INTRODUCTION TO THE PROBLEM OF REMNANTS ON THE PACKAGES AFTER WARPING

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ABSTRACT

In warping process, which deals with the assembling of the wrap threads from the packages into warper beams, the replacement of the exhausted packages by full packages is carried out for all the packages at a time, because the common creel type used in the Egyptian weaving sheds is the carrage creel. The replacement of the creel is normally carried out between two successive warper beams, leaving the remnant of the yarns on the packages. A simple procedure is given to pre-estimate the minimum percentage of yarn remaining on the packages in the case, when only 0.1 up to 1%of the total number of packages are permitted to be exhausted during warping. This minimum percentage of remnant is defined as the maximum theoretical allowable remnant percent. Equations are given to calculate the maximum warping batch length, the corresponding suitable package length and the remnant percent on the packages. The given equations show to what extent the maximum theoretical allowable remnant percent on the package after warping is affected by the coefficients of variation of the outer package diameter, the winding density, the yarn count and the number of spinning bobbins wound on each package. However, The equations show that, the coefficients of variation must be kept at its lowest by setting exactly equal all the winding spindles.

NOMENCLATURE

- b winding stroke (cm)
- d_e average diameter of the empty package (cm)
- d_m average outer diameter of the full package (cm)
- e number of ends (warp threads) per warper beam
- ℓ length of yarn wound on a package (meters)
- L_{max} maximum possible length of the warping batch (meters)
- m number of warper beams produced until recreeling (beams/package)
- n number of spinning bobbins required to produce one package
- N_e English yarn count
- N_m metric yarn count (meters/gr)
- N_{mb} average metric yarn count on the spinning bobbins (meters/gr)
- N_{mc} average metric yarn count on the packages (meters/gr)
- $R\%$ maximum theoretical allowable remnant percent on package after warping which represents in the same time the minimum possible remnant percent without earlier package exhaustion.
- $s\%$ more length on the package required to avoid the sloughing-off of packages at small diameters (%)
- V net volume of package (cm^3)
- W package net weight (kg)
- w_{max} maximum warper beam capacity (kg)
- x early exhausted packages (%)
- γ coefficient of variation of a property (%)
- ϱ package density (gr/cm^3)
- σ standard deviation of a property (the same units of the property)

INTRODUCTION

The economical working conditions in the weaving industry necessitate all the sources of losses in any form and in any stage of the production line to be eliminated. The losses might take place in the form of loss in the quality, loss in the productivity, higher waste percentages in one or more processes, reprocessing the same material, higher energy consumption... etc. The remnant of yarn, that remains on the packages after warping, is one of the different forms of the losses in the long line of fabric production which consists of all processes of weaving preparation as well as the weaving process itself [1,2,3]. However, the specifications and characteristics of the suitable packages for the weaving preparation are to be determined in the weaving shed according to the specified working conditions [4,5].

At present, the problem of the remnants on the packages after warping is treated in one of the following manners:

1. The remnant of yarn is delivered to pirn winders or to the weaving room, according to the type of looms used in the weaving shed, in order to be used as a weft. However, this solution is only possible in the case of producing woven fabrics using identical yarns for both warp and weft. This means that the weft yarns have a twist level higher than the recommended, and accordingly become more expensive than other yarns with lower weft twist level. In addition, the feeding with small packages leads to either a lower production efficiency or to the need of more labours to cope with the frequent replacement of the small feeding packages.
2. The remnant of yarn is delivered back to the package winding in order to be rewound again into package with suitable size. This reprocessing of the yarns leads to an increase in the manufacturing cost of this amount of yarns, and in the same time takes the place of another new amount of yarns. In other words, this leads to a decrease in the productivity of the winding section. In addition, the frequent processing of the yarns causes deterioration in the yarn quality as the yarn might become more hairy, and less extensible with higher initial modulus [6,7].
3. The remnant of yarns is collected over a long period and then is sold very cheaply as a second or even third quality lots.
4. In several weaving sheds, it was observed that the labour let the packages to be exhausted completely on the creel. In this case the remnant percent is zero, the intensity of knots in the warp sheet is high, and accordingly, the quality of the woven fabric might be affected. In addition, the productivity of the warping machine is decreased.

The problem of the remnants on the packages after warping may be too excessive in practice, where the remnant may exceed 8% [2].

