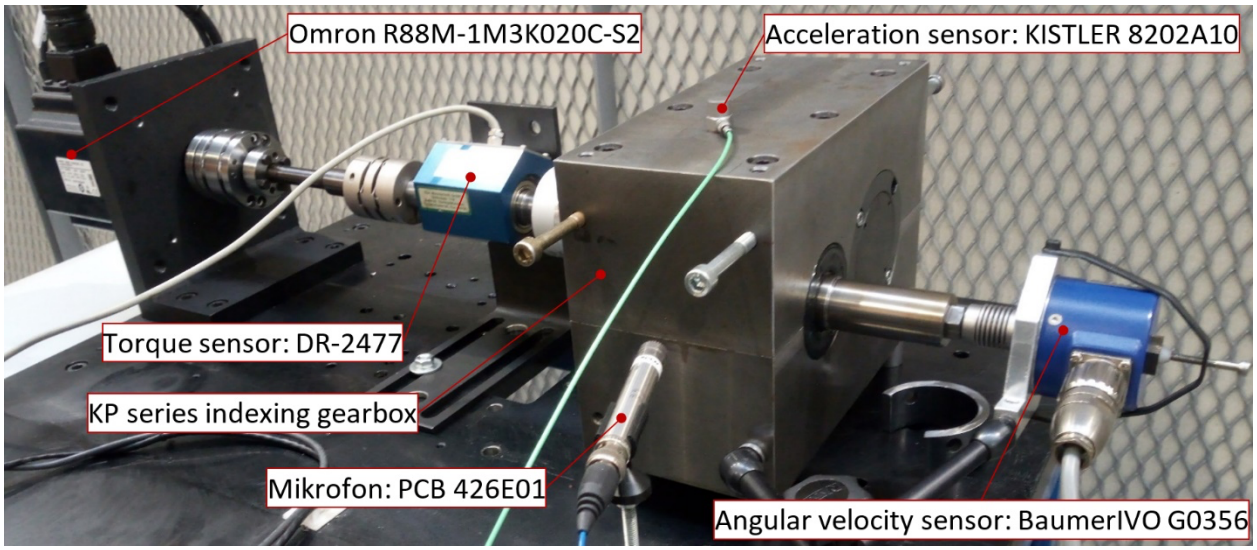

Fig. 3: Test device.

Tab. 1: Relief parameters of conjugate cams.

	Working surface of cams				Sides of cams			
	$\varphi_{II} - \varphi_I$	$\Delta u_{\mathrm{Max}_{12}}$	$\varphi_{IV} - \varphi_{III}$	$\Delta u_{\mathrm{Max}_{34}}$	$\varphi_B - \varphi_A$	$\Delta u_{\mathrm{Max}_{AB}}$	$\varphi_D - \varphi_C$	$\Delta u_{\mathrm{Max}_{CD}}$
	[°]	$[mm]$	[°]	$[mm]$	[°]	$[mm]$	[°]	$[mm]$
*R*385	8	0.25	8	0.25	0	0	0	0
*R*1305/01	0	0	0	0	0	0	0	0
*R*1305/03	0	0	0	0	8	0.25	8	0.25
*R*1305/04	8	0.25	8	0.25	8	0.40	8	0.40
*R*1305/05	8	0.25	8	0.25	18	0.40	25	0.40
*R*1305/06	0	0	0	0	18	0.25	25	0.25

3. Test results

The effect evaluation of the individual relief parameters of the conjugate cam pair on the dynamic properties of the *KP* series indexing gearbox operation was carried out using the RMS acceleration value $a_{Eff_{R,n}}$ in relation to the camshaft revolutions *n*. The subscript *R* is from the set of symbols: $R \in \{R385; R1305/01; R1305/02; R1305/03; R1305/04; R1305/05; R1305/06\}$ and the subscript n is from the set of camshaft revolutions: $n \in \{60; 120; 180; 240; 300; 360; 420; 480; 540; 600\}$ *rpm*. The RMS acceleration values $a_{Eff_{R,n}}$ are given numerically in Tab. 2.

Tab. 2: RMS acceleration values.

n $[rpm]$	$a_{Eff_{R,n}}$ $[ms^{-2}]$					
	*R*385	*R*1305/01	*R*1305/03	*R*1305/04	*R*1305/05	*R*1305/06
60	1.049667	1.049975	1.048276	1.049519	1.048795	1.048688
120	1.052308	1.052507	1.048502	1.048188	1.050829	1.046449
180	1.050303	1.049579	1.052142	1.047430	1.047225	1.049367
240	1.054803	1.064686	1.051648	1.048879	1.048241	1.050428
300	1.053637	1.074316	1.062364	1.054417	1.055253	1.055791
360	1.057443	1.101289	1.066772	1.052888	1.054941	1.058561
420	1.066006	1.100617	1.089390	1.054325	1.056163	1.070366
480	1.082364	1.139174	1.108701	1.057208	1.063243	1.075702
540	1.096985	1.129770	1.094505	1.073672	1.072236	1.093573
600	1.130908	1.137173	1.121098	1.070649	1.088942	1.101677

We expressed the influence of the relief of the conjugate cam pair using the percentage ratio of the RMS acceleration value $a_{Eff_{R,n}}$ of the device relative to the effective acceleration value $a_{Eff_{R385,n}}$ of the device equipped with the *R*385 cam pair through the relationships:

$$W_{a_{R,n}} = \left(1 - \frac{a_{Eff_{R,n}}}{a_{Eff_{R385,n}}}\right) \cdot 100\ [\%] \tag{1}$$

