COMPUTERIZED VELOCITY OPTIMIZATION PROCEDURE FOR CONERS

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Summary

A computerized data collecting and processing was developed for calculating maximum performance attainable with parallel and in-series yarn web systems. It allows automated measurement of corresponding average efficiency and velocity values, and — by algorithms approaching the experimental values — the calculation of optimum velocity yielding maximum performance. An exponential function as approach to the relationship efficiency *versus* velocity is suitable for identification; it includes all earlier models of the authors. It has been applied to Schweiter, Savio and Schlafhorst coners. The average performance increase attainable — at ideal conditions — by the velocity optimization procedure amounts to 14–20%.

Introduction

The operations in spinning and in fabric manufacture (e.g. coning, beaming, sizing, weaving) are termed yarn web systems. With the exception of sizing they are velocity-sensitive, their efficiency decreasing with increasing velocity. This is the result, on the one hand, of yarns breaks, and on the other hand, of joint standstill. Depending on the characteristics of the yarn web, the velocity-sensitive processes are in-series or parallel systems.

In the case of in-series systems, the break of one single yarn will stop the total technological process. All warp-system technologies like beaming, weaving, warp-knitting etc. belong to this group.

In parallel systems, the break of one individual yarn will not affect the other elements of the system: they will continue operation independently of the state of the other elements. Such characteristics are found in spinning and winding operations.

In present industrial practice, yarn web velocities are determined by cumbersome observations and calculations. In more modern plants the velocities are recorded — together with other process characteristics — and processed by computers. The results are not used, however, for intervention into the technological process, but utilized mainly to record production and to detect failures.

In the knowledge of characteristics calculated by the computer, e.g. efficiency, quality parameters etc. and of actual yarn velocity, optimization of the process is feasible relative to a selected objective — maximum production, minimum cost or maximum profit — in the case of velocity-sensitive processes by establishing the mathematical relationship between a value which characterizes the chosen objective and velocity.

Performance and efficiency of yarn web systems

Let us consider a yarn web machine/operator system consisting of m elements with a common drive (e.g. a coner with m heads). The state processes for the alternation of operation and standstill $x_k(t)$, $(k=1, \ldots, m)$ can be defined as follows:

$$x_k(t) = \begin{cases} 1, & \text{if the yarn is in motion in the moment } t \\ 0, & \text{in all other cases} \end{cases} \tag{1}$$

where $x_k(t)$ is a random process.

The yarn web reacts to switch-on (moments t_i in Fig. 1) by acceleration to the set velocity v, and to switch-off (moments t_i') by deceleration to zero velocity.

The acceleration and deceleration processes shown in Fig. 1 will differ depending on the type of the technological process. Deceleration is negligible in coning due to the continuity of the yarn being broken, and in beaming due to the instantaneous action of the brake. Acceleration, however, differs largely in coning and in beaming.

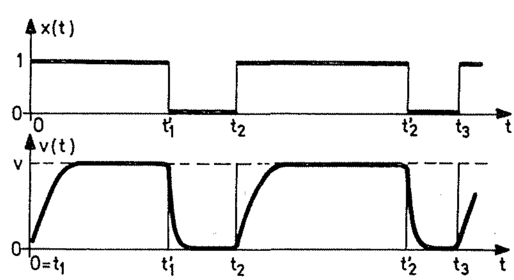

Fig. 1. Switch-on and switch-off process of yarn webs

Coning is characterized by relatively rapid acceleration; a constant loss time T_k (Fig. 1) can be determined by area equalization, the acceleration curves being identical. If a longer period of operation is being considered, the acceleration section may be neglected.

If beaming acceleration is slow, so that its period cannot be disregarded.

The performance of the coning machine is the total of the performance of the individual coning heads. Hence its average performance for the period T will be obtained by scanning the state, that is, the operation-standstill process in intervals of Δt for the individual heads, by adding and averaging the values measured.

