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MUD PUMPING EQUIPMENT ATTACHED TO EXCAVATOR ARM

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ABSTRACT

This study presents a mud pumping equipment that can be attached to the excavator arm. This equipment can solve ecological issues in narrow spaces, in areas where access is limited as well as during floods. Tthe technological constructive designing for this type of equipment may be considered by extension as diversity of equipments that can be attached to the excavator arm.

KEYWORD**:** excavator equipment, mud pump, mode simulation

1. INTRODUCTION

There are multiple constructive solutions for dredging equipments that may be attached to various machines.

In Figure 1.a and Figure 1.b are presented photos of some immersion pumps attached to crane boom.

Fig.1a

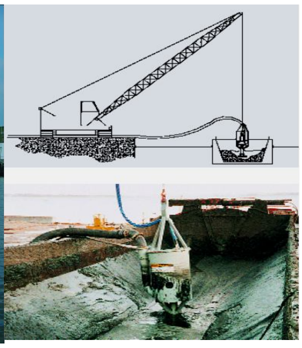

Fig.1b

In Figure 2a and Figure 2b on an excavator pontoon, DOP pump is mounted. This is actually an equipment for environment dredging operations.

There were different pumping pieces of equipment designed independently, but there wasn’t any project for a mud pump attachable arm of navy excavators.

Fig.2a

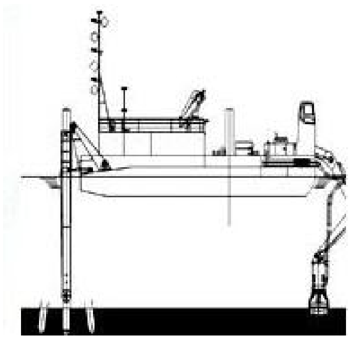

Fig.2b

2. MUD PUMPING EQUIPMENT ATTACHED TO THE EXCAVATOR ARM

In Fig.3, is presented in “3D” the new type of mud pumping equipment attached to the excavator arm:

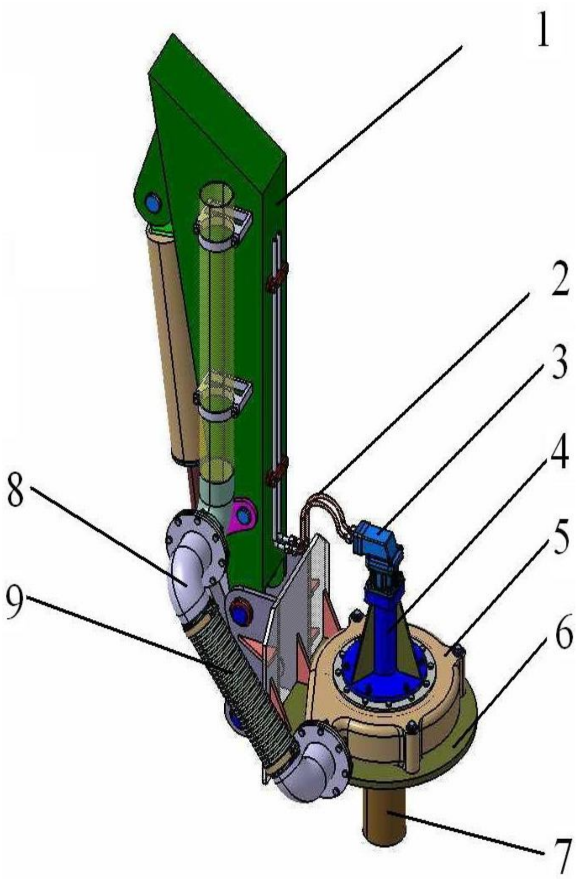

Fig 3. “3D” modelling of the mud pump

The mud is vacuumed through piping 7 due to the vacuum created by a special designed pump 5, positioned on bearing 4 and holder 6. The movement of pump rotor is caused by the rotary hydraulic motor 3. This is fed with hydraulic pressure through hoses connected to the hydraulic installation of the excavator. Discharging of mud is made through hose 9 and piping 8, in other location. The assembly is mounted on the excavator arm (1).