However, the results given in that paper [2] show that about 9% of the packages were exhausted in this case before the replacement of the creel. The replacement of each exhausted package needs a knot, and this means that there is a number of knots in the last warper beam equal to about 9 % of the number of warp threads on the beam. The presence of those knots leads to a decrease in the quality of the woven fabric. In addition, the individual replacement of the exhausted packages might need a period of time until the restart of the machine about three times longer than the average replacement time of one package in case of replacement of all packages at a time.

The high percentage of remnants on the packages might be attributed to:

1. The lack of co-operation between the different sections of the weaving shed. The winding room is the last section in the spinning where it is advantageous to produce all the package with more or less same specification independently from the actual need of the next process, of warping. This co-operation is entirely missed in the weaving sheds, which have to purchase their yarns and accordingly have accept the delivered package specifications.
2. The warping batch length is so selected without taking into consideration the maximum warper beams capacity, average net weight of the package, and the number of warper to be produced before the need of recreeling.

However, the problem of the yarn remnants on the package after warping can be considered a general problem, noticed in many weaving sheds to different degrees [7].

SCOPE OF WORK

In this work, the problem of the remnants, that remain on the packages after warping, will be investigated. The minimum possible of remnants will be statistically estimated in relation with the characteristics of the population of the package fed to the warping machine. These characteristics are the mean and the coefficient of variation of the outer package diameter, the package density, the package weight and the average yarn count on the package. The following points will be taken into consideration during the investigation:

1. The replacement of the creel will be carried out between two successive warper beams.
2. The excessive knots due to the earlier exhaustion of package must be kept very low.
3. The warper beam capacity will be fully utilized.
4. The winding room will deliver the package with the specified weight.

ESTIMATION OF THE MAXIMUM ALLOWABLE PACKAGE REMNANTS

The suitable package weight is specified according to the yarn count as well as to the length required to be withdrawn from it in the warping process. However, the package size is determined in winding with the aid of the outer diameter. The actual package length can therefore be calculated as follows:

$$\ell = (\pi/4)(d^2_m - d^2_e)b\varrho N_{mc} \text{ meters} \quad (1)$$

$$= V\varrho N_{mc} \text{ meters} \quad (2)$$

The three factors mentioned on the right hand side of Equation (2) are independent from each other. The mean package diameter d_m and according the package volume differs from package to package. The winding spindles must be theoretically set produce equal package sizes. Actually all the spindles are not set identically, because the regularity of the settings on the different spindles is not given much attention, specially the setting concerning the package size which governs the doffing time.

As far as the package density [1] is concerned, it is well established that the package density depends on the winding tension and the pressure applied on the package against the driving drum. Also, these two factors are rarely found identical in value in two spindles.

In addition, it is quite convenient, that the yarn count is allowed to vary within an accepted standardized range. It is worth mentioning that the length of yarn on the package is affected by the average count N_{mc} resulting from yarns on the spinning bobbins producing one package. In this case, the standard deviation of the count of the package yarns is calculated from the standard deviation of the count of bobbing yarn assuming a normal distribution. Also, each package is a representative sample consisting of n bobbins in a normal distribution

$$\sigma\{N_{mc}\} \simeq \sigma\{N_{mb}\}/[n]^{\frac{1}{2}} \text{ meters, and}$$

$$\gamma\{N_{mc}\} \simeq \gamma\{N_{mb}\}/[n]^{\frac{1}{2}} \quad (3)$$

The mean value and the coefficient of variation of the length of yarn wound on the package can be estimated using the transforming technique [8].

$$\bar{\ell} \simeq (\pi/4)(\bar{d}^2_m - d^2_e)(1+\gamma^2_{dm})\, b\bar{\varrho}\bar{N}_{mc} \quad (4)$$

$$\simeq \bar{V}\bar{\varrho}\bar{N}_m \quad (5)$$

and, if there is no correlation between the three variables, the coefficient of variation of the length of yarn on the package could be estimated as:

$$\gamma^2_\ell \simeq \gamma^2_v + \gamma^2_\varrho + \gamma^2\{N_{mc}\} \quad (6)$$

$$\simeq 4\gamma^2_{dm} + \gamma^2_\varrho + \gamma^2\{N_{mb}\}/n \quad (7)$$

Equation (7) shows that the coefficient of variation in the length of the yarns on a package is mainly affected by the variation in the package size (mean outer diameter d_m), while the increase in the number of the spinning bobbins wound into one package leads to a decrease in the coefficient of variation of the length.