This principle is demonstrated in Fig. 2 showing the number of units in operation *versus* time. If N_T state observations have been performed during the period T spaced by Δt, then

$$T = N_T \cdot \Delta t \tag{2}$$

It is easy to understand that the mean value of the integral of the state process $x(t)$ for the period T is equal to the average number z_T of heads in operation during this period, and that it is also equal to the sum of the efficiencies $\bar{\eta}_{k,T}$ of the individual heads during the period T:

$$z_T = \frac{1}{T}\int_0^T x(t)dt = \sum_{k=1}^{m} \bar{\eta}_{k,T}; \qquad x(t) = \sum_{k=1}^{m} x_k(t) \tag{3}$$

The total performance of the system in the period T is

$$\bar{\eta}_T(v) = v \cdot z_T = v \sum_{k=1}^{m} \bar{\eta}_{k,T} = m \cdot v \cdot \bar{\eta}_T \tag{4}$$

where, from Eq. (3), the average efficiency of the system $\bar{\eta}_T$ is

$$T = \frac{1}{m} \sum_{k=1}^{m} \bar{\eta}_{k,T} \tag{5}$$

The average length performance of the system is

$$\bar{p}(v) = v \cdot \bar{\eta}_T. \tag{6}$$

The average efficiency reflects the data of the multimachine system material/machine/operator, the state of operation of the individual heads. It reacts very sensitively to the parameters of the system, and what is of main importance: average efficiency is measured readily both discontinuously and continuously.

Continuous state sensing of a machine consisting of m elements is performed by fitting state sensors to each head. The sensors indicate a value of 1 or zero, depending whether the head is in operation or standing (Fig. 2). At

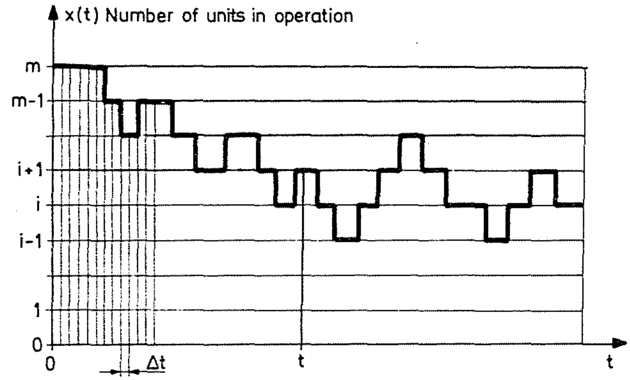

Fig. 2. State process of a parallel yarn web. Principle of sampling

intervals of Δt the state of the heads is scanned one by one, so that in one scanning cycle m values of 1 or 0 are obtained. Their sum indicates the number of heads in operation at the moment in question. From the successive sampling results the average efficiency is obtained by Eqs (3) and (5), and from this value average length performance is calculated using Eq. (6).

Measurement and identification of the relationship efficiency versus velocity for coning

It is a general experience that the efficiency to be expected for a given period is a monotonously decreasing function of velocity for yarn web processes, since the probability of standstills and yarn breaks usually rises progressively and monotonously with yarn velocity. Hence the average length performance (the product of average efficiency and pre-set yarn velocity, Eq. (6)) will have a maximum, defining optimum velocity v_{opt} (Fig. 3).

Average length performance can be measured readily, and velocity can be varied continuously on most modern coners. These data will allow to find, using an appropriate searching procedure, *optimum velocity relative to performance.*

Average efficiency and the average value of the velocity function $v(t)$ involve random variances. Depending on the period of observation a variance

