

BEHAVIOR OF THE TRANSFER OBJECT ON THE DYNAMIC LOADS DURING THE WORKING PROCESS

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ABSTRACT: This scientific paper presents studies and researches in the field of nonconventional technologies, namely in the field of electrical erosion processing with transfer object the metal band. The paper presents the dimensioning elements of transfer object - metallic band, as well as its resistance calculations, to the stresses on the linear part 1-2, as well as to the complex bending stresses of the metal band. It also shows the behavior of the weld seam joint (tilted) to traction and shear, as well as the computation relations corresponding to the lateral buckling load and the welded joint.

KEYWORDS: the structural strapping elements of the metal band, the dynamic stress behavior, the resistance calculation for complex loads and the lateral buckling of the transfer object - the metal band, the behavior of the welded joint (end-to-end), traction and shearing, appropriate calculation relationships.

1. THE BEHAVIOR OF TRANSFER OBJECT - THE METAL BAND DURING THE CUTTING PROCESS THROUGH ELECTRIC EROSION WITH CONTACT BREAKING

The transfer object - the metal band, under analysis, replaces the electric erosion with contact breaking, the metal disc, with the metallic disc presenting itself in work, its behavior with the dynamic stresses existing during the process debiting [1], [2].

In the case of cutting operation through electric erosion with contact breaking, one of the most essential factors with direct influence on transfer object is the diameter of the work wheels (D), within the experimental stand drive system, which determines together with other factors the geometrical dimensions of the metal band [3], [4], [5], [6], [7], [8].

Concerning the behavior of the metal band during the cutting process at mechanical stresses and fatigue efforts, it was envisaged to choose those materials that are compatible both in terms of construction (design, construction, assembly) and exploitation, with particular regard to it;

- Technological conditions;
- The constructive design adopted;
- working conditions;
- Physical and mechanical properties of the material (determined by chemical composition and processing).

1.1 Sizing elements of transfer object - Metal band

1.1.1 Metal band

It has the form of a "narrow strip of cold rolled carbon steel" (according to STAS 1945-90) whose constructional elements are shown in Figure 1; the ends can be joined by various non-removable joints, resulting in a closed contour.

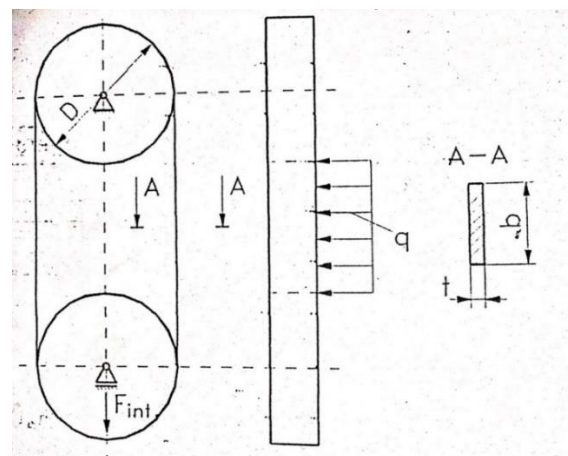


Figure 1. The components of the transfer object.

1.1.2 The extended length of the metal band (L)

It has been set to ensure the possibility of mounting and extending it on the steering wheels, using for this purpose the relationship:

$$L = 2A + \frac{D}{2} + C \quad [mm] \quad (1)$$

Where: C - the metal band length compensation factor, having a value comprised between (2 ... 4) [mm].

$$C = c_1 + c_2 \quad (2)$$

1.2 Factors and criteria are taken into consideration when designing the metal band

The transfer object dimensions were determined considering the following factors:

- characteristics of the processing machine / experimental stand:
 - D – the diameter of the steering wheels [mm];
 - A_{max} - the maximum distance between the horizontal axes of the steering wheels, [mm];
- constructive form of the processing equipment / experimental stand;
- the size of the object of processing (OP);
- geometrical elements of transfer object regarding:
 - L - the length of the transfer object, [mm];
 - b - the width of the metal strip, [mm];
 - t - Thickness of the metal strip, [mm].

The width (b) and the thickness (t) of the metal band. These have been set according to the following criteria:

- technology;
- resistance calculation of transfer object;
- transfer object section;
- constructive;
- work wheel diameter;
- working regime parameters;
- economy.