Technological parameters of these mud pumping equipments are :

1.drum’s diameter : D = 380 mm ;
2.drum’s height : H = 120 mm;
3.drum’s rotary speed : n = 1240 rot/min ;
4.density of solid phase : $\rho_s = 2,2 * 10^3$ kg/m^3;
5.density of liquid phase : $\rho_l = 1000$ kg/m^3 ;
6.concentration of solid phase in suspension : $\Psi = 40$ % ;
7.final humidity of sediment : $\mu_f = 36$ % ;
8.drum’s construction material :stainless steel

Checking and sizing calculations were made in order to define the pumps parameters.

3. TECHNOLOGICAL CALCULATION AND DETERMINATION OF DRUM’S WALL THICKNESS

3.1. DRUM’S GEOMETRY

Drum‘s working volume is given by equation (1)

$V_u = K_u * V_t$
V_u = working volume [m^3];
V_t = total volume [m^3];
K_u = coefficient of admission;
$K_u = 0,5 \div 0,7$

$$V_t = \frac{\pi * D_2^2 * H}{4} \qquad (1)$$

D_2 = drum’s diameter;
H = drum’s height;

$$D_{22} = D_2 * \sqrt{1 - K_s * \psi} \qquad (2)$$

Ψ =drum’s suspension admission coefficient

$$\psi = 1 - (\frac{D_{22}}{D_2})^2 \qquad (3)$$

K_s = volume share in solid phase;
ρ_{s1} = suspension’s density, [kg/m^3];
ρ_s^* = average density of sediment layer thickness, [kg/m^3];
ρ_l^* = average density of liquid layer thickness, [kg/m^3]

$$K_s = \frac{\rho_{s1} - \rho_l^*}{\rho_s^* - \rho_l^*} \qquad (4)$$

$$\rho_{s1} = \rho_d * f + (1 - f) * \rho_c \qquad (5)$$

$$\rho_s^* = (1 + u) * (1 - n_p) * \rho_s$$
$$\rho_l^* = (1 + u) * (1 - n_p) * \rho_l \qquad (6)$$

$\rho_d = \rho_s$ -solid phase density;
$\rho_c = \rho_l$ - liquid phase density;
$\psi = \varphi$ - solid phase concentration in suspension
n_p = porosity
$n_p = 0,1 \div 0,3$
$u = \mu_f$ =final humidity of sediment
$u = 0,36$

3.2. MATHEMATICAL CHECKING

$$\rho_s^{**} = (1 - n_p) * \rho_s + n_p * \rho_l \qquad (7)$$
$$\rho_s > \rho_s^* < \rho_s^{**}$$

P_0 = relative pressure of 2 phases

$$P_0 = \frac{4 * P_s}{D_2^2 - D_{22}^2} \quad (8)$$

where
D^* = circumference diameter specific of mass point of relative pressure parabola distributed on the cover or on flat bottom

P_1= longitudinal force that drives the cover and drum’s bottom
P_s = charge agent pressure

$$P_s = \frac{D_2^2 * \omega^2}{12} * \left\{ \begin{array}{l} \rho_s^* \left[1 - \left(1 - K_s^* * \psi \right)^{3/2} \right] + \\ + \rho_l^* \left[(1 - K_s * \psi)^{3/2} - (1 - \psi)^{3/2} \right] \end{array} \right\} \quad (9)$$

3.3. INITIAL CALCULATION OF POWER REQUIRED TO DRIVE THE DRUM

Calculation of start up power

D_1 – inner diameter of cover

D_1 =300[mm]

$$\omega = \frac{\pi * n}{30} = [rot / s] \quad (10)$$

$$N_p = N_1 + N_2 + N_3 + N_4 \quad (11)$$

$$N_1 = \frac{DE}{t_s} [kW] \quad (12)$$

N_1 - power required to bring the drum at the operating rotary speed;

$$N_2 = \frac{\sum DE}{t_s} [kW] \quad (13)$$

$$N_3 = 2 * F_i * w_i [kW] \quad (14)$$

N_3 - power required to overcome the bearings friction

$$N_4 = 11{,}3 * 10^{-3} * \rho_a * g * L * \omega^3 (Re^4 + R_{22}^4) [kW] \quad (15)$$