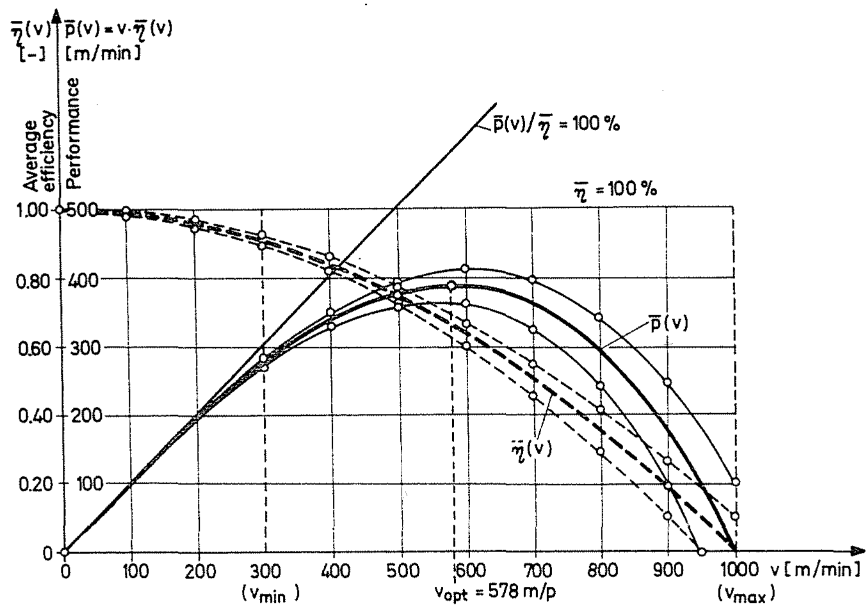

Fig. 3. Average efficiency $\bar{\eta}$ and average performance $\bar{p}$ *vs.* yarn velocity. Width of variance field

field more or less broad will exist along efficiency and length performance *versus* velocity curves. By increasing the period of observation or by applying some suitable screening process, the width of the variance field can be reduced.

Experimental efficiency data obtained with 10 heads of a Schlafhorst Autoconer machine by integration with an Indicator computer are presented in Fig. 4.

The yarn processed was cotton Nm 80/1 (12.5 tex), pre-set yarn velocity was 790 m/min. The values were printed out at intervals of 2 minutes.

The figure shows the average efficiency for 10 heads, average efficiency values for the groups of heads Nos 1–5 and 6–10 having separate automatic tier devices, and the instantaneous maxima and minima of efficiency for individual heads marking the width of the variance field.

The figure demonstrates that the higher the number of heads being considered, the lower the variance of the efficiency: the average efficiency $\bar{\eta}$ for 10 heads becomes stabilized sooner than those for five heads each ($\bar{\eta}_{1-5}$ and $\bar{\eta}_{6-10}$, resp.) and for individual heads. In the case in question the stabilization of $\bar{\eta}$ took 15 minutes, that of $\bar{\eta}_{1-5}$ and $\bar{\eta}_{6-10}$ 30 minutes, efficiency maxima became stabilized after 45 minutes, and efficiency minima after about 70 minutes.

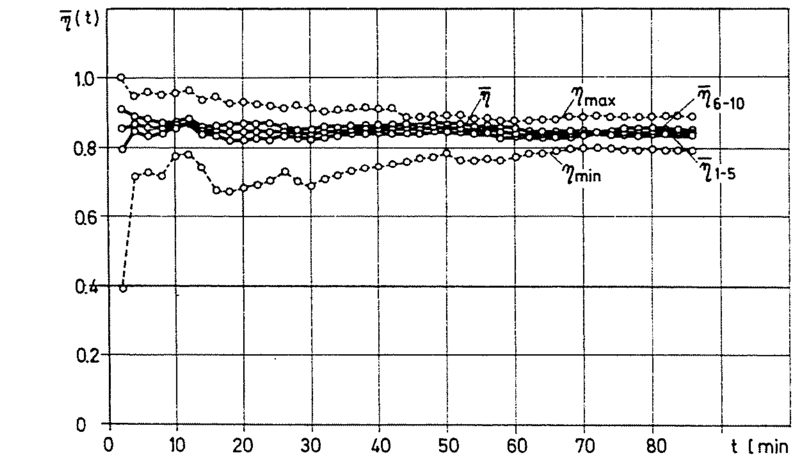

Fig. 4. Average efficiency $\bar{\eta}$ *vs.* observation time on Schlafhorst Autoconer: 12.5 tex cotton yarn, $v = 790$ m/min

The correctness of this steady-state hypothesis was checked at laboratory conditions with manual operation. Results are presented in Fig. 5.

The figure indicates stabilization of the average efficiency for the 10-head non-automatic coner (started with full packages) after a relatively short period (about 20 minutes).