It has been taken into account that during the working process, the metal band (transfer object) is subjected to complex loads (stretching, bending, lateral buckling, torsion, etc.).

2. RESISTANCE CALCULATION FOR TRANSFER OBJECT - METAL BAND

During the electric erosion with contact breaking process, the transfer object has a continuous motion and is required both the contact pressure (p) and the complex stresses (stretching and bending), therefore being subjected:

- Complex loads (stretching and bending) on linear 1-2, according to Figure 2.

For the stresses appearing on the linear 1-2 part, the account was taken of the effect of the contact pressure (p) and the tensile force (F_{int}).

The maximum voltage that arises in transfer object - the metal band, (σ) linear it is the algebraic sum of tensile stress (σ_t) and bending stress (σ_i);

$$\sigma = \sigma_t + \sigma_i \quad (3)$$

Transfer object stresses are determined by the bending of the contact pressure (p) at which the transfer object is considered a simple beam is resting on the winding cylinder contact generators, which in case of transfer object. Lateral buckling is considered to be a beam with side guides (c).

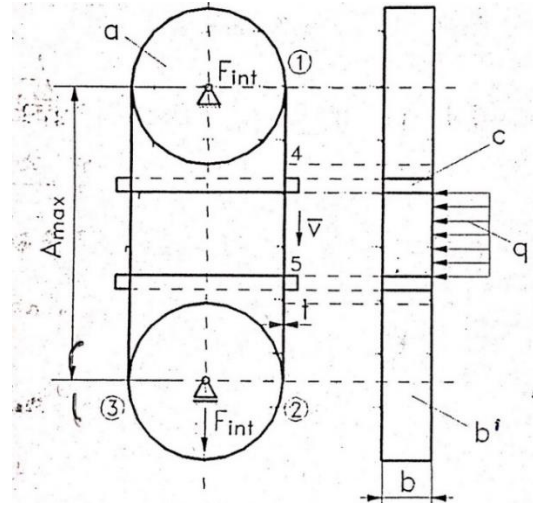


Figure 2. Stresses in linear position 1-2 of transfer object.

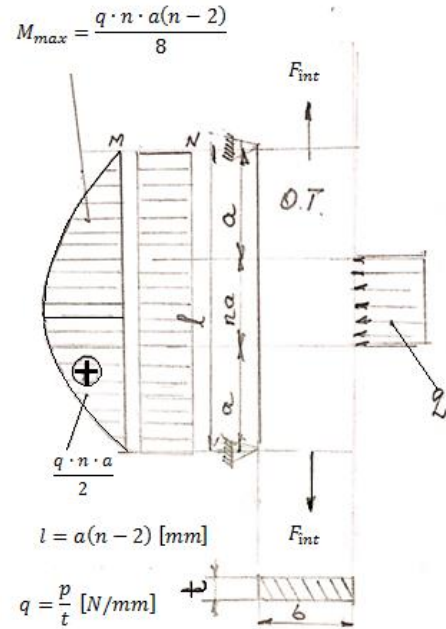


Figure 3. Stresses in linear position 1-2 of transfer object.

The charging scheme and load diagrams are shown in Figure 3. Eroare! Fără sursă de referință., and the calculation relationships are:

$$V_1 = \frac{q \cdot n \cdot a \frac{a(n+2)}{2}}{a(n+2)} = \frac{q \cdot n \cdot a}{2} \quad (4)$$

$$M_{max} = V_1 \frac{1}{2} - V_1 \frac{1}{4} = \frac{q \cdot n \cdot a}{2} \left[\frac{a(n-2)}{2} \right] - \frac{q \cdot n \cdot a}{2} \left[\frac{a(n+2)}{4} \right] = \frac{q \cdot n \cdot a^2 (n-2)}{8} \quad (5)$$

The two categories of normal tension (stretching and bending) are given by relationships:

For the normal tension we will have:

$$\sigma_t = \frac{N}{A} = \frac{F_{int}}{A} \quad (6)$$

moreover, for normal bending stress:

$$\sigma_i = \frac{M_{max}}{W_z} \quad (7)$$

where:

$$W_z = \frac{t \cdot b^2}{6} \text{ (Modulus of axial resistance)} \quad (8)$$

Substituting we have:

$$\sigma_i = \frac{[q \cdot n \cdot a^2 (n-2)]6}{8 \cdot t \cdot b^2} = \frac{3q \cdot n \cdot a^2 (n-2)}{4 \cdot t \cdot b^2} \quad (9)$$

- Complex loads at lateral buckling of transfer object.

