Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679
ISBN 978-3-901509-83-4, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2011
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Annals & Proceedings of DAAAM International 2011

CONTRIBUTION TO ERGONOMIC OPERATING OF SPRING-ACTUATED MECHANISM

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Abstract: *Compensation of variable force performed by a spring can be compensated by a flat cam, for example by operating a drill sleeve. For the construction of the mechanism it is essential to coordinate the movement path and to choose the appropriate possible rigidity of spring with regard to the required force and to the constant required torque*
Key words: *mechanism, spring, cam, ergonomic, force*

1. INTRODUCTION

The force performed by a spring depends on its deflection and rigidity. From the ergonomic point of view it appears to be advantageous to compensate the action of this inconvenient attribute to the controlled mechanism (Malý; Král & Hanáková, 2010).

2. SPRING - ACTUATED MECHANISM

Compensation of the variable force can be performed with an interposed element which can be for example by the control of a drill sleeve the appropriately solved compensatory cam (see Fig.1).

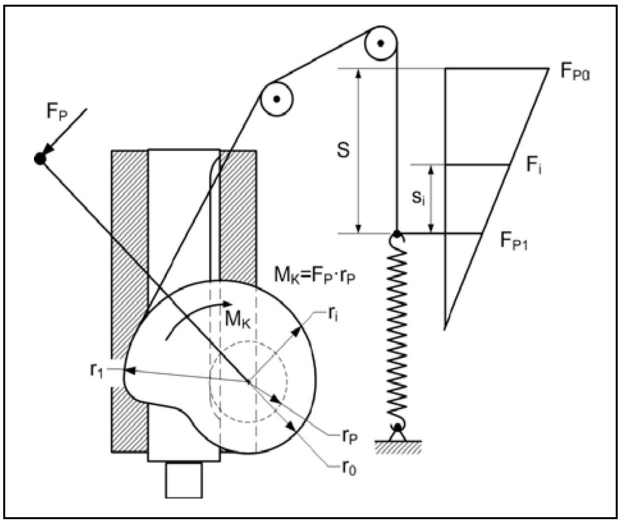

Fig. 1. Mechanism of a drill sleeve with cam

General diagram of such compensatory cam you can see in Fig. 2.

In case of a flat cam (***, 2011) the rise is t = 0 and then its simplified equation is valid:

$$ds' = ds = r.d\varphi \tag{1}$$

Variable radius r [m] of this cam should guarantee the constant force F_p [N] as well as torque M_k [Nm] on the lever which controls the motion of sleeve and eliminates the increased force of spring depending on rotation of elements integrated into mechanism (pinion, cam), consequently:

$$M_k = c.s.r_p = konst. \tag{2}$$

where c….is rigidity of spring [Nm^{-1}]
s….is spring deflection [m]
r_p…is const. radius of pinion [m]

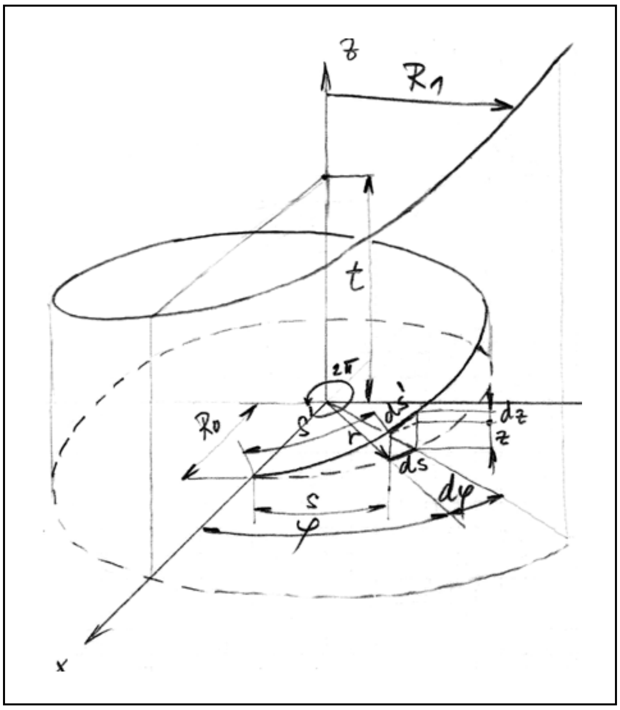
Fig.2. Diagram of compensatory cam

From the equation (2) follows:

$$s = \frac{M_k}{c.r}$$

$$ds = -\frac{M_k}{c.r^2}dr$$

After substitution to the equation (1) and its modification:

$$d\varphi = -\frac{M_k}{c.r^3}dr \tag{3}$$

With definite integration (3):

$$\varphi = -\frac{M_k}{c}\int_{r_1}^{r_0} r^{-3}\,dr$$

You acquire:

$$\varphi = \frac{M_k}{2c}[r^{-2}]_{r_1}^{r_0}$$

$$d\varphi = -\frac{M_k}{c.r^3}dr$$

$$\varphi = \frac{M_k}{2c}\left[\frac{1}{r_1^2} - \frac{1}{r_0^2}\right]$$

$$\varphi = \frac{M_k}{2c}\left[\frac{r_0^2 - r_1^2}{r_1^2 . r_0^2}\right] \qquad (4)$$

For the complete construction of the mechanism it is essential to coordinate the general movement path S [m] (sleeve stroke as well as spring stroke in dependence on pertinently interposed gear – see Fig.1) and to choose the appropriate possible rigidity of spring c [Nm^{-1}] with regard to the required force F_p [N] and to the constant required torque M_k [Nm].