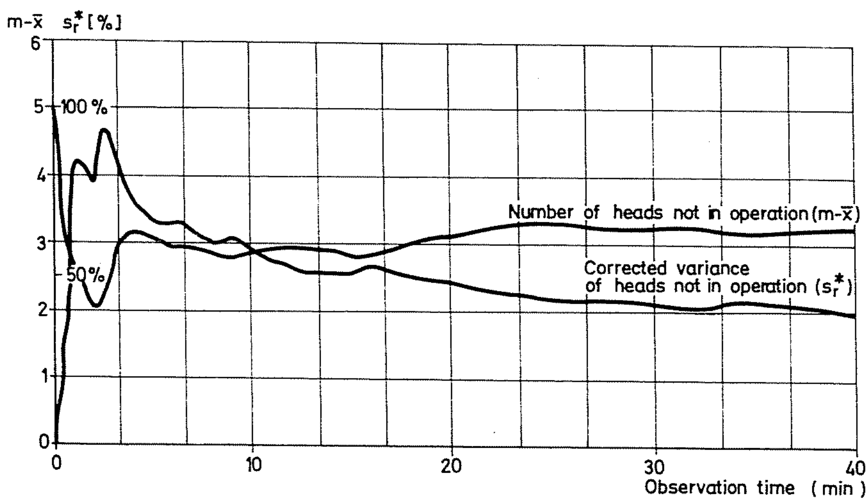

Fig. 5. Efficiency stabilization on manually operated coner. 20 tex cotton yarn on weft bobbin; $v = 500$ m/min, $\bar{\eta} = 0.6696$

Theoretical investigations were made [3] to find approach formulas for the experimental relationship efficiency *vs.* velocity. Assuming that:

— the distribution of standstills due to random breaks is exponential and a function of yarn velocity,

— the distribution of yarn defects of a defined length — removed by cutting — is of the Poisson type, and hence the distribution of the length of the sections between them is exponential, and

— the standstills due to changing packages or full cones are linear functions of velocity, we obtained that in the general case the relationship efficiency *vs.* velocity for coning can be approached by the expression

$$\bar{\eta}(v) = \frac{1}{1+a_1 v + a_2 v^2 + \ldots}. \qquad (7)$$

To simplify identification calculations from measured data for practical purposes, it appears expedient to apply an elastic relationship with not more than two parameters. The following formula was found suitable for this purpose:

$$\bar{\eta}(v) \cong \frac{1}{1+av\, e^{bv}} = h_1(v) \qquad (8)$$

which, if e^{bv} is expanded into a Taylor series, will yield Formula (7). This approach was termed the exponential approach. Its quadratic form (termed hyperbolic approach) is

$$\bar{\eta}(v) \cong \frac{1}{1+av+b_1 v^2} = h_2(v). \qquad (9)$$

The third utilizable approach, termed parabolic approach, is obtained by expanding Eqs (7) and (8), resp., into Taylor series and neglecting the linear term:

$$\bar{\eta}(v) \cong 1 - b_2 v^2 = h_3(v). \qquad (10)$$

Average efficiency vs. velocity relationships for different coner types

The serviceableness of the above approaches was checked experimentally with different types of coner/operator systems. The results are summarized in the followings.

Efficiency vs. velocity relationship for manually operated, non-automated coners

A suitably instrumented two-side coner with five heads on each side, operated by one person, was used for experiments. Yarn velocity could be varied continuously within the range of 0–1200 m/min.

In the first approach the instantaneous value of the state process, as it were in a sampling manner, was read by the operator of the digital table computer EMG-666 in intervals of about 0.7–0.8 seconds. Subsequently readings were performed automatically by the computer by means of a multiplexer (Fig. 6).

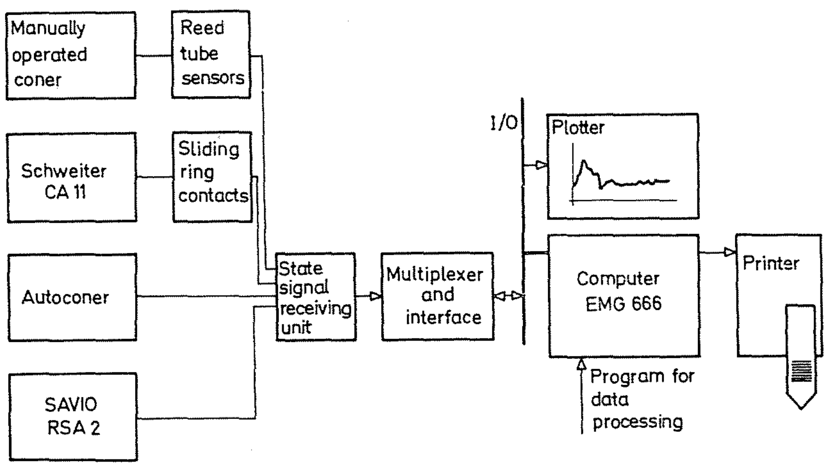

Fig. 6. Diagram of signal transmission and data processing for velocity optimization

After reaching the required number of sample data, the computer summarized the measured data, calculated the actual efficiency and the average performance per head corresponding to the pre-set velocity. By processing these data conforming to the optimization program the computer then calculated the optimum yarn velocity, which was subsequently set manually. All calculated data were printed out in the matrix printer.

