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Assumptions for Constructing an Auto-leveller with a New Algorithm of Operation

Abstract
Regularity of linear density for slivers levelled by a short-term auto-leveller is a function of time, due to the occurrence of retardation. This phenomenon was analysed, and assumptions were made for constructing an auto-leveller with a new algorithm of operation, in which retardation of sliver in the short-term regulation process is used.

Key words: *auto-leveller, card, evenness of mass.*

Introduction

Linking spinning machines and automatic flow production lines, applying elements of high drafting capacity and spinning directly from the sliver all lead to a reduction in the number of spinning machines in the technological process, and hence a smaller number of links. It is possible to obtain regular sliver in the flow production line, both regarding linear density and structure, if the opening, blending and carding processes are carried out effectively, and if the regularity of the fibre stream's linear density is centrally and automatically controlled over a wide range of spectrum of waves. The last task may be done by applying a system of automatic regulation on the following bases: feed regulators, regularity of the fibre stream's linear density regulators, and automatic levelling of long- and short-term irregularities in sliver linear density.

Long-lasting analyses of short-term regulation systems operation [2, 3] have shown that regularity in the linear density of slivers levelled by means of a short-term auto-leveller is a function of time, and only its direct measuring in an on-line system enables immediate and reliable conclusions about the effectiveness of the regulation process to be drawn.

The results of the studies conducted confirmed the need for a short-term auto-leveller whose algorithm of operation would allow the phenomenon of sliver retardation.

Purpose of analysis

Distribution of linear density of sliver, before and after short-term regulation by an auto-leveller working according to the typical algorithm of operation, is shown in Figure 1. Figure 2 presents the same for an auto-leveller with a modified algorithm of operation (allowing for the phenomenon of sliver retardation).

In the first case, i.e. when an auto-leveller working according to the typical algorithm of operation is applied, the sliver achieves small irregularity of linear density immediately after the short-term regulation process (Figure 1b), whereas the regularity of linear density deteriorates during retardation processes (Figure 1c). Thus, the favourable effects of the auto-leveller's operation are eliminated by the process of sliver retardation. In industrial practice, sliver is never transmitted to the next machine in the technological process immediately after the regulation process, but only after some time, usually when its structure has stabilised after short-term regulation. Therefore, the regulated sliver feeding the next machine in the technological process has a worse regularity of linear density than it should

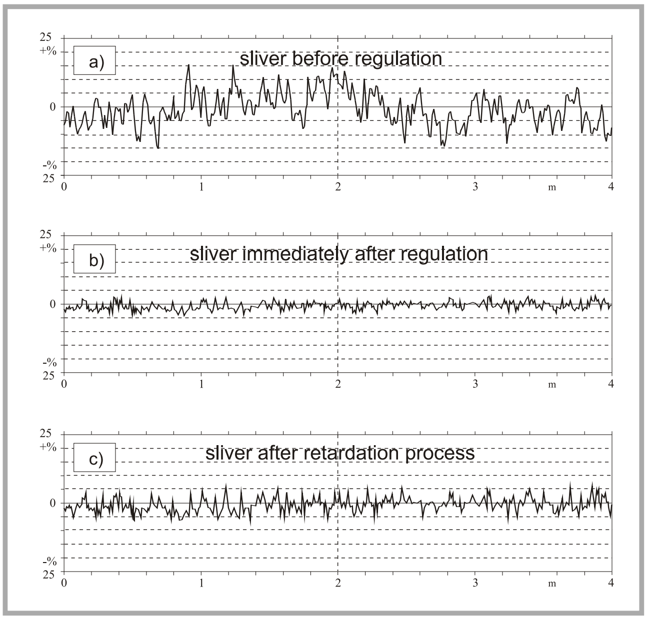

Figure 1. Change in distribution of sliver linear density after short-term regulation (typical algorithm of operation); the regularity of linear density (small) immediately after regulation (b) deteriorates during the retardation process.

