MONITORING OF THE BORING TRAJECTORY IN UNDERGROUND CHANNEL

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Abstract: This paper deals with high precision directional boring of underground conduits, including programmable curved trajectories for enclosed digging driving communications and other purposes.

Keywords: underground channel, dynamic monitoring, driving communisations.

1. INTRODUCTION: As the working tool for boring in soft anisotropic soils a cone is modeled, which is imparted a revolving motion whose angular velocity is ω_{pr}, its impact frequency f. The impact makes the revolving cone penetrate into the soil along the screw trajectory. The cone thus revolves around its symmetry axis OO_1 with angular velocity ω_κ

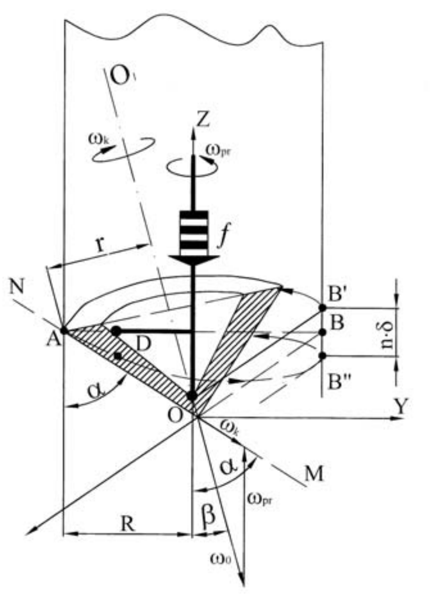

Fig. 1

(Fig. 1) in such a way that the above axis OO_1 itself oscillates eccentrically around O_Z at an angular velocity ω_0 at an angle β.

Acted on by various factors the conditions of oscillating motion of the OO_1 axis can change

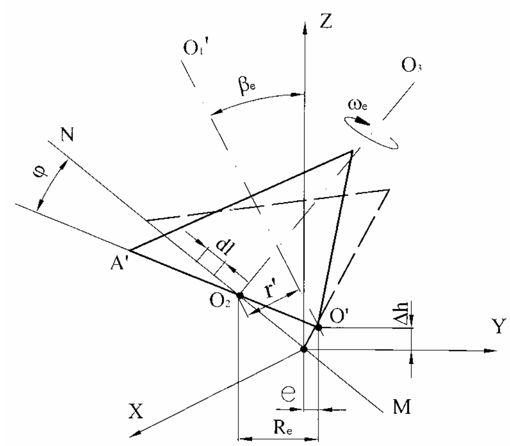

Fig. 2

in such a way that the apex of the cone is displaced from the axis of the O_Z, relative to the tunnel centerline and takes part in oscillating motion as well, its parameters being e and Δh to O_Z axis (Fig. 2). Here, the cone slips and performs friction work while its constituent OA is displaced from NM line during its turn at some angle φ to O_2 and O_3 at an angular velocity ω_e.

The above parameters of this motion are found following the calculation of the location of point O_2, based on the principle of the least action. With uniform distribution of the normal force longitudinal to the generating line of OA, the elementary work of the friction force F on the element $d\ell$ will be

$$dA = F \cdot V \cdot d\ell ,$$

where $V = \omega_\varepsilon \cdot S$ = the linear rate of $d\ell$ element, and S = the distance of $d\ell$ element up to NM.

The total work of the friction forces is

$$A = \frac{F}{2} \cdot \omega_e \cdot \frac{\cos\beta \cdot \sin\varphi}{\sin(\beta - \alpha)} \cdot \left[(L - \ell)^2 + \ell^2 \right].$$

The minimum of the function A will be at $\frac{dA}{d\ell}$=0 or with $\ell = \frac{L}{2}$, where L=OA, i. e. when the cone constituent slips along the tunnel boring face relative to point O_2 located in the middle of cone assembly.