In warping, where more than 500 ends are withdrawn simultaneously from the creel, a certain length is withdrawn from each package, which is sufficient to produce a number of complete warper beams. The creel is then changed completely with the remnant of yarns on the package. In this technique, the intensity or frequency of the last warper beam is entirely avoided. In order to improve this technique, the maximum length to be withdrawn from the package be so calculated, that only 1% (or less) or total number of packages on the warping creel may be early exhausted (expired) during the warping of the last warper beam. In this case, the amount of the yarns remaining on the packages can be defined as the maximum theoretical allowable remnant. The average length of the yarn remaining on the package is equal to $2.4\sigma_\ell$ meters, and the remnant percent is then calculated from the following equation, assuming that the package length variation from package to package has a normal distribution,

$$R\% \simeq (2.4\sigma_\ell/\bar{\ell})\times 100 \simeq 2.4\gamma_\ell$$

$$\simeq 2.4[4\gamma^2_{dm} + \gamma^2_\varrho + (\gamma^2\{N_{mb}\}/n)]^{\frac{1}{2}} \quad (8)$$

The procedure of this calculation is represented in Figure (1).

However, the number of packages, that may be early exhausted during the warping of the last warper beam, could be reduced, furthermore, to about 0.1 % (or less) of the total number of packages on the warping creel. In this case, the remnant percent on the packages after warping must be then increased to about:

$$R\% \simeq (3.1\sigma_\ell/\bar{\ell})\times 100 \simeq 3.1\gamma_\ell$$

$$\simeq 3.1[4\gamma^2_{dm} + \gamma^2_\varrho + (\gamma^2\{N_{mb}\}/n)]^{\frac{1}{2}} \quad (9)$$

This gives an increase in maximum theoretical allowable remnant percent of about 29% considering the remnant percent of the first case as 100%, where 1% of package may be exhausted within the last warper beam.

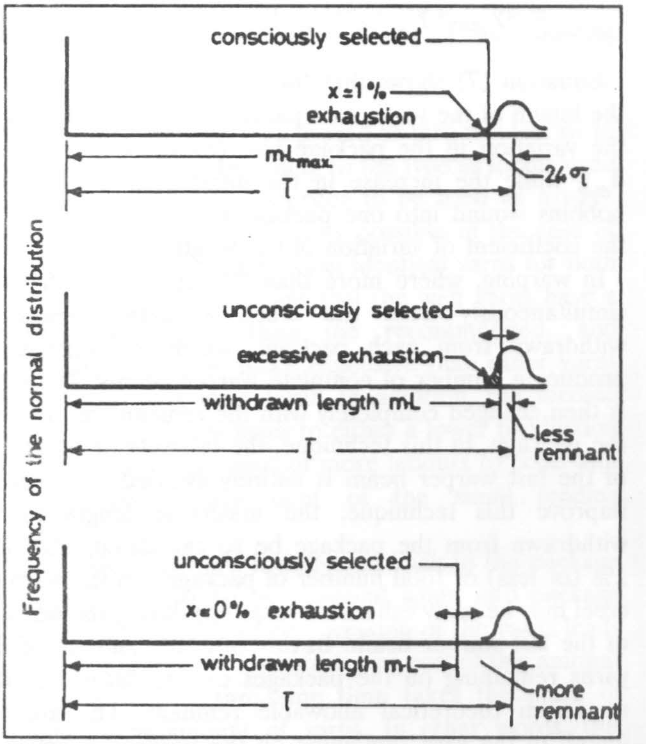

Figure 1. Estimation of the maximum theoretical allowable remnant in comparison with actual cases.

Equations (8) and (9) show the factors affecting the maximum theoretical allowable remnant on the packages, which must be kept at their lowest values in order to reduce the remnant percent on the packages at a very low level. Therefore, attention must be given in the winding in order to produce packages of regular density and regular size. It was found that the specific winding tension varies from one spindle to another within a wide range (0.8 to about 2 gr/tex), a matter which results a variability in the package density. In addition, the higher tension levels lead to deterioration in the yarn properties such as extension percent at break, initial modulus, and hairiness. The proper setting of the specific winding tension is about 1 gr/tex. The variation in the specific winding tension from one spindle to another must be limited within the range of ±0.15 gr/tex. Proper tension setting is found to be difficult to achieve due to the variation in the balloon dimensions from the start to the end of the spinning bobbin, due to the variation of the twist level and accordingly the coefficient of friction between the yarn and its guids over which it passes.

