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WEAVE ROOM MANAGEMENT

Key words: *air-conditioning, helper-weaver system, integrated mill, loom assignment, machine interference, mill, pick counter, pick spacing, relative humidity, smash, smash hand, spinning mill, total cost.*

Introduction

The conversion of yarns to woven fabrics is an integrated system utilizing many types of machinery and skills. Some mills are fully integrated; some are concerned only with weaving and depend on others for the rest of the process. An *integrated mill* will have a different system of weave room management from one which depends on buying the yarn from a *spinning mill*. Since weaving involves the use of all types of yarns—natural, man-made, fine or coarse—this must also have its effect on the weaving system.

Fabric production has become a very competitive industry and the survival of any system depends on the economic production of fabrics suitable for the end use. Fashion and styling play a very important role in fabric production and this has a great effect on the management of weaving mills. Effective management can only be achieved by full knowledge of the mill capabilities, materials used, sales and market situation. Development of new fabrics must be based on this type of knowledge.

Loom Production and Efficiency

The productivity of the loom can be considered to be a function of its speed, width and type, but as was mentioned earlier, the loom speed is function of its width and type. Another very important factor which affects the production of fabric on any loom is the *pick spacing*. Equation 17.1 gives the linear production of the loom in m/h at 100% efficiency.

Theoretical loom production =

$$\frac{\text{loom speed}}{\text{pick density}} \times \frac{60}{100} \text{ m/h} \qquad (17.1)$$

where the loom speed is measured in picks/min and the pick density in picks/cm.

This theoretical production cannot be achieved unless the loom runs continuously without any stoppage; this is not possible in practice, since warps have to be changed and there are bound to be some stoppages because of yarn breakages or mechanical failures. Therefore the loom has an efficiency less than 100 per cent (see eqn. 17.2).

$$\text{Loom Efficiency} = \frac{\text{actual production}}{\text{theoretical production}} \times 100 \text{ per cent} \qquad (17.2)$$

Although the loom speed drops with width, the overall production in m^2/h increases with loom width, as shown in Fig. 16.7. To demonstrate this, consider the following examples. Let the speed of a 1.1 m (45 inch) width loom be 200 ppm and the speed of a 2.1 m (85 inch) loom be 150 ppm. Also assume that the wide loom produces two fabrics side by side, each of 1 m wide and similar to that produced by the narrower loom. Let the fabric have a pick density of 25 picks/cm (63.5 ppi) and let the two looms have efficiencies of 90% for the narrow loom and 80% for the wide loom.

Production of the narrow loom:

$$P = 200\frac{pick}{min} \times \frac{1\ cm}{25\ pick} \times \frac{60\ min}{hr} \times \frac{1\ \ m}{100\ cm} \times 1m \times \frac{90}{100} =$$

$$4.32\ m^2/h$$

Production of the wide loom:

$$P = 150\frac{picks}{min} \times \frac{1\ cm}{25\ picks} \times 60\frac{min}{hr} \times \frac{1\ \ m}{100\ cm} \times 2^{*}m \times \frac{80}{100} =$$

$$6.48\ m^2/h$$

*Note: 2 should be used rather than 2.1 because this gives the *fabric* width.

The *weaving efficiency*, which describes how effectively a batch of looms work in a normal working environment, is affected by many factors including:

(1) Loom type, width and speed.
(2) Yarn type, quality and density.
(3) Fabric structure and style.
(4) The weaver's skill and work load.
(5) The weaving conditions.

The loom speed has a direct effect on the number of warp breaks, filling breaks and mechanical stops. The width also affects the number of breaks because these depend, in part, on the number of ends in the warp.