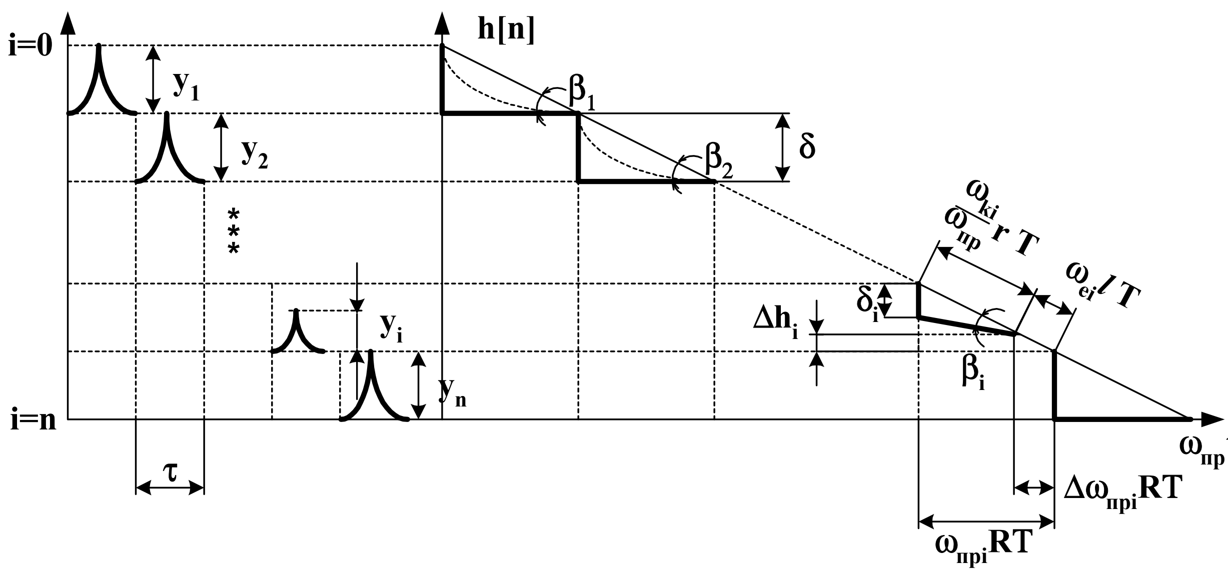

Fig. 3

The slip appearance will make point A shift from the screw line B'AB". The coordinates of point A can be derived as

$$x = (R - e) \cdot \cos\omega_{pr} t ;$$
$$x = (R - e) \cdot \sin\omega_{pr} t ; \qquad z = n \cdot \delta,$$

where n = number of impacts, δ = penetration in a direction of operation of impacts; the R-e value is found from

$$R - e = \frac{\omega_k}{\omega_{pr}} \cdot r ,$$

where r is the greatest cone diameter.

Thus, dynamic monitoring of the trajectory of a working cone motion is carried out by means of defining angular velocities ω_e, ω_{pr} and analysis of the amplitude readings of impacts. These indications can be used to control the directed cone motion. The shift value, e, at every turn can change with varying ω_{pr} and redistributing the number of impacts around the face perimeter.

When boring the tunnel in a uniform medium e is a constant. In a particular case, if e=0, the motion parameter relation is observed

$$h[n] = \frac{\omega_{\kappa} \cdot r}{\omega_{pr}} \cdot \sin\beta, \qquad (1)$$

Where h[n] is the boring length in the preset direction within n impacts, where $h=n\delta$, and β is the angle of screw line inclination. Figure 3 shows the plane projection of a screw line for a turn.

The impact of duration τ=T and amplitude y causes line B'AB" to be formed, which consists of curved portions of separate tunneling for every impact, thus resulting in screw line inclination at angle β.

If the medium is non-uniform, the parameter relationship in equation (1) is violated. Thus, in Figure 3 at the i-th stage the impact amplitude $y_i \ll y_n$, the impact duration $\tau_i < T$, but Δh_i decreases $\delta_i < \delta$, the angle $\beta_i < \beta$ changes and there appears eccentricity e_i. All the above can result in trajectory deviation due to variation of dynamic properties of the tunneling process.

To correct this deviation operatively one must have a self-adjusting system of automatic controlling of the direction, which is effective if the anisotropy of the medium acts weakly. The system shown figure 4 has as a source of data gauge 1 of the amplitude of impact, gauge 2 of angular velocity of the turning cone ω_{κ}, gauge 3 of the angle of drive rotation velocity, a discrete correlator, a controlled filter, and an adaptive regulator. To find the dynamic properties of the system consisting of a drive feeding set, and a penetrating cone with a striker, a pulse transient function as a sequences of coordinates is synthesized in a controlled filter as:

$$W_0 = W(0)\,,\ W_1 = W(\tau)\,,\ W_2 = W(2\cdot\tau)\,,$$
$$W_n = W(n\cdot\tau).$$

These values enter the RAM on OS_1…..OS_n.

Calibration values ω^*_0–ω^*_n are recorded on OS^*_1 to OS^*_n to store the programmable trajectory into ROM.

On the delay line a periodic signal is put from the input unit, which is proportional to the centered correlation input – output function. Thus, the following expression is obtained on the adder output:

$$K^{*0}_{xy}(\tau) = T_m \cdot \sum_{i=0}^{n} W(i\cdot T_m)\cdot K^0_y\cdot(\tau - iT_m)\,.$$

The difference is put to the comparator:

$$\varepsilon = K^{0*}_{xy}(\tau) - K^0_{xy}(\tau),$$

By adjusting the coefficients this difference can be minimized. Extreme regulators are used to make the process of impact function estimate automatic.