We consider the cam labelled *R*385 as the reference. The values of the measured quantities induced by the operation of the modified cams will be related to this cam. To evaluate the influence of the relief of the conjugate cam pair over a wider range of operating revolutions of the indexing gearbox, we introduced the average value of the percentage ratio of the RMS acceleration value $\overline{W}_{a_R}$ for the individual cam pairs with reliefs. If the values of the quantities $W_{a_{R,n}}$ and $\overline{W}_{a_R}$ are positive, then the effect of the reliefs of the conjugate cam pair on the dynamic properties is positive, otherwise negative. The resulting values of the mentioned quantities are summarized in Tab. 3. Examples of acceleration and output shaft angular displacement records are given in Fig. 4 for camshaft revolutions of n = 300 *rpm*. In Fig. 4, the time dependences of the relevant quantities with the successively installed cams *R*385, *R*1305/04 and *R*1305/05 are presented.

Tab. 3: The percentage ratio of RMS acceleration value.

$n\ [rpm]$	$W_{a_{R,n}}$ [%]					
	*R*385	*R*1305/01	*R*1305/03	*R*1305/04	*R*1305/05	*R*1305/06
60	0.000000	-0.0293426	0.1325182	0.014100	0.083074	0.093268
120	0.000000	-0.0189108	0.3616812	0.391520	0.140548	0.556776
180	0.000000	0.0689325	-0.1750923	0.273540	0.293058	0.089117
240	0.000000	-0.9369522	0.2991080	0.561621	0.622107	0.414769
300	0.000000	-1.9626304	-0.8282739	-0.074029	-0.153374	-0.204435
360	0.000000	-4.1464173	-0.8822225	0.430756	0.236608	-0.105727
420	0.000000	-3.2467922	-2.1936087	1.095772	0.923353	-0.409003
480	0.000000	-5.2486964	-2.4332849	2.324172	1.766596	0.615505
540	0.000000	-2.9886462	0.2260742	2.125189	2.256093	0.311034
600	0.000000	-0.5539796	0.8674446	5.328373	3.710824	2.584737
$\bar{W}_{a_R}$ [%]	0.000000	-1.9063435	-0.4625656	1.247101	0.987889	0.394604

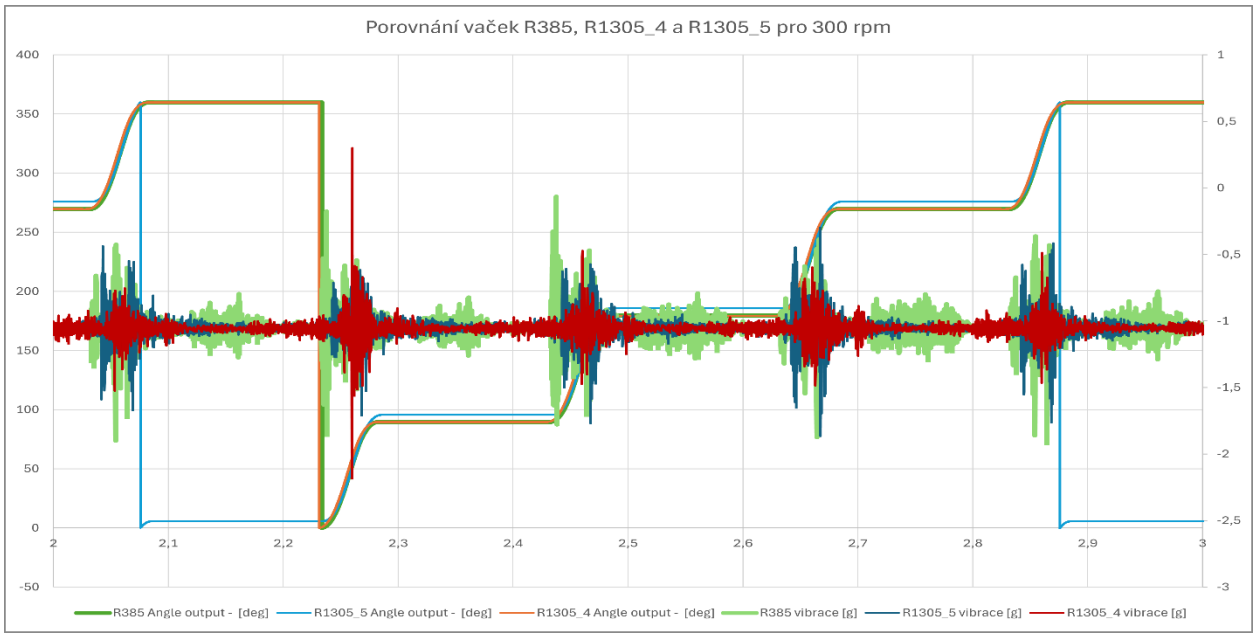

Fig. 4: Examples of acceleration and output shaft angular displacement records.

4. Conclusions

By comparing the relevant values, we can state that the influence of the reliefs of the conjugate cam pair *R*1305/04 among all the examined ones makes the greatest benefits on the dynamic properties and behaviour of the *KP* series indexing gearbox, compared to the standardly manufactured ones labelled *R*385.

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