The quality of the yarn has an obvious effect on loom stoppages and so does the type of yarn. A weak, fuzzy yarn will break very often whereas a strong smooth uniform yarn will withstand the weaving conditions better. The fabric structure also affects the warp breakage rate, since a fabric with a high number of interlacings in the design or a high end density (epi) tends to have a large number of breaks. The style has an effect on the time taken to repair a yarn break. In the case of a one color fabric, the weaver can find and tie the broken end much quicker than in the case of colored stripes; with dark colors it is more difficult to repair broken ends than with light colors. Skilled weavers can repair broken yarns very quickly compared to unskilled weavers. Also the work load of the weaver has a very important effect on the weaving efficiency, since it affects the time a loom is stopped awaiting attendance. Weaving conditions such as humidity, temperature and loom condition are also very important factors affecting the rate of loom stoppages.

The weaving efficiency depends to a very great extent on the number of looms per weaver. This number varies from 4–150 looms per weaver and depends on the number of loom stops and the repair times. Indeed, the maximum loom efficiency can be obtained if the weaver operates only one loom, but this is normally quite uneconomical because the idle labor more than offsets the savings in idle machine costs. Indeed, what is required is a minimum *total cost*. Therefore, there must be a number of looms allocated to a weaver which gives the best compromise between idle labor and idle machine costs. It is the duty of good management to arrive at the best decision for the various different conditions as they arise.

The Weaver's Work Load

Two systems are commonly used for deciding on the type of work the weaver has to perform. In the first, the weaver is allotted a relatively small number of looms and is expected to perform any type of work relating to weaving. This system is only suitable when limited skill or low wages exist. In the second system, the *helper-weaver system*, the weaver is highly skilled and only performs jobs which need these skills; these tasks seldom take more than 1 or 2 min. In this system, the weaver normally has a large complement of looms, and has working with him or her one or more helper weavers. The work of the weaver is to patrol the allotted section inspecting the warp and the fabric to prevent yarn breaks or fabric defects from occurring. Also, the weaver has to repair any broken ends and to start the loom again.

The helper weaver, or *smash hand*, is normally less skilled and his or her work involves those jobs which take more than about two minutes to repair. Such jobs are: repairing a *smash*, changing a warp beam, getting a new warp going, etc. This system uses the weaver to full advantage and is in wide use in large mills.

The work load of the weaver is normally from 45–50 min. every hour, leaving 10–15 min. for relaxation and personal needs. The working time is divided between repairing yarn breaks, walking and inspection. A weaver can walk several miles in an 8-hr. shift and this has to be considered when allotting the weaver his or her load. Table 17.1 lists typical weaving conditions which should give an idea of a weaver's work.

Table 17.1

Loom Stops and Repair Time for a Shuttle Loom

Type of Stoppage	*Typical Occurrence Rate per Loom Hour*	*Typical Repair Time (min.)*
Warp break	1·0	0·9
Filling break	0·3	0·4
Slack ends	0·1	0·5
Other (misdrawn, bang-offs, etc.)	0·1	0·8
Total	1·5	—

From this table it is possible to calculate the time spent by the weaver on repairs per loom hour as follows:

$$\text{Repair time/loom hr} = (1.0 \times 0.9) + (0.3 \times 0.4) + (0{\cdot}1 \times 0{\cdot}5) + (0{\cdot}1 \times 0{\cdot}8)$$

$$= 1{\cdot}15 \text{ min.}$$

If the weaver is allowed 20% of his time for relaxation and subsidiary duties, then the weaver work will amount to 48 min./hr. This time is spent on repairs as well as patrolling. If

30 min·/hr. are considered necessary for repairs, the number of looms per weaver is: $\frac{30}{1 \cdot 15} = 26$ looms.

If on the average the weaver walks from one loom to another in 3 seconds, the time of one patrol is $3 \times 26/60 = 1 \cdot 3$ min. The balance of time available for patrolling is $48 - 30 = 18$ min./hr. and therefore it is possible for the weaver to make $18/1 \cdot 3 \simeq 14$ patrols/hr.

To estimate the distance a weaver has to walk every hour, let the average distance from one loom to the next be assumed to be 3 meters (10 ft).

Patrolling distance/hr = 3 x 26 x 14 = 1092 meters. In English measure this is about 5 miles/shift. This is one of several constraints on the weaver's work load.

