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A method for optimal calculation of total transmission ratio of two step helical gearboxes

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Abstract. The article presents a new and effective method for optimal calculation of the total transmission ratio of two step helical gearboxes for their minimum cross section dimension. Basing on moment equilibrium condition of mechanic system including the two gear units and their regular resistance condition, the author have built the relationship among the ratios of the two steps. In particular, he have built a formula to find out rapidly and exactly the optimal transmission ratios of two step helical gearboxes.

Notation

u_h - gear unit transmission ratio (in two steps);
u_1; u_2 - partial transmission ratios (of step 1 and 2);
a_{w1}, a_{w2} - center distance at cylindrical gears (mm);
b_{w1}, b_{w2} - widths of the cylindrical gear toothings (mm);
ψ_{ba1}, ψ_{ba2} - coefficients of cylindrical gear width (of step 1 and 2);
d_{w11}; d_{w12} - rolling diameters of the driving gears (mm);
T_{11}; T_{12} - torque on the driving shart of gears (Nmm);
$[\sigma_{H1}]$; $[\sigma_{H2}]$ - permissible contact stresses of cylindrical gears (MPa);

1- Introduction

In 1971 Prf. Dr. Kudreavsev V. N. ... (The USSR) presented a method for splitting the total transmission ratio of two step helical gearboxes for minimum gearbox

Figure 1

cross section dimension [2]. The transmission ratio u_1 of hight- speed gear set is found from the curves of Figure 1. The values of λ and c for each curve can be calculated from:

$$\lambda = \frac{\psi_{bd2}[K_{02}]}{\psi_{bd1}[K_{01}]}$$

$$c = \frac{d_{w22}}{d_{e21}}$$

where

c = 1 ÷ 1,3 ; if c=1 then the gearbox cross section dimension is minimum;

$[K_{01}]$, $[K_{02}]$ - coefficients; $\frac{[K_{02}]}{[K_{01}]} = 1 \div 1.3$;

$\psi_{bdi} = b_{wi}/d_{wi}$- coefficients. For helical gear $\psi_{bdi} = \frac{\psi_{bai}(u_i + 1)}{2}$ [1].

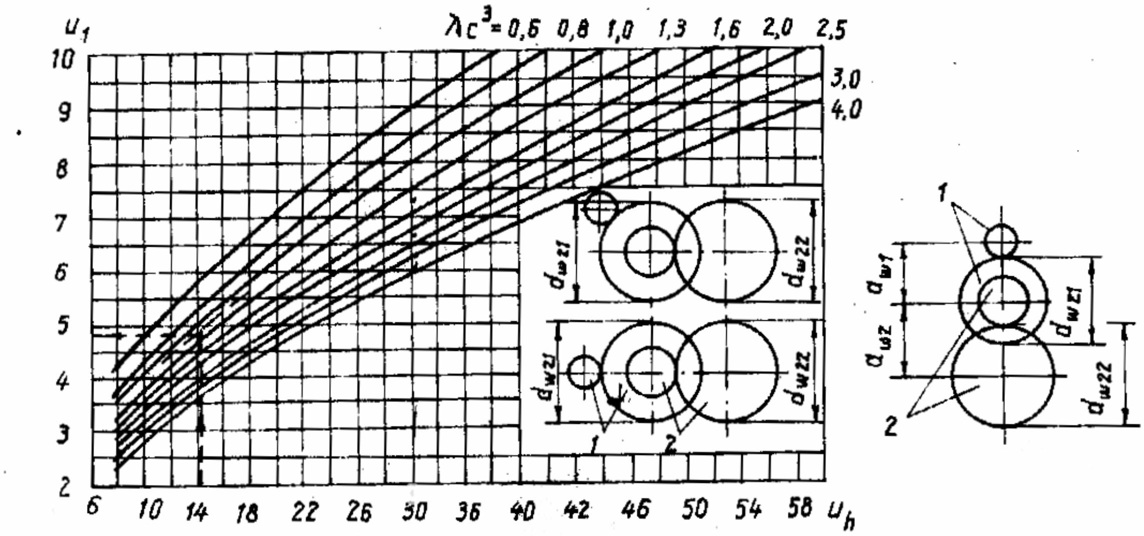

Figure 1

In practice, this method was applied quite commonly, however it's not user-friendly, because the looking up the graph (Fig.1) is complicated. Furthermore, when using this method the obtained coefficient of gear widths ($\psi_{ba} = \frac{b_w}{a_w}$) is not usually reasonable.