As far as the package size is concerned, the proper size of the package must be selected taking the following points into consideration:

1. The length of the warping batch must be so selected that the warper beam capacity is completely utilized. The batch length corresponding to the maximum warper beam capacity can be calculated from the following equation:

$$L_{max} \simeq (1000\ w_{max}\ N_m)/e \quad \text{meters} \tag{10}$$

2. The maximum package size and accordingly the maximum outer diameter of the package is limited by the pitch of the warping creel.
3. The package size and accordingly the length of the yarn on the package must be so selected that this length is sufficient to warp m complete warper beams plus the maximum theoretical allowable remnant percent according to equations (8) or (9). The number of warpers beams m per package is so selected that the bigger package size sufficient to warp (m+1) warper beams is bigger than the pitch of the warping creel, and accordingly is unsuitable for warping.

The so selected package size might be smaller than the maximum possible package size, but it will be the size that gives the least possible remnant percent on the package (defined as the maximum theoretical remnant percent on the package). In this case the number of bobbins per package (n) is high enough to reduce the negative effect of the yarn count variation (γ_{Nmb}) as shown in equations (8) and (9). The length of yarn on the package can be then calculated from equation (11):

$$\ell = (m\ L_{max})/(1\text{-}0.024\gamma_{\ell}) \quad \text{meters} \tag{11}$$

In practice, it is well known that the probability of the sloughing-off of packages during yarn withdrawal increases at smaller package diameters [5], a matter which causes some difficulties as well as more waste during warping. Therefore, it is well recommended to give s% more length on the package for safety in order to reduce the sloughing-off frequency or even to avoid it entirely. Accordingly, the recommended length of yarn on the package will be

$$\ell = m\ L_{max}\ (100+s\%)/(100\text{-}2.4\gamma_{\ell}) \quad \text{meters} \tag{12}$$

and the package weight

$$W = (m\ w_{max}/e)\ (100+s\%)/(100\text{-}2.4\gamma_{\ell}) \quad \text{kg} \tag{13}$$

where s varies between 0.5 and 0.8 % according to the sloughing-off frequency [5].

The selected package size in the way mentioned before leads to the following advantages:

1. The efficiency of the warping machine will increase as a result of the lower rate of creeling (changing the empty package with full packages).
2. The increase of the batch length leads to an increase in the warping and sizing efficiencies: in warping due to the lower rate of doffing of the full warper beams; in sizing due to lower rate of creeling (changing the empty warper beams with full warper beams).
3. The sum of the waste percentages in winding, warping and sizing will be reduced due to the increase in the total weight of the batch.
4. The higher intensity of the knots within a warper due to the improper creeling time is entirely avoided. The proper creeling is carried out as preselected between two successive warper beams (the m^{th} and the $(m+1)^{th}$ beams), during which all the packages are changed and the knots can be easily removed from the warp sheet.
5. The remnant percent on the package can be pre-estimated at its lowest possible rate using the following equation:

$$R\% = [(2.4\gamma_\ell + s\%)/(100+s\%)]\times 100 \qquad (14)$$

which shows that the maximum theoretical allowable remnant percent (R%) could be further reduced by:
a- Keeping γ_ℓ and accordingly the affecting factors given in equation (8) at their lowest levels, specially the coefficient of variation of the outer package diameter γ_{dm}, a matter which means that all the spindles must be set to produce the packages with more or less the same diameter, and
b- Taking the recommendations given previously by the author [5]into consideration in order to reduce the sloughing-off frequency or even to avoid it entirely. In this case the value of the length (s%) for safety could be selected with a smaller value.

In order to make use of this procedure in practice, the delivered package from the package winding process to the warping room are measured in order to evaluated the coefficient of variation for the package diameter γ_{dm}, package density γ_ϱ, yarn count γ_{Nmb}, and package weight γ_{wt}. The sample size is 20 package. The maximum theoretical allowable remnant percent is then calculated for some different yarn counts in two different weaving sheds. The results of the measurements are given in Tables (1), and (2) which show also the actual remnant percentages observed in some cases. The values given for the actual remnant percent on the package are not representative figures, because they vary from batch to batch within the same weaving shed and from weaving shed to another. The actual remnant percent on the package after warping is either higher or lower than the maximum theoretical allowable remnant percent. Tn the first case, it is recommended to reduce the average package weight with the same ratio, or to increase the length of the batch with the same ratio divided by the number of warper beams per package m, specially if the warper beam capacity is not completely utilized. It might be more profitable, if all the working figures such as the average package size, the coefficients of variation given in equation (8), and the warping batch length are reorganized as described in this paper. In the second case, lower actual remnant percent results also an intensive early exhaustion (up to 16%) which is unaccepted from the quality point of view due to the higher knots intensity in the warp sheet.

However, the measured values given in Table (2) show that remnant percent after warping could be further reduced through the more regular package specifications.