Calculation of the Weaving Efficiency

If the weaver works only on one loom, then according to the rate of stoppage and repair times given in the previous example, the efficiency would be $(1 - 1 \cdot 15/60) \times 100 = 98$ per cent. This means that the weaver's work load would be only 1·15 min./hr., which would make the cost of weaving very high. Normally the weaver has to attend to a large complement of looms and there is no guarantee that, when the loom stops, the weaver will be immediately available to repair the break and restart the loom. Thus the loom has to be stopped for a certain period of time waiting for the weaver to attend to it. This results in a loss of machine efficiency due to *machine interference*. As the stops occur at random, prediction of the weaving efficiency is complicated. However, it is not difficult to measure the loom efficiency over a certain weaving time and obtain the average weaving efficiency for any set of looms. This is normally done by counting the actual number of revolutions of the loom crankshaft using a *pick counter*.

Let measured loom efficiency = η

$$\eta = \frac{\text{No. of picks actually inserted}}{\text{loom speed} \times \text{time}} \times 100 \text{ per cent} \quad (17.3)$$

This is actually the number of picks inserted in the fabric expressed as a percentage of the number of picks which should have been inserted.

It is important for the weave room manager to be able to estimate the weaving efficiency before assigning looms to a weaver even though it is usually necessary to adjust it subsequently. It should be remembered that the assignment should vary according to weaving conditions. In other words, the manager should be in a position to calculate the weaving efficiency for any new *assignment* which arises as the yarn, fabric structure, or some other factor is changed. There is no simple formula to give an immediate answer, but there are methods available by which the weaving efficiency can be estimated. One of the methods used in this connection is the one given by Kemp and Mack[30]; tables were produced from which the weaving efficiency can be estimated with relatively simple calculations. According to this method, the weaving efficiency for the previous example is calculated as follows:

Let x = Average number of loom stoppages per minute

$$= \frac{1{\cdot}5}{60} = 0{\cdot}025$$

C = Average repair time in minutes

$$= \frac{1{\cdot}15}{1{\cdot}50} = 0{\cdot}77$$

N = Number of looms per weaver

$= 26$

k = Walking and inspection time (between two looms) in minutes

$$= \frac{3}{60} = 0{\cdot}05 \text{ min.}$$

For 20 per cent personal relaxation time the values of C and k are inflated to C' and k'.

$$C' = \frac{C}{1 - (\text{relaxation factor})} = \frac{0{\cdot}77}{0{\cdot}8} = 0{\cdot}96 \text{ min.}$$

$$k' = \frac{0{\cdot}05}{0{\cdot}80} = 0{\cdot}0625 \text{ min.}$$

To find the efficiency in the tables, the following two parameters are used.

$$xC' = 0{\cdot}025 \times 0{\cdot}96 = 0{\cdot}024$$

and

$$xNk' = 0{\cdot}025 \times 26 \times 0{\cdot}0625 = 0{\cdot}041$$

These two parameters relate the idle time of the looms to the total machine and patrol times respectively. In the particular case, the tables show by means of linear interpolation that the weaving efficiency is 91·9 per cent. It should be noted here that the efficiency values obtained from these tables exclude stops outside the control of the weaver, such as mechanical stops. This may reduce the efficiency by as much as 3 per cent and therefore the estimated weaving efficiency might be reduced to some 89 per cent.

The foregoing example shows how the tables can be used to estimate the effects of interference. It does not show what the optimum weaving efficiency should be. Before this can be considered it is necessary to consider some other aspects.

Computers

With computers it is possible to store all the data from the tables and, by using only a simple program, the efficiency can be calculated quickly and expeditiously. The weaving efficiency so calculated can be no more accurate than the estimate of the parameters involved but the use of computers enables the parameters to be continuously assessed so that better accuracy can be obtained. Furthermore the computer can be used to monitor performance and analyze the fault rates in terms of failures of machines, men or materials.