2- Optimal calculation of total transmission ratio of two step helical gearboxes

From maximum condition of contact stress of helical gear [1]:

$$\sigma_{H1} = Z_{M1}.Z_{H1}.Z_{\varepsilon 1}\sqrt{\frac{2T_{11}.K_{H1}(u_1+1)}{b_{w1}.d_{W11}^2.u_1}} \le [\sigma_{H1}]$$

we have

$$[T_{11}] = \frac{b_{w1}.d_{w11}^2.u_1}{2(u_1+1)}.\frac{[\sigma_{H1}]^2}{K_{H1}.(Z_{M1}.Z_{H1}.Z_{\varepsilon 1})^2} \tag{1}$$

where

$[T_{11}]$ - permissible torque on the driving shart of step 1(Nmm);

b_{w1} - widths of the driving gear toothings of step 1(mm);

$$b_{w1} = \psi_{ba1}.a_{w1} = \frac{\psi_{ba1}.d_{w11}.(u_1+1)}{2} \; ; \tag{2}$$

d_{w11} - rolling diameters of the driving gears of step 1 (mm); $d_{w11} = d_{w21}/u_1$;

Substituting equation (2) into equation (1) we get

$$[T_{11}] = \frac{0{,}25.\psi_{ba1}.d_{w21}^3.[K_{01}]}{u_1^2} \tag{3}$$

Where

$$[K_{01}] = \frac{[\sigma_{H1}]^2}{(Z_{M1}.Z_{H1}.Z_{\varepsilon 1})^2.K_{H1}} \tag{4}$$

By analogy calculation we have

$$[T_{12}] = \frac{0{,}25.\psi_{ba2}.d_{w22}^3.[K_{02}]}{u_2^2} \quad (5)$$

where $$\frac{T_{12}}{T_{11}} = \frac{[T_{12}]}{[T_{11}]} = u_1.\eta \quad (6)$$

In formula (6)

$[T_{12}]$ - permissible torque on the driving shart of step 2(Nmm);

$\eta = \eta_{brt}.\eta_o$ - efficiency of the gearset;

$\eta_{brt} = 0.95 \div 0.97$ [1] - efficiency of cylindrical gear;

$\eta_o = 0.99 \div 0.995$ [1] - efficiency of a rolling bearing;

Choosing $\eta_{brt} = 0.97$; $\eta_o = 0.992$ and substituting equations (3), (5) into equation (6) we get

$$\frac{[K_{02}]}{[K_{01}]}.\frac{\psi_{ba2}}{\psi_{ba1}}.\left(\frac{d_{w22}}{d_{w21}}\right)^3.\frac{u_1^2}{u_2^2} \approx 0{,}96.u_1 \quad (7)$$

Substituting $c_k = \frac{[k_{02}]}{[k_{01}]}$, $c_{ba} = \frac{\psi_{ba2}}{\psi_{ba1}}$, $c_d = \frac{d_{w22}}{d_{w21}}$ we obtain

$$u_1 = \frac{0{,}96}{c_k.c_{ba}.c_d}.u_2^2$$

The gear unit transmission is

$$u_h = u_1.\ u_2$$

hence

$$\frac{0{,}96}{c_k.c_{ba}.c_d}.u_2^2.u_2 = u_h$$

and $$u_2 = \sqrt[3]{\frac{c_k c_{ba} c_d}{0{,}96} u_h} \quad (8)$$

In practice, $c_d = 1 \div 1.3$; if $c_d=1$ then the gearbox cross section dimension is minimum[2].

When $c_k=1$; $c_d=1$ we have

$$u_2 = \sqrt[3]{\frac{\psi_{ba2}}{0{,}96.\psi_{ba1}} u_h} \quad (9)$$

Formula (9) can be used to calculate the transmission ratio u_2 of low - speed gear set u_2. From this u_2, we can determine the transmission ratio u_1 of hight- speed gear set ($u_1 = u_h / u_2$).

In practice, $c_{ba} = \frac{\psi_{ba2}}{\psi_{ba1}} = 1{,}2 \div 1{,}3$ [1]; Choosing $c_{ba}=1{,}3$ we get

$$u_2 \approx 1{,}1\sqrt[3]{u_h} \quad (10)$$

References

[1] Trinh Chat, Nguyen van Uyen, *Design and calculus of Mechanical Transmission (in Vietnamese),* Educational Republising House, Hanoi, 1998.

[2] V.N. Kudriavsev, Iu.A. Gierzaves, E.G. Glukharev, *Konstrucksi i rastriet zubtratux reduktorov (in Russian),* Leningrad Masinoxtroenhie, 1971.

MỘT CÁCH PHÂN PHỐI TỐI ƯU TỈ SỐ TRUYỀN
CHO HỘP GIẢM TỐC BÁNH RĂNG TRỤ HAI CẤP KHAI TRIỂN

Tóm tắt. *Bài báo trình bầy một phương pháp tính toán tối ưu tỉ số truyền của hộp giảm tốc bánh răng trụ hai cấp khai triển nhằm đạt kích thước tiết diện ngang của hộp nhỏ nhất. Trên cơ sở điều kiện cân bằng mô men của cơ hệ gồm hai cấp bánh răng và điều kiện sức bền đều của chúng, tác giả đã đưa ra mối quan hệ giữa các tỉ số truyền của hai cấp. Đặc biệt, tác giả đã đưa ra được công thức cho phép xác định nhanh và chính xác tỉ số truyền các cấp của hộp giảm tốc bánh răng trụ hai cấp khai triển.*