2.0 CONCLUSIONS:

Thus, the procedure of trajectory monitoring envisages a complete analysis of dynamic system properties taking into account stochastic character of effect. This control method uses intensifying impact effects for probing anisotropic properties at the face and controlling the process of direction correction.

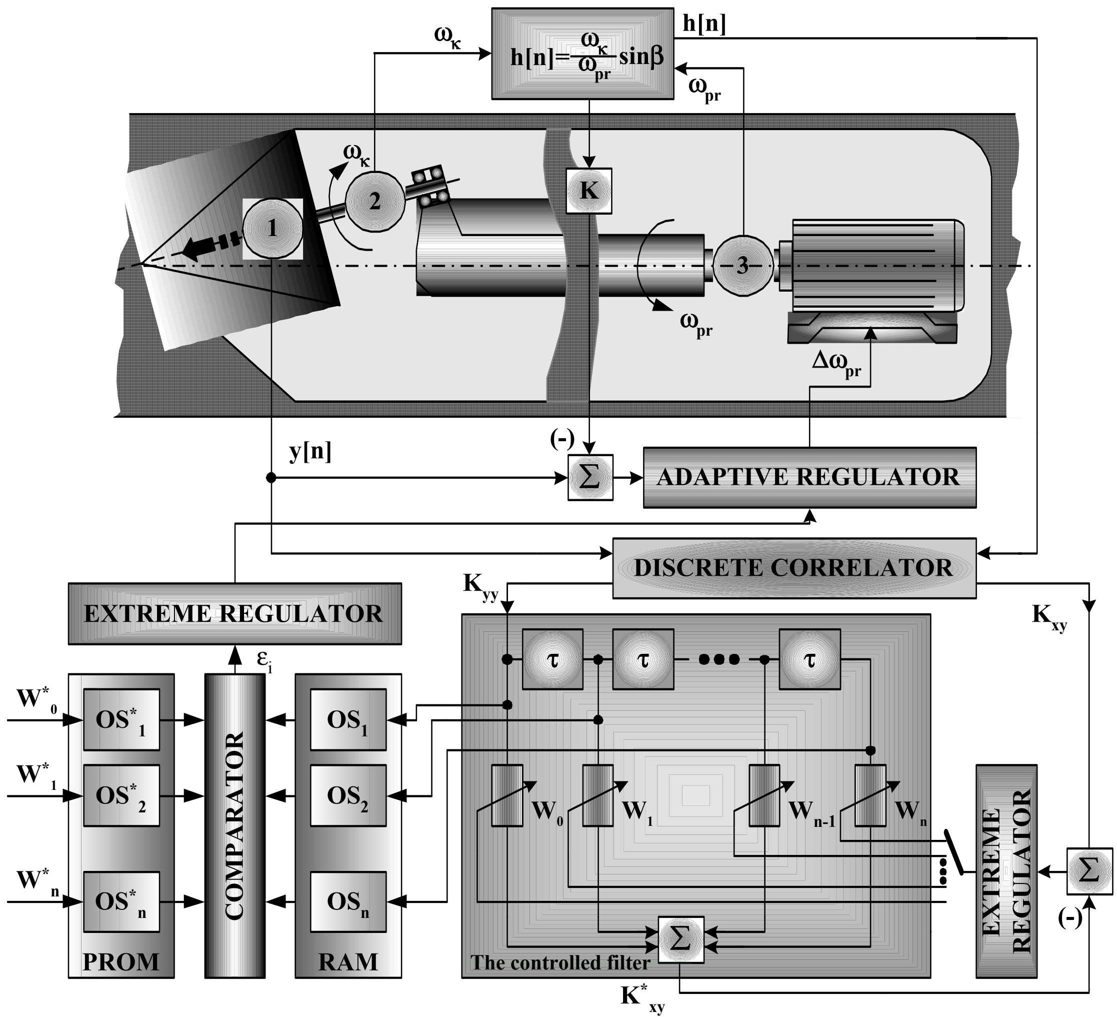
h[n]
ωκ
$h[n]=\frac{\omega_\kappa}{\omega_{pr}}\sin\beta$
ωpr
2
1
K
3
Δωpr
y[n]
(-)
Σ
ADAPTIVE REGULATOR
DISCRETE CORRELATOR
EXTREME REGULATOR
Kyy
Kxy
εi
W*0
W*1
W*n
OS*1
OS*2
OS*n
PROM
COMPARATOR
OS1
OS2
OSn
RAM
τ
W0
W1
Wn-1
Wn
The controlled filter
EXTREME REGULATOR
K*xy

Fig. 4