Weaving Costs

The success of any industrial or business enterprise can be measured by the profit per unit capital investment. Since the profits can be considered as the difference between sales income and production expenditures, total profits can be increased by increasing the volume of sales or by reducing expenditures or by increasing the value of the product. Normally, the market is highly competitive and the sales income per unit production is closely defined by supply and demand; rarely can the product dictate the price.

The sum of expenditures assigned to any product represents the cost of the product. Assuming that the price of the product and the productive capacity of the mill are fixed, then any increase in profit must be accounted for by a reduction in the cost of the product. The cost of a meter (yd) of a finished fabric includes a proportion incurred by each department which has a part in the production of the fabric. The elements of production costs can be defined as:

(1) Material costs (which in the case of a weaving mill are mainly due to yarn costs).
(2) Labor costs.
(3) Overheads, such as the cost of building, heat, power, machinery, insurance, tax, etc.

All these costs may be classified as direct or indirect costs.

Again this part deals only with weaving mill costs, but the discussion can only be general because of changing nature of weaving mills as far as the type of machinery, type of yarn, systems of organizations, etc., are concerned. It is intended merely to direct the attention of the reader to some of the important factors. Actual figures vary considerably according to the yarn material, count, fabric structure and so on. However, it is appropriate at this stage to present, in rough figures, the percentage of the different cost elements of a plain cotton woven fabric. In this example the costs are:

Raw material (yarn purchased)	65 per cent
Labor	20 per cent
Other manufacturing costs	15 per cent

The important point arising from these figures is that the weaving management has no control over about 65 per cent of the cost of the fabric they produce and profits can be earned only by very careful control of the remaining 35 per cent or so of the total cost.

The weaving costs (i.e. the cost of conversion of yarn to fabric) may be divided into three main elements:

(1) Labor costs.
(2) Fixed costs.
(3) Other expenses.

The labor cost is a function of the skill and personal efficiency of the operator and the type of work. However, it is not always advantageous in terms of total cost to consider the maximum efficiency in one isolated area. The labor cost is the sum of costs of personnel directly involved in operations from preparation through to inspection of the final fabric. Efficiency in one area may be bought at the price of inefficiency elsewhere. It is therefore necessary to optimize in terms of minimum *total* cost. Of the total conversion cost, labor forms a high proportion (often as much as 50 per cent).

The fixed costs are those which do not depend upon production; examples of these are rent, interest, depreciation on machinery, overheads, etc. These have to be paid irrespective of whether the machinery is earning revenue or not. These costs are of the order of 30 per cent of the total conversion costs, but the proportion is gradually changing.

This is especially true where expensive new weaving machinery is installed. These costs should be expressed in terms of cost/kg (cost/lb) of product and therefore the production rates have to be taken into account; it is entirely possible that the weaving cost/kg when using an expensive modern high-production machine is lower than the traditional cost. However, a new cost balance may be necessary to give the lowest possible total cost.

There is a considerable incentive to increase production rates using advanced machinery, and a corollary to this is that there is usually an increased demand for power. The cost of this power is reflected in the cost of the product; in tropical or semi-tropical areas, the increased power usage leads to a need for air-conditioning which inflates the cost of power and of the installation generally.

With the more expensive machinery and installations, it becomes necessary to spread the cost by shift working and increasing productivity.

Optimization of Costs

Frequently there is an ill advised insistence on high weaving efficiencies, but this does not necessarily lead to minimum weaving costs. To understand this, let the operation be analyzed mathematically after making certain simplifying assumptions.

Assume that the weaver's patrol is always along a fixed path which is in the form of a closed loop. Assume that the looms are equally placed around the loop and that the weaver patrols only in one direction (i.e. she does not turn back to repair a break, even though it occurs just after she has passed the particular loom). Furthermore, assume that the mending time is negligibly small compared to the average running time between breaks.

