Calculation of Carrier and Interchangeable Element Combination

Ergashev Ilhomjon Olimjonovich	PhD, Fergana polytechnic institute
Mahmudov Nasimbek Odilbekovich	PhD applicant, Fergana polytechnic institute farpi2019@gmail.com

ABSTRACT

This article proposes a new structural steel carrier in the form of a three-part trapezoidal, interchangeable element mounted and bent sheet to reduce its contact with the saws due to bending of the carrier grille and assembly errors. To increase the performance of this interchangeable element carrier structure, it is necessary to calculate the displacement of the interchangeable element relative to the carrier.

Keywords: Interchangeable element, Carrier element, Static equation, coefficient of friction, efficiency, fastening force.

Introduction

As a result of the calculation of the carrier of the interchangeable element, the stiffening force *W* and the external force *Q* determined in the displacement of the interchangeable element decrease. The carrier is considered fastened. The alternating element is affected by the following forces: the force *Q* on the external extension side, the normal forces N, N_1, N_2, and the friction forces F, F_1, F_2 (Figures 1a and 1b). The friction force *R* is directed towards the force *Q*. To construct a static equation, it is necessary to determine the forces acting in the horizontal and vertical directions.

Mainpart

For this purpose, the force vectors N, N_1, N_2 F, F_1, F_2 are added geometrically on the inclined surface of the interchangeable element, resulting in a force *R* (inversely directed to *Q*) and it is equal to the interlocking element 1 and the carrier 2 in the vertical direction.

Static equation of a carrier of an interchangeable element:

$$\left.\begin{array}{l} R=(F+F_1+F_2) \\ W=N+(N_1+N_2)\cdot\cos \end{array}\right\} ,$$

(1)

If we consider that $N_1 = N_2$ and $F_1 = F_2$ are equal:

$$\left.\begin{array}{l} R=F+2\cdot F_1 \\ W=N+2\cdot N_1\cdot\cos\alpha \end{array}\right\} .$$

(1’)

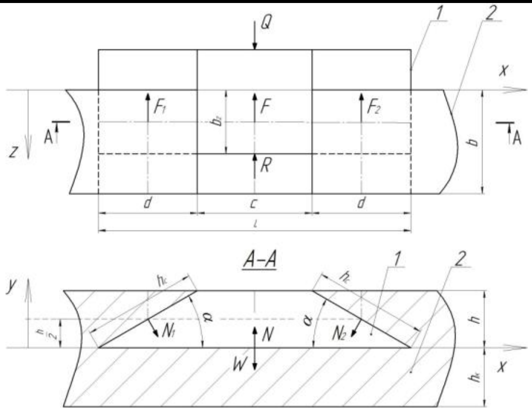

Figure 1. Calculation scheme of the carrier combination of the interchangeable element (a) and its section on A-A (b): 1- insert; 2- Carrier

Carrier-based normal power:

$$N = m_{вс} \cdot g \quad (2)$$

Normal force on the inclined surface of the carrier and exchange element:

$$N_1 = N_2 = [\sigma] \cdot h_c \cdot b_z = [\sigma] \cdot \frac{h \cdot b_z}{\sin\alpha} \quad (3)$$

here $h_c = \dfrac{h}{\sin\alpha}$,

Carrier-based friction:

$$F = f \cdot N = f \cdot m_{вс} \cdot g \quad (4)$$

Frictional force on the bearing surface:

$$F_1 = F_2 = f \cdot N_1 = f \cdot [\sigma] \cdot h_c \cdot b_z = f \cdot [\sigma] \cdot \frac{h \cdot b_z}{\sin\alpha} \quad (5)$$

After we put the terms (2) and (3) in the static equation (1), we obtain the formula for calculating the forces of the alternating element of the relative equation of the variable W in the following form:

$$W = m_{вс} \cdot g + 2 \cdot [\sigma] \cdot \frac{h \cdot b_z}{\sin\alpha} \cdot \cos\alpha \quad (6)$$

The force that bends the carrier from the interchangeable element:

$$W_x = 2 \cdot [\sigma] \cdot h \cdot b_z \quad (7)$$

From the analysis of fig. 2 and equation (6) it follows that, with increasing thickness of the interchangeable element *h*, the clamping force, the penetration depth of the interchangeable element b_z and the strength of the interchangeable element material increase. An increase in the angle of inclination a of the carrier and the exchanging element from 10^0 to 90^0 decreases the strength *W* from 59888 *N* to 0.25*N*.

The following parameters were used in the calculation for the carrier and the replacement element: *f*=0.57; [σ]=110 MPa; h=0.004 м; b_z=b=0.012м; g=9.806 м/s^2 $m_{вс}\cdot g=0.026\cdot 9.806=0.255$ Н, E=$2\cdot 10^{11}$ N/м^2, L=0.05975 м [3, 4].

Analysis of equation (7) showed that the maximum bending force of the carrier from the place of installation of the carrier on the x-axis is W_x = 10560 N and depends on the width and height of the replacement element and the material.