The lateral buckling of the transfer object is manifested by a lateral bend around the O_y axis, accompanied by a torsion, according to Figure 4.

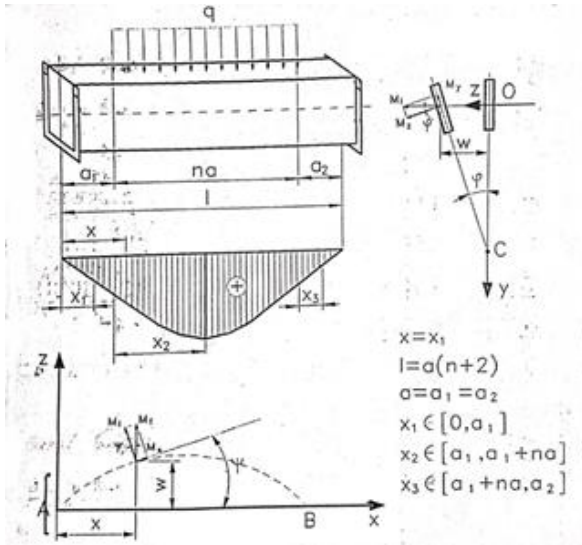


Figure 4. Transfer object lateral buckling

Due to the metal band stiffness EI_y used as transfer object is very small, it presents the danger of lateral buckling thus: $V_1 = \frac{q \cdot n \cdot a}{2}$.

$$M_{x_1} = V_1 \cdot X_1 \quad (10)$$

we will have the relations:

$$M_{x_2} = V_1(x_2 + a_1) - \frac{qx_2^2}{2} \quad (11)$$

$$M_{x_3} = V_1(a_1 + na + x_3) - q \cdot n \cdot a \left(\frac{n \cdot a}{2} + x_3 \right) \quad (12)$$

The lateral buckling of the transfer object is manifested laterally by a lateral bend around the O_y Axis with its torsion, buckling due to the increase in the contact pressure (p), which may, at some point, reach a critical value (p_f). In the flame state, any cross-section of transfer object (included between the guide axes), expressed by the distance l, moves in the plane xAz with the arrow w and rotates with the angle φ .

Deformations of buckling correspond to the moment of bending M_{iy} moreover, the torque M_t , where:

$$M_{iy} \cong M_f \cdot \varphi$$

$$M_{iz} \cong M_f \quad - \text{bending moments;}$$

$$M_t = M_x \cong M_f \cdot \psi - \text{Moment of torsion.}$$

If any section moves in the horizontal plane with the distance w, and the bending stiffness module from the axis O_y is EI_y , then the equation of the approximate differential equation of the average deformed fiber in this plane becomes:

$$\frac{d^2 w}{dx^2} \cong \frac{M_{iy}}{EI_y} = - \frac{M_f}{EI_y} \cdot \varphi \quad (13)$$

If any section rotates with the torsion angle φ , and the modulus of torsional stiffness of the cross section is GI_t , then the specific torsion angle will have the expression:

$$\frac{d\psi}{dx} = \frac{M_t}{GI_t} = \frac{M_f}{GI_t} \cdot \psi \quad (14)$$

Determination of critical buckling load p_f , is based on the following equation system:

$$\frac{d^2 w}{dx^2} \cong \frac{M_{iy}}{EI_y} = - \frac{M_f}{EI_y} \cdot \varphi \quad (15)$$

$$\frac{d\psi}{dx} = \frac{M_t}{GI_t} = \frac{M_f}{GI_t} \cdot \psi$$

Taking into account the geometric relationship: $\psi \cong \frac{dw}{dx}$. By eliminating the unknowns ψ and w from the equation system, the lateral buckling of the transfer object is reduced to solving the differential equation:

$$\frac{d^2 y}{dx^2} - \frac{1}{M_f} \cdot \frac{dM_f}{dx} \cdot \frac{dy}{dx} + \frac{M_f^2}{EI_y GI_t} \cdot \varphi = 0 \quad (16)$$

NOTE: The equation can be integrated only for certain particular loading states of the transfer object, and the solution will be done for each concrete case of load and bearing.