Let a = number of looms/weaver,

n = actual number of breaks/hr.,

N = number of breaks/hr. if they are repaired immediately,

L = labor and other variable costs/hr

F = fixed cost/loom hr

P = machine productivity (e.g. lb/hr) at 100 per cent efficiency

C = total cost/unit mass added to product during weaving

t = average time to walk from one loom to the next in hours

T = average machine cycle time in hours

= average time between one break and the next on one loom

η = machine efficiency.

Also let

T_O = average running time between breaks on one loom

= 1/N and let this be independent of the loom assignment

T_W = average waiting time for a repair = kat

k = distribution constant

$$T = T_O + T_W$$

$$\eta = \left(1 + \frac{T_W}{T_O}\right)^{-1}$$

Total added cost/unit mass = C

$$= \left(\frac{1}{\eta P}\right)\left(F + \frac{L}{a}\right) \qquad (17.5)$$

$$= \quad U \times V$$

For a minimum value of C with respect to (a):

$$U\frac{dV}{da} = -V\frac{dU}{da}$$

$$-\left(\frac{1}{\eta P}\right)\frac{L}{a^2}=\left(F+\frac{L}{a}\right)\frac{1}{P\eta^2}\frac{d\eta}{da}$$

$$-\frac{L}{a^2}=\left(F+\frac{L}{a}\right)\frac{1}{\eta}\frac{d\eta}{da}$$

$$\text{but } \eta=\left(1+\frac{kat}{T_O}\right)^{-1} \text{ and } \frac{d\eta}{da}=-\eta^2\frac{kt}{T_O}$$

$$\frac{L}{a^2}=\left(F+\frac{L}{a}\right)\eta\frac{kt}{T_O}$$

$$\frac{L}{a}=\left(F+\frac{L}{a}\right)\eta\frac{kat}{T_O} \quad \text{but } \eta\frac{kat}{T_O}=1-\eta$$

$$\text{and} \quad \frac{L}{Fa}=\frac{kat}{T_O} \tag{17.6}$$

$$\text{Let} \quad \frac{L}{Fa}=X=\text{cost ratio}$$

$$\text{then} \quad X=\frac{kat}{T_O}$$

$$\text{and} \quad a=\frac{X\,T_O}{kt}$$

$$\text{or} \quad a=\frac{X}{kNt} \tag{17.7}$$

The constant (k) is a statistical parameter which describes the distribution of breaks actually encountered, and (a) is that assignment which minimizes the cost of conversion of the warp and filling into woven fabric.

The fixed cost (F) includes interest, depreciation, overhead, maintenance, air-conditioning, space and management costs. The variable cost (L) is comprised of the labor cost (i.e. weaver's wages) and any other costs that vary likewise. The quality of the warp shows up in the number of warp end breaks/hr (N) and such quality has a considerable impact on the optimum assignment.

Equation (17.7) implies that the loom assignment also depends on the relative costs of man and machine, as well as the distance apart of the looms. The time of operator traverse (t) depends on the duties assigned to the weaver. If the conversion cost is to be minimized, adjustments in assignments have to be made from style to style, and also when new machinery, working hours, wage rates or altered working conditions are involved.

As wage rates go up in relation to the fixed costs, so the weaver's time has to be conserved by raising her assignment, and this implies that the weaving efficiency will drop. Conversely, any increase in fixed costs (such as that arising from new investment in machinery) requires that the machine efficiency be raised. It is always an advantage to keep the end breakage rate as low as possible as far as weaving is concerned. To ensure a good end breakage rate it is usually necessary to spend money on good preparation or good quality yarn or both. Once again, there has to be a compromise to achieve the lowest overall cost.

Often, market pressures can make it necessary to weave cloth narrower than the loom is capable of doing; this means that the production of the loom is correspondingly reduced and the cost of the final article is correspondingly increased. Hence it is desirable to insure that the width capability of the looms be used to the fullest extent. Where the market demands flexibility in this respect, consideration should be given to working in multiple widths on wide looms to get that flexibility or to having as wide a range of widths of loom as is practicable.