In Fig. 7, the measured average efficiency values and performance values belonging to different pre-set velocities are marked by circles. In the figure the exponential, hyperbolic and parabolic approaches are also plotted.

The monotonous decrease of average efficiency and the first increasing and then decreasing performance with yarn velocity is well observable in the

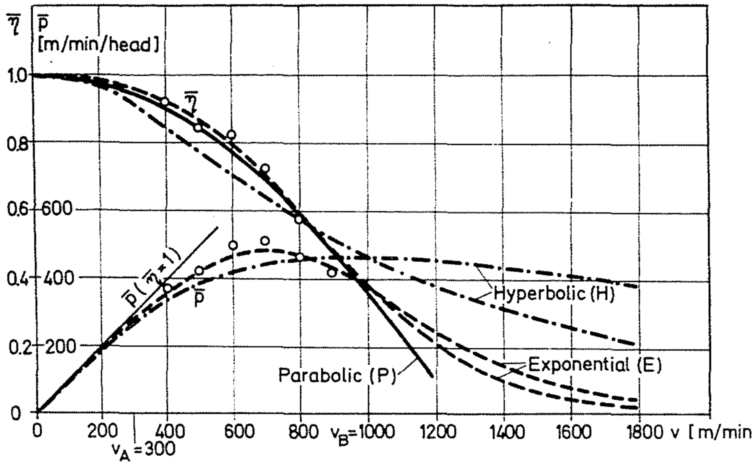

Fig. 7. Average efficiency $\bar{\eta}$ and average performance $\bar{p}$ *vs.* velocity on manually operated coner. 10-head Franz Müller machine, 20 tex cotton yarn

figure. Both the parabolic and the exponential approach are in good agreement with experimental data. The optimum velocity value corresponding to performance maximum coincides in these approaches. Its value is

$$v_{opt} = 700 \text{ m/min}.$$

Average efficiency vs. velocity relationship for the Schweiter CA automatic coner

The stabilization of efficiency of this machine was studied by connecting the electronic yarn cleaner which is the accessory of this coner over an interface to the computer EMG 666 as shown in Fig. 6.

Experiments demonstrated that within the velocity range that can be set on this machine, the measured results are best approached by the exponential (E) and hyperbolic (H) formulas (Figs 8, 9). However, velocity optimum regarding performance is higher than the maximum velocity that can be set on the machine, as shown by the figures.

We extended the experiments to the total yarn spectrum processed in the plant, and determined optimum coning velocities and the additional volume of production that could be attained by using them.

For the yarn types included in the experiment, on the basis of their quantity coned in 1978, we estimated that the surplus production that could be

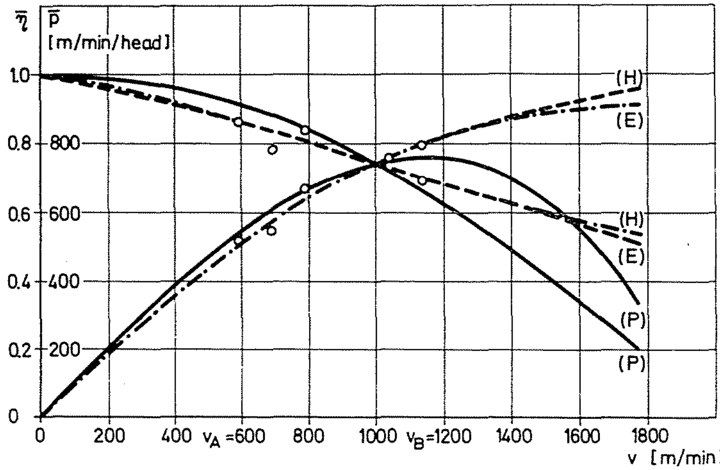

Fig. 8. Average efficiency $\bar{\eta}$ and average performance $\bar{p}$ *vs.* velocity on Schweiter CA-11 automatic coner. 19.2/2 tex 100% polyester yarn, 10 heads/1 tier device

