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Effects of Vibration Absorbers on the Longitudinal Vibration of a Pipe String in the Deep Sea — Part 1: In Case of Mining Cobalt Crust

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ABSTRACT

In order to reduce the longitudinal vibration of the pipe string for mining the cobalt crust at the bottom of the deep sea, a vibration absorber, which was composed of a mass, springs and dampers, was attached to the pump module as well as the buffer. Then, the effect of the absorber on the vibration was analyzed theoretically. The results indicate that the above-mentioned absorber attached to the buffer can reduce the resonance amplitudes of the buffer and pump module to almost 40% values and that larger mass of the absorber reduces those amplitudes more within the range where the mass ratio of the absorber to the buffer is small, although the effective range of the absorber is more limited. There are the optimum values for the spring constant of the absorber and the above-mentioned mass ratio to reduce the vibration of the pipe string. Furthermore, the absorber attached to the buffer causes much greater effect on the vibration of the pipe string than that attached to the pump module.

NOMENCLATURE

A	:	cross-sectional area of pipe string
$\bar{A}$	:	amplitude of longitudinal vibration of buffer, pump module or vibration absorber
a	:	amplitude of forced displacement at top of pipe string
C_d	:	drag coefficient for buffer, pump module or vibration absorber
C_i $(i=3,4)$	:	$c_i / \sqrt{EAm_o}$; nondimensional damping coefficient for vibration absorber
C_m	:	added-mass coefficient for buffer, pump module or vibration absorber
c	:	equivalent linear damping coefficient
c_i $(i=1\sim4)$	:	equivalent damping coefficient for buffer, pump module or vibration absorber
c_o	:	coefficient of structural damping in pipe string
D	:	outer diameter of buffer or pump module
D_i $(i=0\sim2)$	:	$c_i / \sqrt{EAm_o}$; nondimensional damping coefficient for pipe string, pump module or buffer
E	:	Young's modulus of pipe string
$F(t)$	:	fluid force due to ambient water
f	:	excitation frequency (frequency of forced displacement)
G_i $(i=3,4)$	:	$g_i / \sqrt{EAm_o}$; nondimensional damping coefficient of absorber's damper
$g_i(i=3,4)$	:	damping coefficient of absorber's damper
K_i $(i=3,4)$	:	$k_i\, L/EA$; nondimensional spring constant of absorber's spring
k_i $(i=3,4)$	:	spring constant of absorber's spring
L	:	total length of pipe string
L_m	:	length of buffer or pump module
l_1	:	vertical distance from sea surface to pump module
l_2	:	vertical distance from sea surface to buffer
$\bar{l}_1$	:	interval between sea surface and pump module
$\bar{l}_2$	:	interval between pump module and buffer
M_i $(i=1\sim4)$	:	$m_i / m_o L$; nondimensional mass
m_i $(i=1\sim4)$	:	$\bar{m}_i + \tilde{m}_i$; total mass of pump module, buffer or absorber
$\bar{m}_i$ $(i=1\sim4)$	:	mass of pump module, buffer or absorber
$\tilde{m}_i$ $(i=1\sim4)$	:	added mass of pump module, buffer or absorber
m_a	:	mass of water displaced by pump module, buffer or absorber
m_o	:	mass per unit length of pipe string
R_A	:	amplitude ratio of buffer with absorber to that without absorber
R_M	:	mass ratio of absorber to buffer
$\bar{S}$	:	cross-sectional area of pump module, buffer or absorber
t	:	time
U_o	:	u_o / L ; nondimensional forced displacement
U_v	:	u_v/L
u	:	longitudinal displacement of pipe string
u_B	:	amplitude of buffer
u_{BR}	:	resonance amplitude of buffer
u_m	:	longitudinal displacement of pump module, buffer or absorber
u_p	:	amplitude of pump module
u_{PR}	:	resonance amplitude of pump module
$u_o(t)$	:	forced displacement applied at top of pipe string
u_v	:	$u-u_o$
W_b	:	sum of submerged weights of pump module, buffer and absorber equipped below the position considered along pipe string
w_o	:	submerged weight per unit length of pipe string including inner fluid
X_i $(i=3,4)$	:	x_i / L
x	:	vertical distance from sea surface
γ	:	a/L ; nondimensional amplitude of forced displacement
ξ	:	x/L ; nondimensional distance from sea surface
ξ_i $(i=1,2)$	:	l_i/L
ρ	:	density of ambient water
σ	:	stress induced in pipe string
σ_M	:	maximum axial stress induced at top of pipe string in first resonance

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KEY WORDS: Longitudinal vibration of pipe string, vibration control, buffer, pump module, vibration absorber, amplitude, axial stress.