IMITATION BONE OPTIMIZATION OF COMPOSITE PIPE USING TRENCHLESS TECHNOLOGY

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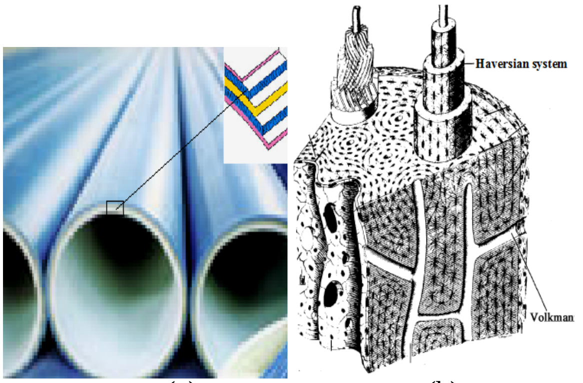
Introduction

The pipe of city water supply and drain system is crucial to Millions of urban resident's lives and health. In the past, the pipe was made of steel or concrete in china, these two types pipe's service life is short, very susceptible to be corrosion or jam . At present the whole country faces a tough mission to transformate the city water supply and drain system. For such large-scale transformation to the water supply and drainage network construction, must be used trenchless technology to avoid air pollution and traffic congestion. People expect a longer life pipe which has corrosion resistance and better integrated economic and social benefits also can be apply to trenchless technology. Under this situation the composite pipe is precisely the new high performance pipe which arises at the historic moment. Electrical networks, communication networks also need trenchless construction, composite pipe is the best option. Composite pipe is made of two or more material, its structure is similar to biological bone Haversian system ,Fig.1(a),(b). In this paper ,the optimization has been made to the composite pipe which will be used for trenchless technology through the imitation of biological bone Haversian system.



(a) (b)

Figure 1(a) Composite pipe ,(b) Haversian system[2]

Theoretical Analysis

The Composite pipe's constitutive relation of mesomechanics:

$$
\begin{aligned}
\sigma_x &= [(2\mu+\lambda)V_m + E_f l^4 V_f]\varepsilon_x \\
&\quad + [\lambda V_m + E_f l^2 m^2 V_f]\varepsilon_y \\
&\quad + \lambda V_m \varepsilon_z + E_f l^3 m V_f \tau_{xy}^f \\
\sigma_y &= [\lambda V_m + E_f l^2 m^2 V_f]\varepsilon_x \\
&\quad + [(2\mu+\lambda)V_m + E_f m^4 V_f]\varepsilon_y \\
&\quad + \lambda V_m \varepsilon_z + E_f l m^3 V_f \tau_{xy}^f \\
\sigma_z &= \lambda V_m \varepsilon_x + \lambda V_m \varepsilon_y + (2\mu+\lambda)V_m \varepsilon_z \\
\tau_{xy} &= E_f l^3 m V_f \varepsilon_x + E_f l m^3 V_f \varepsilon_y + 2(\mu V_m + E_f l^2 m^2 V_f)\gamma_{xy} \\
\tau_{yz} &= 2\mu V_m \gamma_{yz} \\
\tau_{xz} &= 2\mu V_m \gamma_{xz}
\end{aligned}
\qquad (1)
$$

The optimum Objective is make the max deflection of the composite pipe being minimum or volume of the composite pipe being minimum

$$F_i(x_1, x_2, ..., x_n) \to \min \qquad (i = 1, 2, \cdots) \qquad (2)$$

Design Variable is the thickness $T(x_1, x_2 \dots x_n)$,angle of fiber with principal axis $\alpha(x_1, x_2 \dots x_n)$,length $L(x_1, x_2 \dots x_n)$,diameter and ratio of length to diameter $BI(x_1, x_2 \dots x_n)$ of the composite pipe：

$$
\left.
\begin{aligned}
t_1 &\le T(x_1, x_2 \dots x_n) \le t_2 \\
\theta_1 &\le \alpha(x_1, x_2 \dots x_n) \le \theta_2 \\
l_1 &\le L(x_1, x_2 \dots x_n) \le l_2 \\
d_1 &\le D(x_1, x_2 \dots x_n) \le d_2 \\
t_1 &\le BI(x_1, x_2 \dots x_n) \le t_2
\end{aligned}
\right\} \qquad (3)
$$

The constraints is earth pressure in different depth and different soil, strength conditions of composite, deformation conditions of the composite pipe and boundary conditions.

So, the optimum problem[3] is

$$\min F(x_1, x_2, ..., x_n)$$

$$s.t. \quad g_u(x_1, x_2, ..., x_n) \le 0 \qquad (u = 1, 2, \cdots, m)$$
$$h_v(x_1, x_2, ..., x_n) = 0 \qquad (v = 1, 2, \cdots, p) \qquad (4)$$

Results and Discussion

Table 1 Optimum volume for different angle of fiber with principal axis

		Before optimization	After optimization
$[\pm\alpha_1]_{4s}$	α	$[\pm 0]_{4s}$	$[\pm 71.54]_{4s}$
	Volume （m^3）	0. 7886	0. 4965
$[\pm\alpha_1/\pm\alpha_2]$	α	$[\pm 0/\pm 0]_{2s}$	$[\pm 65.80/\pm 65.8$
	Volume （m^3）	0. 7886	0. 4559
$[\pm\alpha_1/\pm\alpha_2/\pm\alpha_3/\pm\alpha_4]_s$	α	$[\pm 0/\pm 0/\pm 0/\pm 0]_s$	$[\pm 69.92/\pm 39.0$ $/\pm 35.41/\pm 69.8$
	Volume	0. 7886	0. 4463

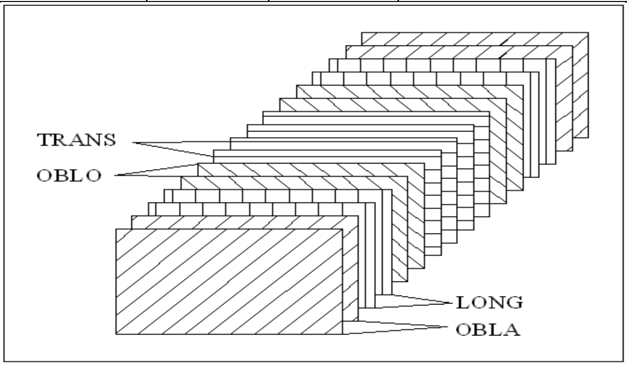


Figure 2 Angle of fiber with principal axis of Haversian system from different layer[1]

From Tab.1 it can be seen that when angle of fiber with principal axis is $[\pm 69.92/\pm 39.03/\pm 35.41/\pm 69.88]_s$ the volume of the composite pipe is minimum and distributing of angle of fiber with principal axis is similar with Haversian system in Fig.2.

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Table 2 Optimum max deflection in conglomerate

		Before optimization	After optimization
$[\pm\alpha_1]_{4s}$	α	$[\pm 0]_{4s}$	$[\pm 62.16]_{4s}$
	Max deflection(m)	0. 02649	0. 00802
$[\pm\alpha_1/\pm\alpha_2]_2$	α	$[\pm 0/\pm 0]_{2s}$	$[\pm 90.00/\pm 41.31$
	Max deflection(m)	0. 02647	0. 00805
$[\pm\alpha_1/\pm\alpha_2/\pm\alpha_3/\pm\alpha_4]_s$	α	$[\pm 0/\pm 0/\pm 0/\pm 0]_s$	$[\pm 45.58/\pm 34.36$ $/\pm 90.00/\pm 90.00$
	Max deflection(m)	0. 02647	0. 00701

Acknowledgments

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