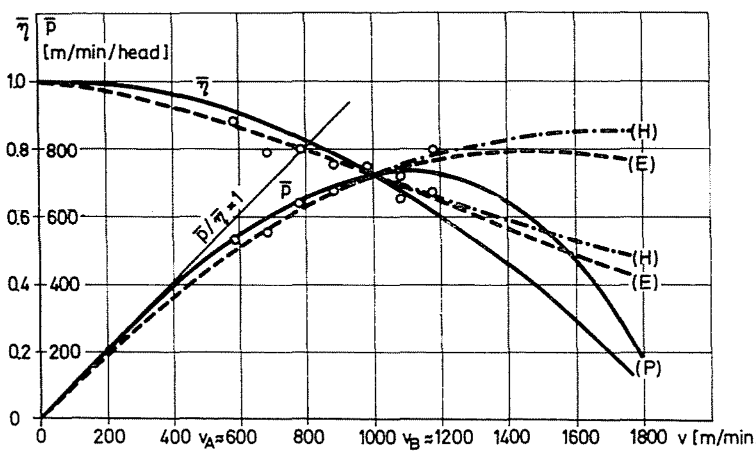

Fig. 9. Average efficiency $\bar{\eta}$ and average performance $\bar{p}$ *vs.* velocity on Schweiter CA-11 automatic coner 22.2/2 tex 70% PES-30% wool yarn on cops. 10 heads/1 tier device

achieved by utilizing the velocities proposed would amount — under ideal conditions — to around 201.8 tons, that is 20.88%. The detailed data for the calculations are summarized in Table 1.

Table 1

Estimated values of performance increase by velocity optimization on the Schweiter CA 11 Coner (total production of the coning department in 1978: 1108 metric tons)

Yarn count, Nm	Yarn composition	Production in 1978	Specified coning velocity, m/min	η, %	Performance m/min	Proposed velocity, m/min	Estimated η, %	Estimated performance m/min	Estimated increase in performance, %	Estimated increase in production tons*
32/2	3456 B/C-35% PES	162	900	80.4	643	1150	66.5	764	18.9	30.62
36/2	8248 A/AA-55% PES	144	800	79.6	637	1150	65.4	752	18.1	26.06
44/2	3487 A/AA-55% PES	138	900	70.8	637	1100	61.8	680	6.8	9.23
	3591	500	900	80	720	1150	71	817	25.1	125.50
52/2	3584 A/AA-70% PES	22.4	600	88.2	529	1150	67.1	772	45.8	10.26
	Total	966.4								201.82 (20.88%)

* On the basis of production in 1978

Average efficiency and performance vs. velocity for the Savio automatic coner equipped with individual tier devices

This machine has a Loepfe yarn cleaner device. Its signals were utilized for state sensing. The signals were scanned in defined intervals with the multiplexer interface and processed by the computer EMG 666. The results are presented in Fig. 10, demonstrating that in this case the hyperbolic approach

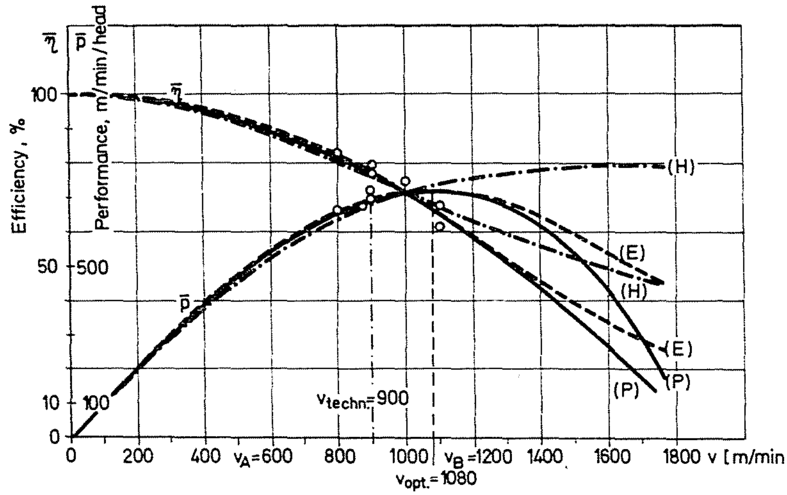

Fig. 10. Average efficiency $\bar{\eta}$ and average performance $\bar{p}$ *vs.* velocity on Savio 48-head coner. 27.8 tex 55% PES-45% wool yarn

