# VIBRATION MONITORING OF THE RING SPINNING

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## INTRODUCTION

In the ring spinning process the yarn has two basic types of motion: a rotation upon the spindle axis and a longitudinal displacement controlled by the roller draft system. Due to the yarn rotation results the yarn balloon which shape depends on the ring spinning parameters: yarn linear density $\rho$; traveler rotational speed $\omega$; traveler mass $m$, rig-traveler friction coefficient $\mu$ ring radius $R$, ring bar position $l$; and spindle winding radius $\mathbf{r}$.

One of the most important parameters of the ring spinning is the yarn tension $T$. It must be permanently controlled, since any increase of its value above a certain limit is the cause of an end/down. In order to measure this parameter, a special piezoelectric force transducer has been designed and realized. The dependence of the yarn tension on the above mentioned parameters can be obtained from the mathematical model of the yarn balloon shape.

## MATHEMATICAL MODEL

The yarn tension at the yarn-pig tail contact point (see figure 1) is given by:

$$T_o = \sqrt{V_o^2 + H_o^2} \tag{1}$$

where the vertical and horizontal tension components can be expressed as:

$$V_o = \int_o^1 \rho \cdot g \cdot \sqrt{1+y^2} \cdot dx + \frac{\mu \cdot \omega^2 \cdot R^2}{2r} \tag{2}$$

$$H_o = \int_o^1 \omega^2 \cdot p \cdot y\sqrt{1+y^2} \cdot dx$$

The function y(x) describing he yarn balloon shape at a given moment of time satisfies the following integro-differential equation:

$$y''\left[\int_x^1 p \cdot g \cdot \sqrt{1+y^2} \cdot dx + \frac{\mu \cdot m \cdot \omega^2 \cdot R^2}{2 \cdot r}\right] - p \cdot g \cdot y' \cdot \sqrt{1+y^2} + \omega^2 \cdot p \cdot g \cdot \sqrt{1+y^2} = 0 \tag{3}$$

with the boundary conditions:

$$y(0) = 0, \quad y(1) = R \tag{4}$$

Since $\rho = \rho(x,t)$, $l = l(t)$ and $x = r(t)$ are slowly varying functions of time as compared with the yarn rotational motion, in equation (3) the time *t* can be considered as *a* parameter.

Once the solution of the boundary problem (3), (4) is determined, one can easily obtain from (1) and (2) the yarn tension as function of the ring spinning parameters:

$$T_o = T_o(\rho, \omega, m, \mu, r)$$

While the spindle winding radius r(t) and the ring bar displacement l(t) are deterministic functions of time, the variation of the yarn linear density is practically random. Therefore the yarn tension $T_o$ will be also a random function of time.

Generally, the function $\rho(x,t)$ can be assumed to have the form:

$$\rho(x,t) = \rho_o + \rho_1(t) + \sum_i m_i \cdot \delta[x - v \cdot (t - t_i)] \tag{5}$$

where $\rho_o$ is the imposed yarn linear density (which must be kept as constant as possible), $\rho_1(t)$ represents the random variation of the linear density (which dispersion must be as small as possible), $m_i$ are small additional fault masses carried on by the yarn (neps, for example), $v$ is the viscosity of the longitudinal motion, and $t_i$ are the time moments at which the masses $m_i$ pass through the pig tail.

The integro-differential equation (3) was solved approximately by an iterative method, trying to find a solution of the parabolic form:

$$y(x) = \frac{R - bl}{l^2} x^2 + bx \tag{6}$$

which satisfies the boundary condition (4). This approximation was used only to evaluate the elementary arc length second $ds = \sqrt{1+y^2}dx$ in equation (3). Thus, (3) becomes an ordinary second order differential equation which can be solved by standard methods. For an initial value of the coefficient b the iterative process is continued until the desired accuracy is obtained.