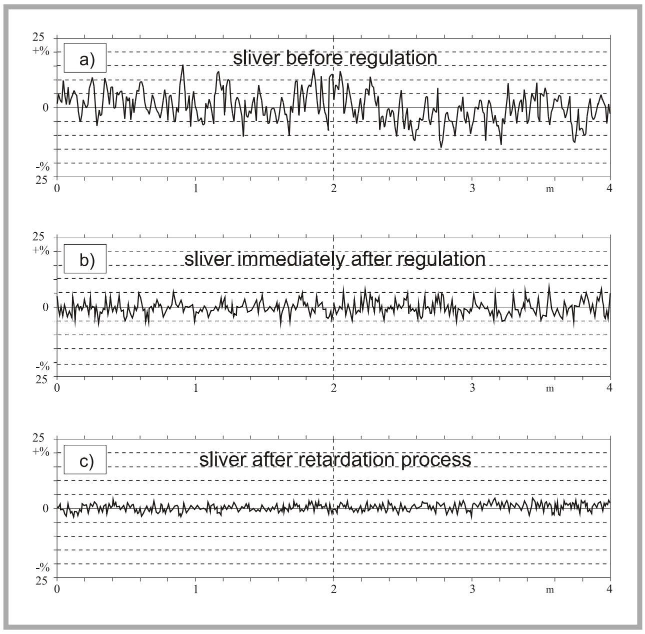

Figure 2. Change in distribution of sliver linear density after short-term regulation (modified algorithm of operation) the medium size regularity of linear density immediately after regulation (b) decreases after the phenomenon of sliver retardation.

have as the result of the auto-leveller's operation.

In the second case, i.e. when the auto-leveller with a modified algorithm of operation is used, the smallest irregularity of linear density should be obtained only after the process of sliver retardation (Figure 2c). Therefore, during the process of short-term regulation, the sliver should be 're-regulated' by applying drafts to the auto-leveller which allow for the retardation phenomenon to occur later. In this case, the sliver feeding the next machine in the technological process should show a considerably smaller irregularity of linear density than it does immediately after leaving the auto-leveller.

New algorithm of operation or auto-leveller

The functioning of a typical short-term regulation system is based on this equation:

$$R(t) = R/m_1 \times m_1(Q;t\text{-}t_z) \qquad (1)$$

where:

$R(t)$ – the momentary draft in the auto-leveller;

R – the nominal draft in the auto-leveller;

m_1 – the average density of fibres in the feeding product;

$m_1(Q;t\text{-}t_z)$ – the momentary density of fibres in the product of measuring intersection Q.

It follows from this equation that the draft in a given moment t is equal to the product of density of fibres in the measuring intersection Q at the moment t - t_z and of the constant value R/m_1. The fibre density or the quantity which is its function (linear density, thickness), as determined at the moment t in the measurement section Q, should be changed by changing the draft, i.e. the change of delivery speed after time t_z, which is the delay time.

Since it was proved that the linear density of the feeding fibres stream is a function of density of fibres in the product, Equation 1 may take the following form:

$$R(t) = R/Tt_{zas} \times Tt_{zas}(Q;t\text{-}t_z) \qquad (2)$$

where:

Tt_{zas} – the average linear density of the feeding fibre stream;

$Tt_{zas}(Q;t\text{-}t_z)$ – the momentary linear density of a fibre stream in measuring intersection Q.

In the measuring device of a card auto-leveller, the cross-section of the fibres stream is forced and forms a rectangle of a given base (5 mm) and variable height, depending on the thickness of the sliver. Since there is proportional dependence between the height, i.e. the distance between the top and bottom measuring roller g_1, and the linear density of the feeding sliver, Equation 3 will have the following form:

$$R(t) = R/g_1 \times g_1(Q;t\text{-}t_z) \qquad (3)$$

where:

$g_1(Q;t\text{-}t_z)$ – the momentary thickness of a fibre stream in measuring intersection Q.

There is also an equation for sliver retardation after the short-term regulation process [3], which has the following form:

$$r = a\,(R\text{-}k)^b\, e^{c\,(R\text{-}k)} \qquad (4)$$

where:

r – the retardation of sliver thickness,

R – draft in the regulator,

a, b, c – coefficients of shape showing the changes of the retardation curve,

k – limit draft where retardation does not occur.

Coefficient a is decisive for the magnitude of retardation, whereas coefficients b and c determine the draft value when retardation reaches the maximum:

$$r_{max} = -\,b/c \qquad (5)$$

The correctness of the assumed model was confirmed during two research projects by the Committee for Scientific Research (conducted by the author), as well as during earlier studies [2, 3]. In those studies, the values of the factors for this equation were also determined for various drafts in the auto-leveller and for fibres of various length.