Table 1: Estimated and actual remnant

			20 / 34 □	30 / 50 □	30 / 50 ▵	40 / 66 □
Nominal count		N_e / N_m	20 / 34	30 / 50	30 / 50	40 / 66
$\bar{d}_m$		cm	181 3	193 8	218 9	205 9
γ_d		%	2.86	3.55	2.59	2.86
$\bar{\varrho}$		gr/cm³	0.41	0.42	0.46	0.44
γ_ϱ		%	0.98	2.8	4.5	3.4
actual	$\bar{N}m_b$		34.7	51.96	44.83	63.83
actual	γ_{Nm_b}	%	5.6	4.37	8.15	3.79
n		bbns/pkg	15	17	21	20
$\bar{V}$		cm³	3651	4163	4695	4619.3
γ_V		%	7.17	7.00	5.24	5.54
$\bar{W}$		kg	1.504	1.740	2.189	2.037
γ_W		%	7.06	7.4	6.4	6.61
γ_l		%	5.98	7.7	7.08	6.7
s		%	0.8	0.8	0.8	0.8
estimated	x = 1%	mL_{max}	44 344 m	73 106 m	80792 m	108 224 m
estimated	x = 1%	R %	15.03	19.14	17.67	16.76
estimated	x = 0.0%	mL_{max}	42 177 m	68 268 m	75 961 m	102 167 m
estimated	x = 0.0%	R %	19.18	24.5	22.59	21.42
actual	x	%	0.01	16.0		4.5
actual	mL	m	39 794	83136		114 900
actual	R	%	23.75	8.04		11.63

□ weaving shed 1 ▵ weaving shed 2

Table 2 : Estimated remnant on pkgs. of relatively imp. wt. reg.*

Nominal count N_e	14	20	40
Nominal count N_m	24 Δ	34 Δ	66 Δ
$\bar{d}_m$ cm	20.11	20.13	20.21
v_d %	1.35	1.32	1.03
$\bar{\varrho}$ gr/cm^3	0.46	0.48	0.48
v_ϱ %	2.24	2.48	3.1
actual $\bar{N}_{m_b}$	21.85	34.18	66.47
actual $v_{N_{m_b}}$	5.55 %	3.81 %	3.11 %
n bbn/pkg	17	19	20
$\bar{V}$ cm^3	3888	3949	4139
v_V %	2.98	2.96	2.33
$\bar{W}$ kg	1.784	1.902	1.967
v_W %	3.76	3.62	3.82
v_1 %	3.75	3.72	3.78
s %	0.8	0.8	0.8
estimated, x=1%, mL_{max}	35 190 m	58 736 m	117 921 m
estimated, x=1%, R %	9.72	9.65	9.8
estimated, x=0.1%, mL_{max}	34 175 m	57 057 m	114 483 m
estimated, x=0.1%, R %	12.33	12.23	12.44

• pkgs = packages wt = weight
imp. = improved reg = regularity
Δ weaving shed 2

CONCLUSION

The complicated problem of the remnant percent packages after warping could be eliminated by using the simple procedure explained in this work. The knots intensity due to the early exhausted packages would be entirely avoided or at least kept at a very low level. In the same time, the remnant percent could be kept at a reasonable pre-estimated level through the selection of the proper working conditions such as the length, the number of warper beams until recreeling, and the suitable package weight [equations (12) and (13)]. The number of complete warper beams until the recreeling may be so selected that any excess warper beam will make the required package size unsuitable for the pitch of the warping creel.

However, the pre-estimated level for the remnant percent, which is defined as the maximum theoretical remnant percent ,equation (14), could be reduced by using package of more regular specifications and namely with lower coefficients of variation for the outer diameter of the package, package density, and yarn metric count, equations (8) and (9). The improvement in the regularity of the package specifications lead to about 30-40% reduction in the theoretical allowable remnant percent on the packages after warping.

It is worth mentioning that it is found to be very difficult to conclude the reduction of the actual remnant percent in the form of definite figures because the actual remnant percent results from the non-accommodation or non-adaptation of the average package size with the batch length. Thee extent of the non-accommodation varies between the observed weaving sheds and even within each weaving shed even for the same batch specifications, a matter which makes it very difficult to state a definite figure for the actual remnant percent and accordingly the amount of the reduction. The accommodation of the batch length and the number of beams per package with the package weight needs reorganization of the working order in the weaving shed, a matter which was found to be very difficult within a research work. However, the explained procedure is applicable for the routine work of the mass-production in the industry.

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