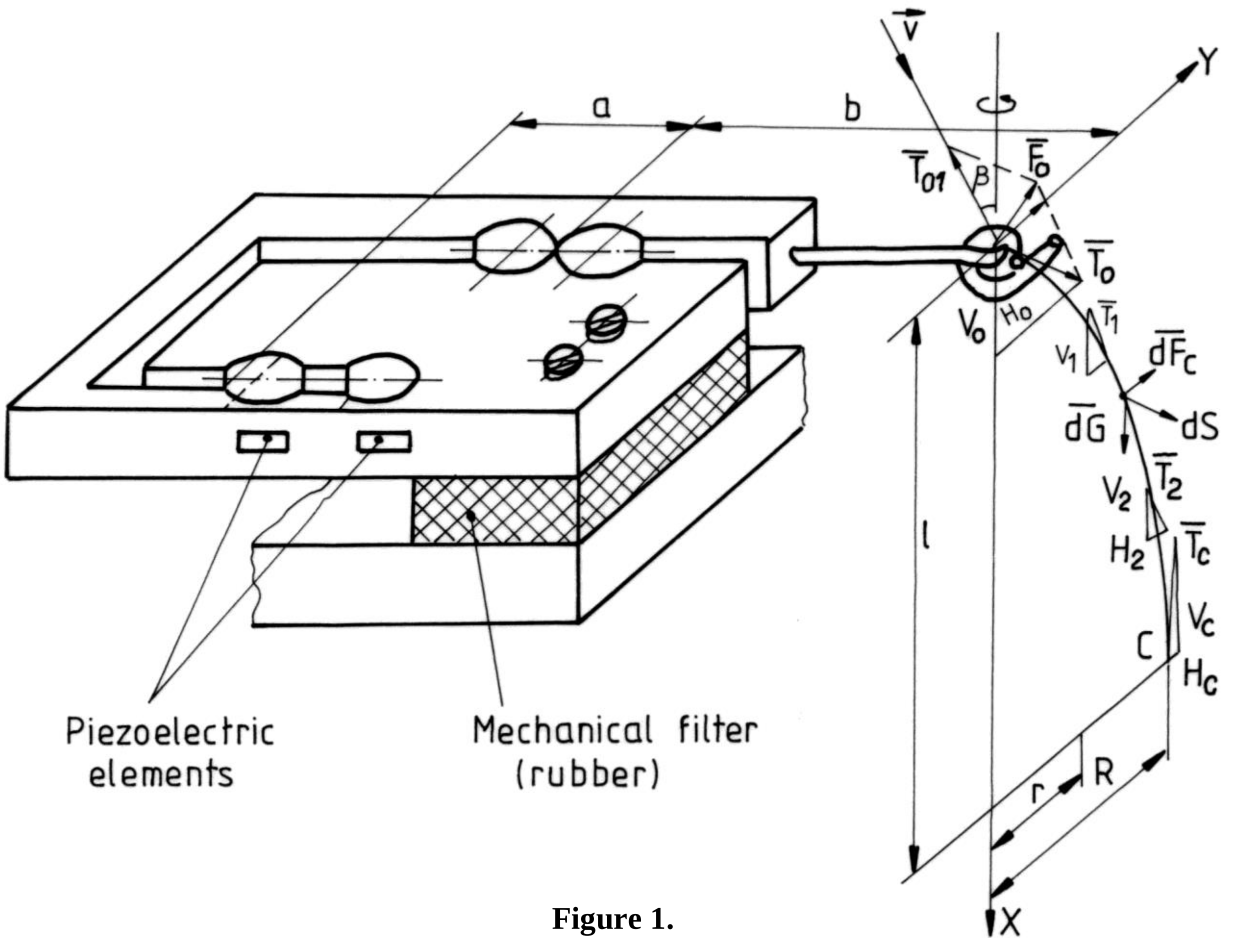


**Figure 1.**

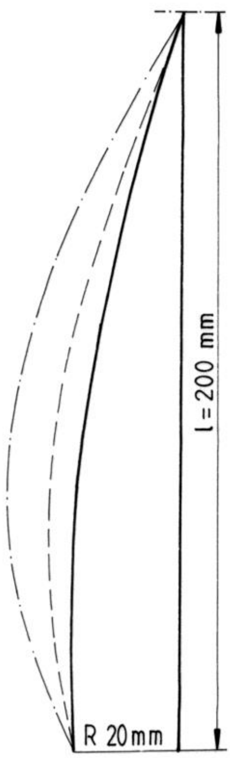


**Figure 2.**

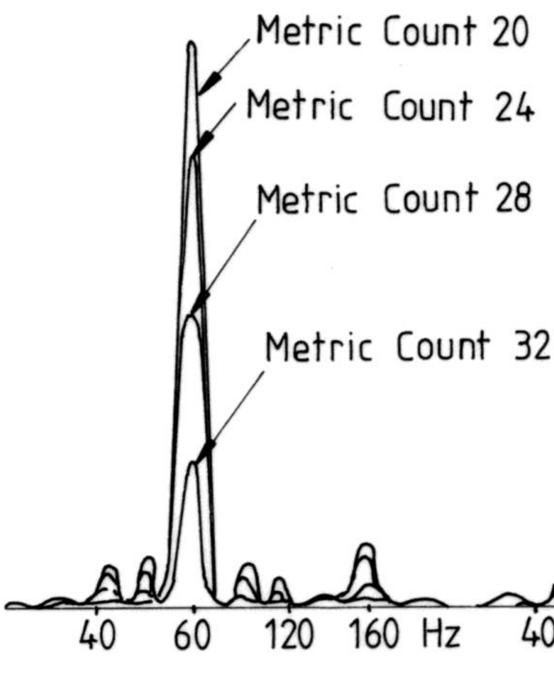


**Figure 3.**

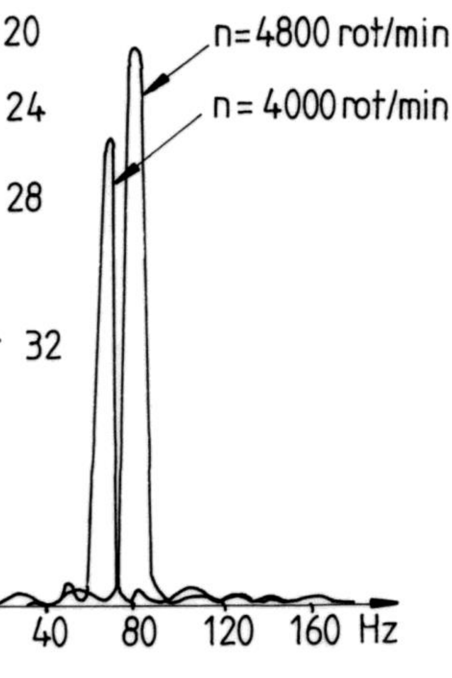


**Figure 4.**

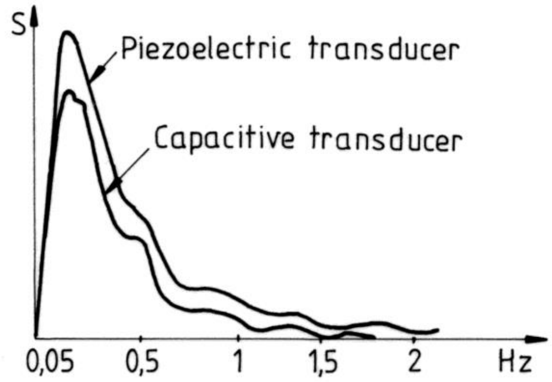


**Figure 5.**

In figure 2 there are given the shapes of the yarn balloon and the corresponding yarn tension values for the shown values of the remaining parameters. As one can see, the yarn tension resulted proportional to the yarn linear density.

## EXPERIMENTAL RESULTS

Refering to figure 1 one can see that the transducer was mounted between the ring frame and the pig tail using a mechanical filter (rubber) in order to reduce the vibration transmissibility. The force measured by the transducer is the modulus of the Oy projection of the tension forces resultant at the yarn - pig tail contact point. Therefore, the output signal of the transducer is an amplitude randomly modulated harmonic function of t:

$$F(t) = F_o(t) \cdot \sin(\omega t - \varphi) \qquad (7)$$

where:

$$F_o(t) = T_o(t) \cdot (\sin\alpha_o - \sin\beta), \quad tg\,\alpha_o = y'(0) = b \qquad (8)$$

The linear density ρ is directly related to the yarn metric count: $N_m = \frac{L(m)}{M(g)} = \frac{1}{\rho}$ and, as obtained from the mathematical model, the yarn tension will be also a function of this parameter. Therefore, the r.m.s. value of the transducer output is a measure of the yarn metric count and the r.m.s. value of its envelope is a measure of the metric count constancy. In figures 3 and 4 are plotted the mean square spectra of the transducer output signals corresponding to different values of metric count and traveler speed. Figure 5 shows the envelope spectrum of the piezoelectric transducer output obtained on the ring frame and the output spectrum of a special capacitive transducer used in the textile factory laboratories for metric count constancy measurement.

## CONCLUSIONS

The piezoelectric force transducer and the mathematical model presented in this paper enable a permanent control of the yarn tension and of the metric count constancy during the ring spinning process. The method can be also used to study the influence of the variation of the ring spinning parameters on the yarn tension evolution. The transducer output can be used as a feed-back signal for an automation loop of the roller draft system in order to keep the yarn tension or the metric count within the allowed range. As a by/product, the lack of the transducer output will promptly point out any end down.

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