The rigidity of spring follows from the equation (5):

$$c = \frac{M_k}{2\varphi}\left[\frac{r_0^2 - r_1^2}{r_1^2 . r_0^2}\right] \qquad (5)$$

where the size of angle φ [rad] corresponds to the structural possibilities of the thought flat cam according to Fig. 3 and equation (6):

$$\varphi = \frac{2.\pi.\alpha}{360} \qquad (6)$$

where α [°] is angle of cam girt with a tension element (cable, chain etc.).

The construction conditions in the whole solution of mechanism determine geometric conditions of particular design of compensatory cam (Václavík & Koloc, 1988), for example in Fig.3 the total angle of cam girt α = 286° with radius difference:

$$\Delta r = r_1 - r_0 = 16\ mm$$

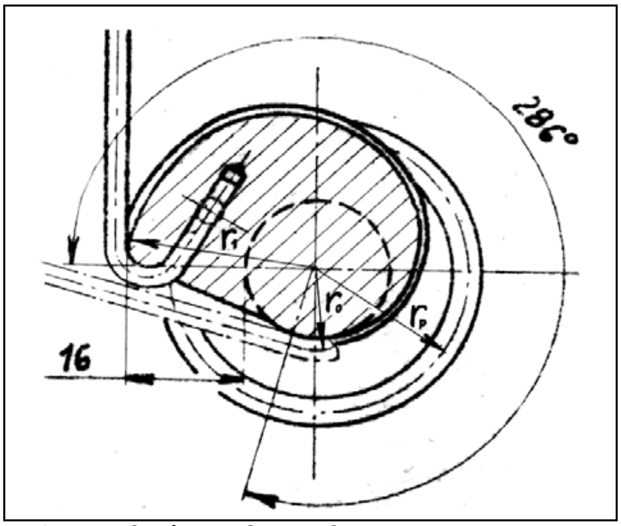

Fig.3. Example of particular cam design

From the required constant torque on the operating lever of mechanism

$$M_k = F_p . r_p$$

the forces at the beginning and the end of rise can be assigned:

$$F_{p_0} = \frac{M_k}{r_0} \qquad \text{and} \qquad F_{p_1} = \frac{M_k}{r_1}$$

The difference of them is in following equation to the total required rise (stretch) of spring s [m] with rigidity c [Nm^{-1}]:

$$s = \frac{F_{p_0} - F_{p_1}}{c} \qquad (7)$$

In case there is a spring with given rigidity, it is essential to emend appropriately the calculation from equations (4), (5), (6) and (7) and to match the basic radiuses on the cam r_0 and r_1 to the construction of mechanism.

From the equation (4) you can get the resulting equation (8) for compensatory cam with help of substitution of variable r instead of the boundary condition r_1:

$$r = r_0\sqrt{\frac{M_k}{M_k - 2.c.r_0^2.\varphi}} \qquad (8)$$

It is possible to set the table / chart for production of the cam from this equation

$$r = f(\varphi)$$

The particular successful industrial application of such compensatory mechanism is in Fig. 4.

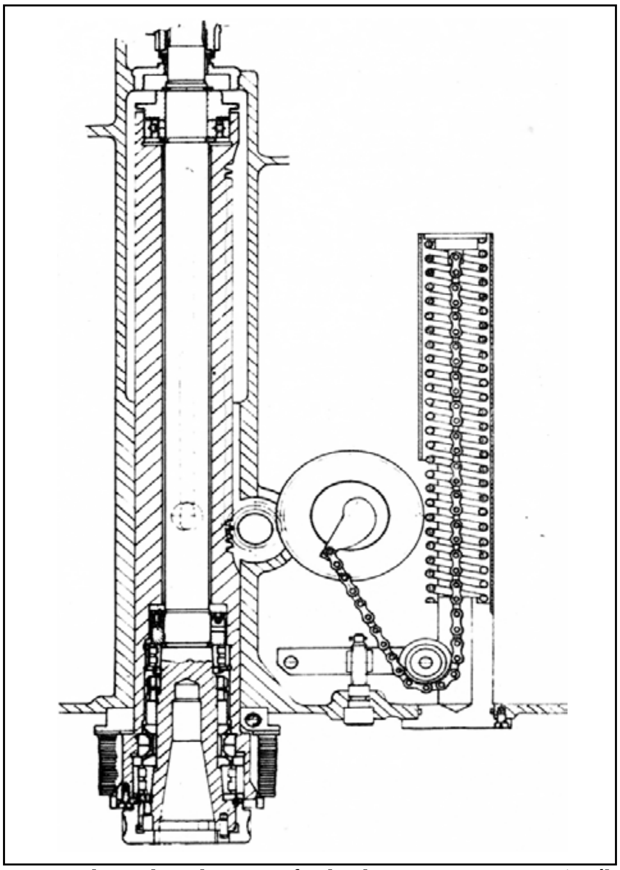

Fig.4. Industrial application of solved ergonomic system (Král, 2002)

3. CONCLUSION

Further research of compensation of variable force with the spring-actuated mechanism will be the way how to guarantee the constant force on the drill sleeve which is advantageous from the ergonomic point of view (Petrů, 1980).

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