

1. 一种高温高压高产气井完井管柱振动预测方法，其特征在于，包括下列步骤：

A、以水平向右为 x 轴，井垂深方向为 y 轴，建立管柱的纵横向耦合动力学模型，得管柱总动能 T、总势能 U 计算式分别如下：

$$T = \frac{1}{2} \int_0^L \left\{ \rho A \left[ \left( \frac{\partial u}{\partial t} \right)^2 + \left( \frac{\partial w}{\partial t} \right)^2 \right] + \rho I \left( \frac{\partial^2 w}{\partial t \partial x} \right)^2 + \rho_0 A \left[ \left( \frac{\partial w}{\partial t} + V \frac{\partial w}{\partial x} \right)^2 + V^2 \right] \right\} dx$$

$$U = \frac{EA}{2} \int_0^L \left[ \left( \frac{\partial u}{\partial x} \right)^2 + \frac{1}{4} \left( \frac{\partial w}{\partial x} \right)^4 + \frac{\partial u}{\partial x} \left( \frac{\partial w}{\partial x} \right)^2 \right] dx + \frac{EI}{2} \int_0^L \left( \frac{\partial^2 w}{\partial x^2} \right)^2 dx$$

式中：L 为管柱长度，(m)； $\rho$  为管柱密度，(kg/m<sup>3</sup>)；A 为管柱横截面积，(m<sup>2</sup>)；u 为管柱纵向位移，(m)；w 为管柱横向位移，(m)；V 为管内流体速度，(m/s)； $\rho_0$  为管柱内流体密度，(kg/m<sup>3</sup>)；E 为管柱弹性模量，(MPa)；EI 为管柱弯曲刚度，(N·m<sup>2</sup>)；t 为时间，(s)；

B、根据哈密顿原理，由所述管柱总动能 T、总势能 U 计算式推导出管柱纵向振动微分方程 f(x,t)和管柱横向振动微分方程 p(x,t)的计算式分别如下：

$$f(x,t) = \rho A \left( \frac{\partial^2 u}{\partial t^2} \right) - EA \left( \frac{\partial^2 u}{\partial x^2} \right) - EA \left( \frac{\partial w}{\partial x} \right) \left( \frac{\partial^2 w}{\partial x^2} \right)$$

$$p(x,t) = \rho A \left( \frac{\partial^2 w}{\partial t^2} \right) - \rho I \left( \frac{\partial^4 w}{\partial^2 t \partial^2 x} \right) + \rho_0 A \left( \frac{\partial^2 w}{\partial t^2} - 2u \frac{\partial^2 w}{\partial t \partial x} - u^2 \frac{\partial^2 w}{\partial x^2} \right)$$

$$- \frac{3EA}{2} \left( \frac{\partial w}{\partial x} \right)^2 \frac{\partial^2 w}{\partial x^2} - EA \left[ \left( \frac{\partial u}{\partial x} \right) \frac{\partial^2 w}{\partial x^2} - \left( \frac{\partial^2 u}{\partial x^2} \right) \frac{\partial w}{\partial x} \right] + EI \left( \frac{\partial^4 w}{\partial x^4} \right)$$

C、对管柱的纵向、横向振动微分方程进行求解，并用计算机输出计算结果；

D、利用所述计算结果分析管柱的纵、横向振动位移、管柱轴向应力、管柱有效载荷和管柱弯矩。