(H) is unsuited, owing to the steep "cutoff" found on the experimental efficiency curve. However, the parabolic approach (P) which was found to be very restricted in applicability fits the experimental points fairly well. None the less, in this case too the best approach was attained by the exponential formula (E).

Average efficiency and performance vs. velocity relationships for the Schlafhorst Autoconer

The coning department fitted with the Schlafhorst Autoconers is process-controlled by an Indicator computer. We therefore developed an optimization procedure connected to this computer.

The condensed algorythm of optimum velocity search is shown in Fig. 11, together with the interpretation of the initial and basic data. The velocity range

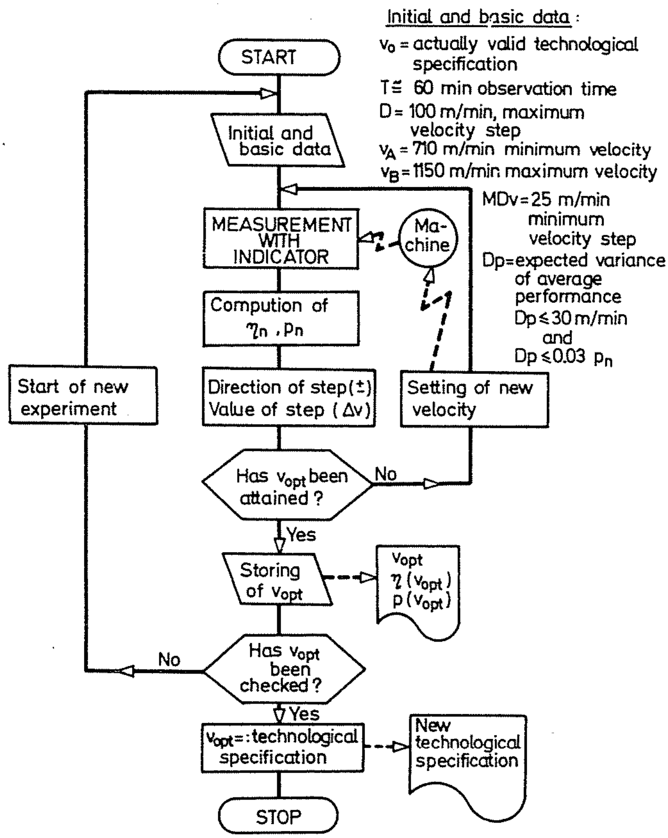

Fig. 11. Condensed algorythm for finding optimum velocity with Indicator computer for Schlafhorst Autoconer

that can continuously be set on the Autoconer is $v_A = 10$ m/min to $v_B = 1150$ m/min.

The procedure consists of two stages:

— first, starting from a given initial velocity, optimum velocity is found, and

— the obtained optimum velocity is subsequently checked in another shift, in another period of time, or with another worker.

To test the procedure in practice, extensive experiments were carried out in the coning department. By way of example, the experiments with 20 tex polyester/cotton yarn and 20 tex polyester yarn are presented in Fig. 12 and Fig. 13, resp., demonstrating v_{opt} values of 1150 and 1800 m/min, resp.

In the whole department, with one or two exceptions only, the performance curves of the yarns processed rose monotonously, similarly to the examples shown in Figs 12 and 13. This finding indicated that the velocity