In solving the inverse problem (the force *W* is known and the required force is *Q*), after changing equation *(1)* we obtain:

$$R = (f \cdot m_{вс} \cdot g + f \cdot [\sigma] \cdot \frac{h \cdot b_z}{\sin\alpha} + f \cdot [\sigma] \cdot \frac{h \cdot b_z}{\sin\alpha}) = f(m_{вс} \cdot g + 2 \cdot [\sigma] \cdot \frac{h \cdot b_z}{\sin\alpha}) \quad (8)$$

Analysis of Figure 3 and Equation (8) shows that the mass of the exchange element $m_{вс}$, material strength [σ], the thickness of the exchange element h, the depth of the entrance of the exchange element b_z and the friction coefficient f increase with increasing friction force *R*, From 10^0 to 90^0, the frictional force *R* decreases from *R* 34663 N to 6019 N as the angular slope α between the carrier and the exchange element increases.

Taking into account equations (6) and (8) similar to the wedge mechanism, the efficiency of the carrier-exchangeable element is equal to:

$$\eta = \frac{W}{R} = \frac{m_{вс} \cdot g + 2 \cdot [\sigma] \cdot \frac{h \cdot b_z}{\sin\alpha} \cdot \cos\alpha}{f \cdot (m_{вс} \cdot g + 2 \cdot [\sigma] \cdot \frac{h \cdot b_z}{\sin\alpha})}$$

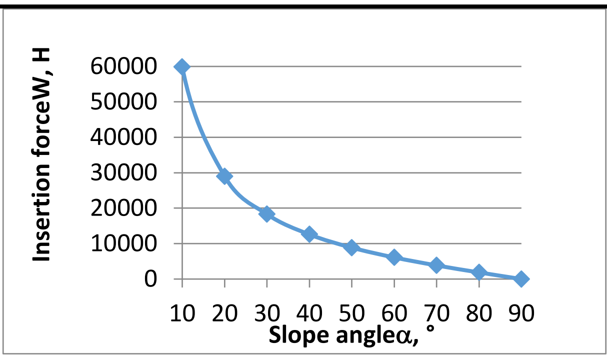

Figure 2. The angle of inclination of the carrier and the exchange element α is the change in the dependence W on the clamping force of the exchange element

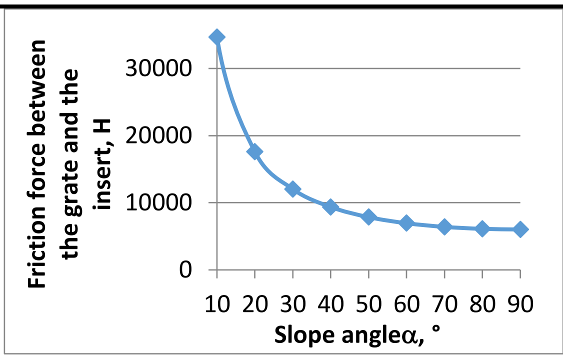

Figure 3. The angle of inclination of the carrier and the exchange element α the change in the dependence of the friction force R between the carrier and the exchange element

Analysis of Figure 4 and Equation (9) showed that the useful work coefficient η of the carrier compound of the interchangeable element depends mainly on the angular slope α of the carrier and the interchangeable element and the coefficient of friction *f*. When the angle of inclination of the carrier and the exchanging element increases from 10^0 to 90^0, the efficiency decreases from η 1.73 to 0. When α= 55^0, the efficiency is equal to η = 1.

When the interchangeable element (Fig. 5) moves from the input b_z=0 to the input b_z=*b* at a distance S_q=*b*, the inclined surface of the interchangeable element approaches in a vertical direction at a distance from the carrier S_w (Interchangeable element path).

For the calculation it is necessary to shift the exchange element placed in the structure of the carrier and the exchange element to S_q=*b*, where the wedge angle θ and the reliable path S_w are given. The S_w path is pre-calculated using the following formula:

$$S_w = \Delta_e + \frac{W}{J_к} + \frac{W}{J_в} + h_x, \quad (10)$$

where: Δ_e=0.0001м is the reliable clearance between the carrier and the replacement element for free installation of the carrier interchangeable element; h_x=0.0001 м is an additional path that takes into account the frictional wear on the surface of the carrier during long-term use; W/$J_к$ - carrier virginity ($J_к$=E·b·$h_к$/L= 883682008 N/м); W/$J_в$ is the virginity of the exchange element ($J_в$=E·b·h/L= 160669456 N/м). The following parameters are used in the calculation: E=$2 \cdot 10^{11}$ N/м^2, L=0.05975 м, b_z=b=0.012м, h=0.004 м, $h_к$=0.022 м [1].