A further item is obsolescence due to the inertia caused by the large amount of material in process at one time. Sudden changes in fashion can render the time and money spent on preparing and even weaving these materials into utter waste. Therefore, it is essential to minimize the effects of this as far as possible by reducing the inventory to the lowest level practicable. It is also helpful to use fabric designs which delay the final styling to the latest possible moment so as to keep the options open as long as possible. This is one reason why print materials are so popular, since the final product can be altered to suit the market without having to change the specification of the cloth being woven. Similarly, it is easier to change the filling or the filling pattern than it is the warp.

Weave Room Environment

The atmospheric conditions in a weaving mill are very important not only for the comfort of personnel but also for efficient weaving. The temperature and *relative humidity* of the air can be critical in determining the efficiency of weaving. The required temperature varies between 21° and 25°C (70° to 77°F) and the relative humidity can vary from 50 per cent for some synthetic fibers up to 80 per cent for low grades of cotton depending on the fiber processed. Depending on the location of the weaving mill and the season, this may require heating or cooling and humidity control. Therefore it is necessary to have an adequate *air-conditioning* and control system. This can be of the central station type or it may consist of individual units. The central station system is preferred, especially if the plant is new and the site provides for the necessary space for the duct work, cleaning apparatus and circulation fans. In this case, good maintenance and control is essential since a shut down affects the whole plant; care must be taken, therefore, to ensure that the system consists of readily replaceable units, so that a defective unit can be removed quickly without interrupting operations unduly. All dry textile operations produce *lint* and *fly* (i.e. fiber particles) and the quantity of fly depends upon the yarn being processed; the maintenance schedule for cleaning the filters and plant must be adjusted accordingly.

Good illumination of the weave room is another important factor in maintaining high weaving efficiency. With modern and expensive machinery it is inevitable that the weaving mill will be operated on a shift system. This makes it unnecessary to depend on natural lighting, even where the mill can use the natural light during the day. With the use of modern building materials, such as prestressed concrete, it is possible to have very long unsupported spans in the building. This reduces the number of pillars or vertical obstructions and makes uniform lighting easier to attain. With such large floor areas, windows become unimportant.

It is the responsibility of good management to make sure that the quality of the light and the lighting intensity are such that the weaver can perform his duties without undue strain. Such strain is related to human fatigue and affects the efficiency of the weaver, which in turn affects the efficiency of the mill. Lighting which is considered adequate for certain fabric structures and colors will not necessarily be so for others. The color of walls and ceilings affects the lighting conditions. It has been suggested by many experts that cream and gray are the best colors to be applied.

Vibration and noise are important factors in the environment of the weaving mill; they affect the efficiency and safety of the personnel. Vibrations can affect the running of the loom and reduce its efficiency. Noise is a more comlicated problem because it has an effect on the health of the operators in the weaving room. It can also affect their desire and ability to continue work and may reduce their efficiency. Lack of motivation to work in such environment may well cause recruitment problems in the future. Acoustic treatment of the walls and ceiling has limited value because noise reaches the operators directly from the machines. In many areas the law requires that weavers be provided with ear-protection devices, such as ear-plugs or ear-muffs. Although modern weaving machinery has lower noise levels than hitherto, it is all too often above the allowable limits and thus there is a considerable problem to be solved.

The lay-out of the looms is important, particularly in respect of the width of the alleys through which the weavers walk. The alleys should be wide enough to permit efficient changing of beams and doffing of cloth rolls; also, it should be possible for people to pass each other without difficulty.

Where trucks or portable machinery, such as the warp tying machine, are used, the width of these must be taken into account.

Conclusion

An attempt has been made to provide an understanding of historical, technical, and fundamental concepts relating to weaving, and appreciation of the purpose of the whole operation. The overall object is to produce fabric of suitable quality at a cost which is acceptable. The industry is highly competitive and it is far from easy to satisfy this apparently simple objective. To do so, it is imperative that management of both man and machine should be carefully studied in order that they may give of their best.