In the analyzed case, considering the transfer object like a fork bar, at the ends (on the guides), with an evenly distributed force, Figure 5, applied to the height of the average deformed fiber we will have:

In this case, the calculation relations become:

$$I_y = \frac{b \cdot t^3}{12} \quad (17)$$

$$I_t = \frac{b \cdot t^3}{3} \quad (18)$$

The bending and torsion stiffness module will have values:

$$E = 2,1 \cdot 10^4 \text{ MPa}$$

$$G = 0,385 \cdot E = 0,385 \cdot 2,1 \cdot 10^4$$

$$l = n \cdot a$$

$$q_{max} = \frac{28,3}{n^3 \cdot a^3} \sqrt{2,1 \cdot 10^4 \cdot \frac{bt^3}{12} \cdot 0,385 \cdot 2,1 \cdot 10^4 \cdot \frac{bt^3}{3}} \quad (19)$$

For: $t = 1,0$ [mm]; $b = 50$ [mm]; $a = 50$ [mm] and $n = 10^3$

We have; $q_{max} = 1,3$ [N/mm].

For: $q = \frac{p}{t}$; and $p = t \cdot q$

$q_{max} \leq 1,3$ MPa; $p = 1,3$ MPa.

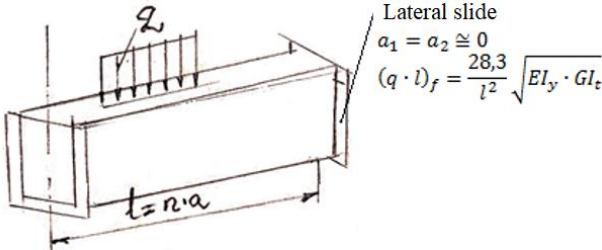


Figure 5. Distribution of contact pressure on TRANSFER OBJECT, (q)

Finding:

- Alternatively, the usual dimensions (b, t) of transfer object and for values n and a, depending on the dimensions P.O, very low values will be obtained.
- To eliminate the danger of lateral buckling was followed as normal tension (σ), which originated in transfer object, have positive values at any point;

$$\sigma = \sigma_i - \sigma_t \quad (20)$$

Thus, for $\sigma_a = 70$ MPa; and for $\sigma_i = \frac{M_{max}}{W_z}$; $\sigma_t = \frac{N}{A} = \frac{F_{int}}{t \cdot b}$; we have:

$$\frac{M_{max}}{W_z} - \frac{F_{int}}{A} \leq \sigma_a \quad (21)$$

moreover, replacing, for $q = 5/N \cdot mm$, we have: $F_{int} = 11$ KN.

- in the case of the winding-to-run cycle (transfer object) - the metal band on the drive wheels, it is subjected to a variable duty cycle, which is why the value of the safety coefficient of the produced output is intended to be higher than those prescribed in some specialized works.
- Taking into account the SODERBERG, SERENSEN, and BUZDUGAN criteria, the calculation relation corresponding to the symmetric alternating stress domain for the safety coefficient, the calculus relation used, takes the form:

$$C_\sigma = \frac{\sigma - 1}{\frac{K_\sigma}{\xi \cdot \gamma} \sigma_a + \psi \cdot \sigma_m} \quad (22)$$

where:

ξ – dimensional factor;

γ – surface quality factor;

K_σ – effective concentration coefficient.

$$\sigma_m = \frac{\sigma_{min} + \sigma_{max}}{2} \quad (23)$$

- Safety Coefficient Values (C_σ), and also be determined experimentally, and the values obtained to satisfy the conditions of some papers in the literature.

3. BEHAVIOR OF THE WELDED END-TRANSFER OBJECT -HEAD JOINT, TENSILE, AND SHEAR

The welded joint can be of equal strength if it is inclined with the angle φ , this being required at traction (N) and shear (T), according to Figure 6 (a and b).