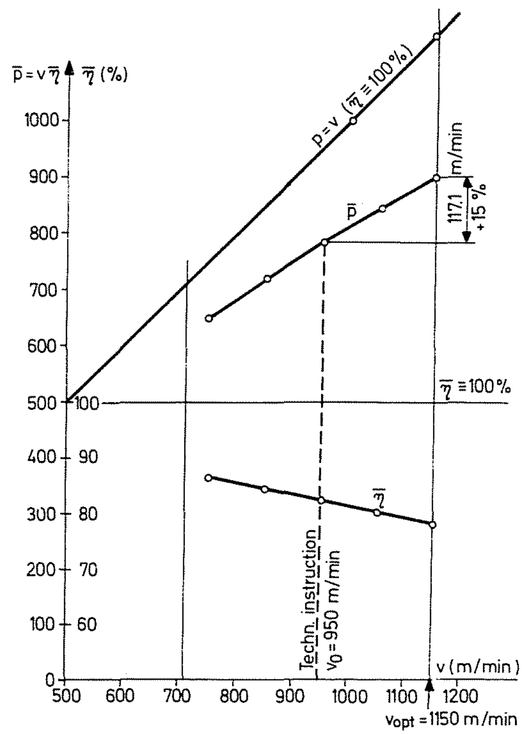

Fig. 12. Average efficiency $\bar{\eta}$ and average performance $\bar{p}$ *vs.* velocity on Schlafhorst Autoconer, 50 heads (16–20 units), 20 tex 67% PES-33% cotton yarn

range which can be set on the Autoconer does not correspond to the velocity optimum regarding performance, a constraint is placed to the velocity optimum by the upper velocity limit of the machine.

The summarized results of the series of experiments performed in this coning department are presented in Table 2 the velocities specified in the technological instructions, optimum velocities proposed on the basis of our experiments, and the additional relative increase in performance to be expected by applying these optimum velocities. The performance increases vary between zero and 33%.

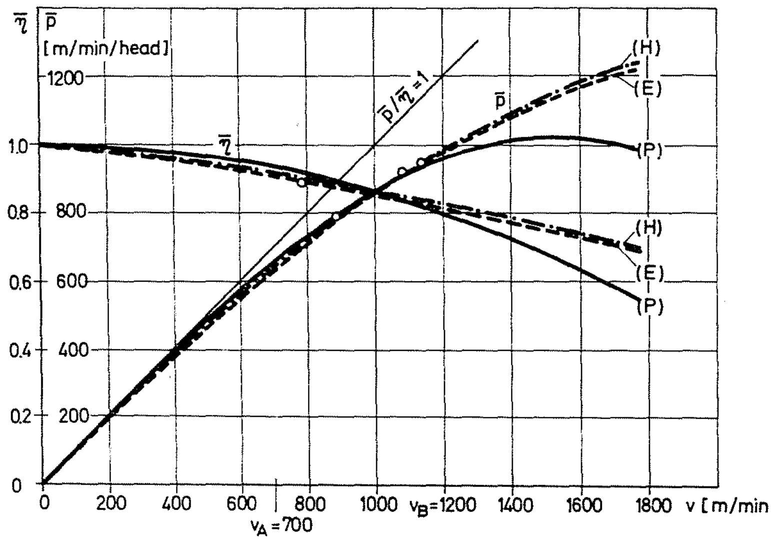

Fig. 13. Average efficiency $\bar{\eta}$ and average performance $\bar{p}$ *vs.* velocity on Schlafhorst Autoconer, 50 heads, two tier devices/10 heads, 20 tex PES yarn on cops

Table 2

Estimated values of performance increase by velocity optimization on the Schlafhorst Autoconer

Yarn type	Count, tex	Velocity specified m/min	Velocity optimum m/min	Performance increase, %
PES	20	950	1150	~15
Cotton	14.5	800	1150	~33
Neon H, paraffined	20	850	1150	~14.5
Neon V, paraffined				
20 heads 20 tex	10.5	950	1150	~14.5
30 heads 10.5 tex		840	1150	~29
PES	12.5	1150	1150	~ 0
PES	16.5	1100	1150	~ 4.5
Paraffined weft	10.5	950	1140	~17.6
Cotton GZ				
40 heads 10.5 tex	12.5	900	1140	~26
10 heads 12.5 tex		940	1140	~19.7
Knitting yarn paraffined 20		850	1200	~20
Weft paraffined				
40 heads 10.5 tex weft	10.5	950	1200	~25
10 heads 20 tex knitting yarn		900	1200	~25

On the basis of yarn composition and actual production in the third quarter of 1978, the estimated production increase amounts to $6118 \cdot 10^3$ km or 92.90 tons of yarn. This corresponds to 14% in length and 13% in mass of total production.

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