Since the factors of the retardation equation are constant for individual values of nominal drafts in the auto-leveller, the only variable in Equation 4 is the momentary draft. With the continuous changing of draft in the auto-leveller, retardations of individual lengths of the regulated sliver will change as well. Equation 4 will then take the following form:

$$r(t) = a\,[R(t)\text{-}k]^b\, e^{c\,[R(t)\text{-}k]} \qquad (6)$$

where:

$r(t)$ – the momentary value of retardation of individual lengths of the regulated sliver.

Having left the draft zone, which is changeable in time, the sliver is subject to the retardation process. The value of retardation for individual sliver lengths depends on the momentary draft in the auto-leveller that occurred at the time when a given length was in the regulation zone. This situation refers only to these lengths of regulated sliver which were drafted with a draft bigger than k (limit draft, where retardation does not occur).

Since retardation is an unavoidable element of the process of equalising stresses in a fibre stream, while it has an unfavourable influence on the distribution of linear density of sliver which is levelled by a short-term auto-leveller, this phenomenon must be taken into account in the algorithm of operation of a short-term auto-leveller. During the process of levelling the linear density distribution, the sliver should be 're-regulated' by applying momentary drafts in the auto-leveller which allow for retardation phenomenon to occur later.

Sliver shrinks during the process of retardation, and the length of individual sliver segments decreases. Therefore the applied momentary drafts in the auto-leveller should be bigger, allowing for the future predicted retardation of these segments.

The new algorithm of operation for the auto-leveller should be expressed by the form of equation (7) or (8):

$$R'(t) = R(t) + R(t)\, r(t) \qquad (7)$$

$$R'(t) = [1 + r(t)]\, R(t) \qquad (8)$$

Having taken into account Equations 3, 6 and 8, we obtain the new algorithm for the operation of the auto-leveller, in the form of Equation 9. The only variable in equation 9 is the value of $g_1(Q;\ t\text{-}t_z)$.

$$R'(t) = \left\{ 1 + a \cdot \left[\frac{R}{g_1} \cdot g_1(Q; t - t_z) - k \right]^b \cdot e^{c\left[\frac{R}{g_1} \cdot g_1(Q; t - t_z) - k \right]} \right\} \cdot \frac{R}{g_1} \cdot g_1(Q; t - t_z) \qquad (9)$$

Equation 9.

Conditions for practical realisation of the algorithm

Momentary draft R in the auto-leveller is proportional to the voltage signal U as supplied to a direct current engine driving the drawing roller. Thus Equation (8) can be written as:

$$U'(t) = [1 + r(t)] \cdot U(t) \qquad (10)$$

that is:

$$U'(t) = \{1+a\,[U(t) - k]^b\, e^{c[U(t)-k]}\}U(t) \qquad (11)$$

The voltage signal U(t) is known, because it controls the work of the drawing engine in the standard working conditions of the auto-leveller. When the algorithm of operation is changed, the signal U'(t) should be supplied to the drawing engine, according to Equation (11). The values of all factors of the equation change, depending on the nominal draft in the auto-leveller, the linear density of the feeding sliver and the type of fibres processed. Therefore a new algorithm of operation must be realised digitally. For this purpose, a correction system will be used. This system consists of a computer set with the relevant software. Continuously drawing on the voltage signal U(t) transmitted from the power amplifier to the drawing wobble-plate engine, the system will process it in such a way so that the drawing engine is supplied with the voltage U'(t), which allows for the sliver retardation phenomenon.

Summary

The analysis of algorithm of operation of a card auto-leveller, and the suggested modifications of this algorithm which we have presented, should result in the construction of a test auto-leveller which would enable the smallest possible variations of linear density of sliver to be achieved before it is transmitted to the next machine in the technological process. It is predicted that only after the retardation process will the sliver have the lowest value of linear density irregularity, below CV_{1m} = 2.7% according to Uster, at a linear density of about 4 ktex. In longer segments, the values of CV coefficient should not exceed the level CV_{1m} = 0.8%, CV_{3m} = 0.5%. These values refer to an auto-leveller fed with a sliver for which the irregularity of linear density is at the level of 50%, according to Uster statistics, and if we assume that the levelling capacity of the auto-leveller reaches the mean value at the level of 25-50%. These assumptions will be verified in further studies.

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