N_4 - power required to overcome the air friction;

$$DE = j * \left(\omega_2^2 - \omega_1^2 \right) \quad (16)$$

- energy that has to be provided to the rotor;

$$\omega_1 = 0, \omega_2 = 2{,}16 [rot / s] \quad (17)$$

$$j = \frac{m * (R_1^2 + R_2^2)}{2} \left[kg * m^2 / s^2 \right] \quad (18)$$

Inertia Moment of the assembly that is rotating against its axle

$$m = \rho * \pi (R_2^2 - R_1^2) * L [kg] \quad (19)$$

m - drum‘s mass
L= *H* – drum’s height

$$R_1 = \frac{D_2}{2} \quad (20)$$
- drum’s inner radius;

$$R_2 = \frac{D_2 + h_2}{2} \quad (21)$$
-drum’s outer radius

ρ - steel density,

ρ_{ol} =7800 kg/m^3;

t_s – time necessary to bring the drum at the operating rotary speed
(centrifuge duration = 0,5 min)

$$N_3 = 2 * F_i * w_i [kW] \quad (22)$$

$$F_i = f_l * P_d \quad (23)$$

f_l = 0,01 – bearing friction factor;

$$P_d = m_r * (1 + 2 * 10^{-3} * \Phi) * g \quad (24)$$
- dynamic force

$$m_r = m_t + 2 * m_c \quad (25)$$
- rotor’s mass

$$m_t = (D_{n2}^2 - D_2^2) * \frac{\pi}{4} * \rho_{OL} * H \quad (26)$$

- drum’s mass

$$m_c = (D_{n_2}^2 - D_1^2) * \frac{\pi}{4} * \rho_{OL} * h_1 \quad (27)$$
- cover mass

$$w_i = \omega * \frac{d_f}{2} [rot / s] \quad (28)$$
- drum’s circumferential speed during cutting

d_f – journal neck diameter
d_f = 100 mm = 0,1 m

- air density

$$N_p = N_1 + N_3 + N_4 [kW] \quad (29)$$

3.4. ROTOR'S STRENGTH CALCULATION

Initial sizing of rotor's shaft at torsion

$$\sigma_{ech} = \frac{M_{ech}}{W_i} \leq \sigma_a \quad (30)$$

$$M_{ech} = M_t = 9{,}55 * 10^6 * \frac{N}{n}[N * mm] \quad (31)$$

M_t – torsion moment [N*mm];
N – motor's power [kW];
n – motor's rotative speed [rot/min];

$$W_i = \frac{\pi * d^3}{16}$$ -moment of polar resistance [N*mm]; (32)

$$d = \sqrt[3]{\frac{16 M_t}{\pi * \sigma_a}} \quad (33)$$

σ_a - permissible working stress [N/mm^2],

The shaft with nominal diameter is selected from standard dn

Shaft material: stainless steel.

$$F_c = m_t * r * \omega^2 [N]$$
$$m_t = m_r + m_{am} [kg] \quad (34)$$

m_r = rotor's mass [kg],
m_{am} = mixture's mass [kg];
$m_{am} = m_{solid} + m_{lichid}$

$$r = \frac{D_2}{2}[m]$$
$$\omega = \frac{\pi \cdot n}{30} \quad (35)$$

3.5. ROTOR'S HARDNESS CALCULATION

Calculation of shaft's critical rotative speed

$$\frac{1}{n_{cr}^2} = \frac{1}{n_a^2} + \frac{1}{n^2}$$

$n_a = 1{,}595 \cdot K_1 \sqrt{\frac{E \cdot I}{G_a \cdot l_{c1}}}$ - critical rotative speed of the shaft considered with its own mass (36)

$n = \frac{3}{\pi}\sqrt{\frac{g}{f}} \cong \frac{30}{f}$ - Critical rotative speed of the shaft considered without its own weight but with weight of centrifuge (37)

$f = \frac{G_a \cdot l^3}{3E \cdot E}$ - shaft chamber (38)

K_1 –coefficient (580÷620)
l –shaft lenght
$l = l_1 + l_2$ = mm
d – shaft diameter
d = 30 mm =0,03 m

$G_a = \frac{\pi \cdot d^2}{4} \cdot l \cdot \rho_{OL} \cdot g$ shaft weight (39)

$I = \frac{\pi d^4}{64}$ - inertia moment (40)

E – longitudinal elasticity module of the shaft's material
$l_{c1} = l_1$
l_2=v selected constructive value

4.CONCLUSION

The special equipment for mud pumping attached to the excavator arm shall contribute to greening of environment for

- removal of mud from narrow spaces and areas with restricted access;
- dredging of inland waterways collection channels and technological sewage collection channels
- removal of mud during floods;
- cleaning of barges.

Advertising for new type of equipment that helps the constructions companies to improve quality of execution and reliability may lead to extension of equipping for many excavators.

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