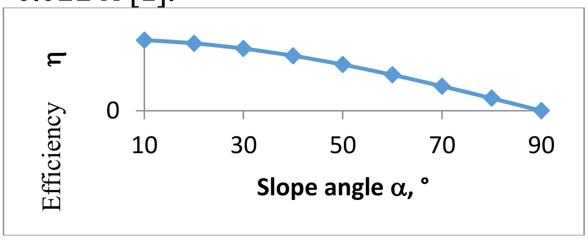

Figure 4. Variation of the angle of inclination of the carrier and the exchanging element α depending on the efficiency η

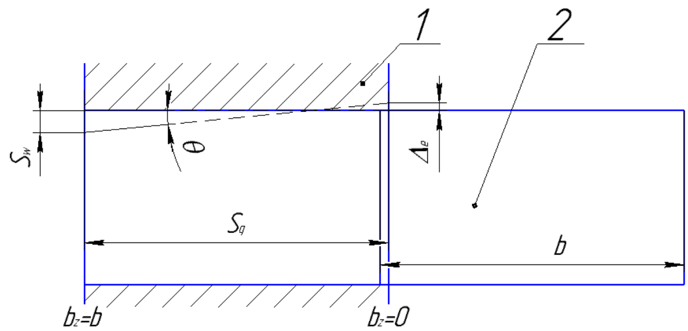

Figure 5. Computational scheme of displacement of the interchangeable element (2) on the carrier (1).

The analysis of the equation is shown in Figure 6, where the displacement of the alternating element S_w is directly proportional to the binding force of the alternating element W and the displacement of the alternating element decreases from 0.64 mm to 0.2 mm when ini = 60. while Sw = 0.25 mm.

Transfer element shift ratio [4]:

$$i = \frac{S_w}{S_q} = tg\theta$$

(11)

When the displacement S_q = b = 0.012 m, S_w = 0.0002458 m at α= 60^0, we calculate the relative deformation of the carrier:

$$\varepsilon = \frac{S_w}{S_q} = \frac{0.000245 м}{0.012 м} = 0.020404$$

(12)

If in the manufacture of the interchangeable element and the carrier the slope is θ view and the allowable deviation from the size for the displacement S_q and S_w is allowed, then we determine the angle of inclination θ from formula (11)

$$\theta = arctg\frac{S_w}{S_q} = arctg\,\varepsilon = arctg\frac{0.000245 м}{0.012 м} = arctg\,0.020404 = 1°10'$$

(13)

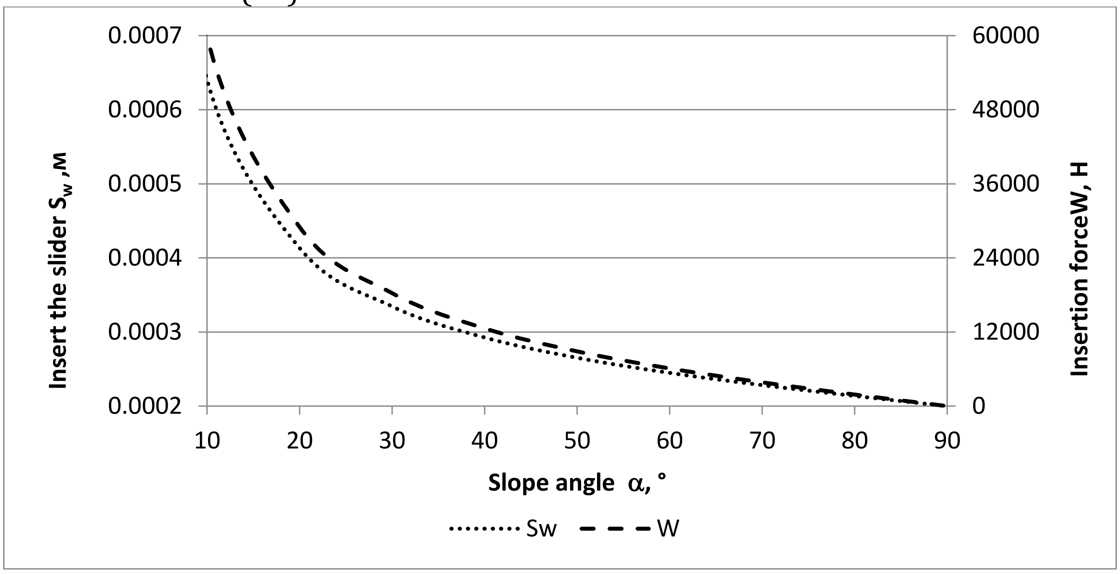

Figure 6. Vertical displacement of the interchangeable element S_W and the binding force of the interchangeable element W

The values of displacement Sq and Sw, angle of inclination θ and relative deformation ε of the carrier, should be set in the design of the carrier and interchangeable element.

Conclusion

Calculation of the strength of the carrier joint of the interchangeable element, the maximum force of fastening of the interchangeable element (4 mm thick) W = 59888 N, taking into account the angle of inclination of the carrier and the interchangeable element bo'lganda α= 60^0 when the friction force R = 6950.5 N and the effective working coefficient η = 0.6. allowed to determine.

In this case, the allowable preparation of the interchangeable element (4 mm thick) is S_W=0.245 mm and θ= 1°10′ (for W = 59888 N and R = 6950.5 N).

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