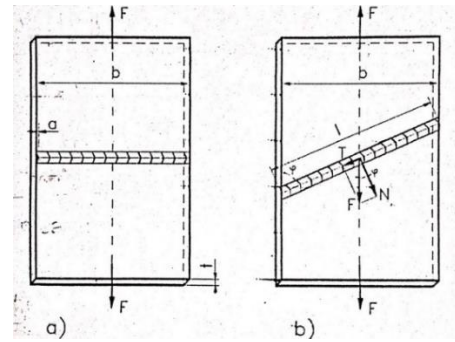


Figure 6. Traction request of welded joints

where:

$$N = F \cdot \cos\varphi \quad (24)$$

$$T = F \cdot \sin\varphi \quad (25)$$

The equivalent tension for the compound request is:

$$\sigma_{ech} = \sqrt{\sigma_N^2 + \sigma_T^2 - \sigma_N \cdot \sigma_T + 3\tau_T^2} \leq \sigma_{as} \quad (26)$$

$$\sigma_N = \frac{F \cdot \sin^2\varphi}{b \cdot t} \quad (27)$$

alternatively:

$$\sigma_N = \frac{N}{l \cdot a} = \frac{F \cdot \cos\varphi}{\frac{b}{\cos\varphi} \cdot t} \quad (28)$$

$$\tau_T = \frac{F \cdot \sin\varphi \cdot \cos\varphi}{b \cdot t} \quad (29)$$

If it is shared with the welding resistance reduction coefficients, then it can be compared with σ_{as} , where: $\alpha_1 = 0,8$ and $\alpha_2 = 1,0$.

By replacing the expressions of tension in the previous expression, it is obtained:

$$\sigma_{ech} = \frac{F}{b \cdot t}; f(\varphi) \leq \sigma_a \quad (30)$$

which for $f(\varphi) = 1$ becomes: $\sigma_{ech} = \frac{F}{b \cdot t} \leq \sigma_a$ (31)

For different values of φ , the value of the function is given in Table 1.

No.	φ $f_{(\varphi)}$	Values for the joint angle						
		0°	20°	30°	40°	45°	60°	90°
0	1	2	3	4	5	6	7	8
1	$f_{(\varphi)}$	1,176	1,134	1,089	1,044	1,028	0,994	1,000

Table 1. Values for the joint angle

So for $\varphi = 45^\circ$ and $f_{(\varphi)} = 1$, the joint is of equal strength. For compression loads of the welded joint, the welding has the same strength as the base metal (B.M.), because: $\sigma_{as} = \sigma_a$ și $\alpha = 1$.

Butt weld inclined has the advantage that the welding tension concentrator does not appear in a single cross-section, and the fatigue resistance of the metal strip is influenced by its thickness.

4. CONCLUSIONS

The research on the behavior of the transfer object at the complex stresses (stretching and bending), on the linear part 1-2, and determined the following findings:

- during the transfer object processing/cutting process is required at stretching and bending on the linear portion 1-2, these being generated by the contact pressure (p) and the tensile force (F_{int});
- the lateral buckling deformations of transfer object correspond to the two categories of moments: bending (M_{iy}); of torsion (M_t);
- lateral buckling is influenced by the stiffness level (EI_y) of the metal band and is manifested by a lateral bend of the transfer object, around the axis O_y , accompanied by a torsion;
- to highlight the demands in lateral buckling behavior analysis, transfer object - metal band, was considered a beam with side guides (c);
- determining the critical buckling load (p_f) was based on the use of a system of equations, which by eliminating the unknowns (ψ și w) from this system, facilitates the solution, a system that reduces to solving a differential equation for a specific case of application and support;
- in the case of the winding-deployment cycle of the metal strip on the drive wheels, to determine the value of the safety coefficient of the product load (C_σ), the criteria SODERBERG, SERENSEN, and BUZDUGAN were considered;
- safety coefficient values (C_σ), results, meet the conditions mentioned in some works in the field of processing by nonconventional technologies;
- Butt welding inclined has the advantage that the welding tension concentrator does not appear in a single cross section;

- it was found that the fatigue resistance of the metal band was influenced by its thickness.

At 0.5 mm thick it had a better operating life (approx. 30%) than metal bands with thicknesses greater than 0.5 mm.

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