2002 BELTWIDE COTTON CONFERENCES, ATLANTA, GA – JANUARY 8-12

UNIQUE FEATURES OF THE TATHAM HIGH-PERFORMANCE TMC CROSSLAPPER

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Abstract

The Presentation is intended to review the development of the new design "Total Motion Control" TMC Crosslapper recently introduced by Tatham to the Nonwoven Industry.

The paper summarises the development of this special design Crosslapper where the Quin 'Camlinks' design system was adopted for dynamically visualising the machine and creating the different motions. This data and information was then downloaded into the Quin Motion Generator to programme the electronic drives to establish the motor profile designs to achieve high performance combined with maximum smoothness of operation.

The principle of the machine, representing mechanical simplicity, is also reviewed together with other unique features.

Manuscript

Established in 1866, Tatham has been involved in the Nonwoven Sector for more than 70 years. The company was responsible for the design and manufacture of the world's very first Horizontal Crosslapper machine, patented in 1929. This was a revolutionary concept from a motion and fibre transportation aspect, the principles forming the basis of all modern Crosslappers.

To progress the development it was necessary to first establish the demands of industry for the new Crosslapper design. These were summarised as follows:

- High speed
- High performance
- Accurate control of Batt formation
- Rapid product changeover
- Adjustments on the 'fly'
- Minimum maintenance
- Excellent machine diagnostics

At the start of the project, Design and Development Engineers implemented a comprehensive review of both existing and emerging technology, concentrating on basic machine principles. This was followed with a Mathematical analysis where the 'Speed' and 'Relative Motion' of every conveyor and roller, on a conventional design Lapper, was assessed for every inch of traverse movement for a complete cycle.From motion graphs produced, an important breakthrough, fundamental to the new machine design, was established:

- Not necessary to have both a conveyor drive system and also a traversing carriage drive system
- Providing all conveyor rollers could be controlled, according to the maths of the motion graphs, the Crosslapper would function.

This conclusion provided two significant advantages for the new machine design:

1. Carriage assemblies would have no connection to the 'head' or 'tail' stocks except via the conveyor systems – this ensured the elimination of any inherent mechanical problems associated with traverse belts, chains, reversing shafts, motors or clutches etc.
2. Having only conveyor drives there is no possible error between conveyor and traverse drives – this ensured the elimination of any consequential apron stress resulting from speed differentials.

The most important factor, which has allowed the latest generation of Crosslappers to operate at high speed, is the reduction in inertia of all moving parts. Consequently, the mathematical analysis also involved an assessment of both Inertia and Roller Deflection.

$$\text{Inertia } I = WR^2 \qquad \text{Roller Deflection } D = \frac{5WL^3}{384EI}$$

Reducing radius 'R', therefore the diameter of the rollers, the Inertia of the machine can be significantly reduced. However, by reducing Inertia 'I' roller deflection 'D' is increased. Therefore the calculations for Inertia and Deflection have to be carefully balanced to maximise performance. From the mechanical analysis the inertia of each moving part had to be reflected back, by calculation, to their respective driving points so that the combined inertia could be balanced with the individual motor inertia.

From the accumulated data it was now necessary to construct a small scale model of the provisional machine design incorporating servo drives with associated controls. Motion graphs, developed in the earlier stages of the project, were fed into the control system which enabled a comprehensive feasibility study to be implemented when all functions of the proposed machine design were described in detail.

At this stage of the development a collaboration was established with Quin Systems to introduce the necessary expertise in multi-axis co-ordination technology. The required machine motions were analysed using 'Mathcad', each motion then applied to the Quin 'Camlinks' model, a specialised mechanical design tool. 'Mathcad' software enabled complicated mathematical equations to be calculated for the motions which are analysed via 'Camlinks' to visualize the full machine.

'Camlinks' is used for:

- **Dynamically visualizing the machine** – concentrating on the dynamic aspects of the machine, mechanisms and motions can be designed and analysed in detail before manufacture.
- **Experimenting with different motions** – motions can be altered interactively and their results run on animated drawings of the machine or mechanism.
- **Modelling forces to the size of motors and drives** – inertia and forces can be applied with the resultant torque profiles displayed graphically to specify the high tech motors.

The Quin Motion Generator was adopted to implement the motions created in 'Camlinks' on the new electronic drives to establish the motor profile designs to achieve high performance combined with maximum smoothness of operation.

Resulting from the in-depth technological review the basic machine design was formulated. The following figure illustrates the conveyor apron configuration where it can be observed that the conveyor systems are 'mirror imaged', top to bottom, to provide a balanced stress-free motion.

Aprons are configured in a simple 'U' format, eliminating wrap-backs and complex conveyor paths around the rollers. There is a short fibre web transfer route through the Crosslapper ensuring absolute control with no web distortion.

How the Machine Works (Figure 4, Figure 5)
With Reference to Figure 4:

- To traverse inner carriage system right - stop rollers 1 & 4 and rotate rollers 2 & 3 clockwise.
- To traverse inner carriage system left – stop rollers 2 & 3 and rotate rollers 1 & 4 anticlockwise.
- As an example, if conveyor rollers rotate at 200 m/min then the traverse speed will be 100 m/min and therefore the delivery speed from the conveyors will be 100 m/min

With Reference to Figure 5:

- Roller 5 must always rotate anticlockwise at the Card Doffer delivery rate.
- As an example, to traverse outer carriage system right, with roller 5 at 100 m/min, roller 6 must rotate clockwise at 200 m/min to provide a traverse speed of 50 m/min. Roller 7 would rotate clockwise at 200 m/min and roller 8 would rotate anticlockwise at 100 m/min.
- For outer carriage system to traverse left, again at 50m/min traverse speed (plaiting speed 100m/min), rollers 6 & 7 would be stopped whilst rollers 5 & 8 rotate anticlockwise at 100 m/min.

Conveyor Drive System

As indicated earlier the conclusions from our mathematical analysis suggested it was not necessary to have both a conveyor drive system and also a traversing carriage drive system. Carriage motion is therefore via the conveyor drive system.

Two AC servo motors provide the drive to each conveyor apron, each motor, when operating, only rotating in one direction. All motors and controllers only function in the following modes:

- 'Hold' in a stationary position
- Accelerate – run – decelerate
- Accelerate and run continuously

Two AC servo motors, at all times, also provide the traverse for each carriage system, the motors digitally locked. Adopting two motors, rotating in only one direction, eliminates the necessity of utilising reversing motors with their inherent mechanical and electrical problems.

Contour Distribution

Via the 'Touch Screen' facility the density can be programmed at ten divisions across the plaited width in order to obtain the preferred 'Contour Distribution'. With reference to figure 6, the inner delivery carriage is positioned centrally above the delivery apron. If we assume that we require 10% more material delivered at this point then, for an operating speed of 100 m/min, we can establish:

- Traverse speed must remain constant at 100 m/min
- Conveyor speed must be increased by 10%
- Roller 1 is increased by 10% to 220 m/min
- Roller 2 is increased from zero to 20 m/min

Reducing from 10% progressively, as the carriage moves away from the centre point, we can produce a 'contour distribution' of any desired profile.

For high speed Crosslapper operation it is essential to have efficient and reliable apron tensioning and tracking systems. As indicated in figure 7, four conveyor apron assemblies require four conveyor tracking systems, the systems utilising the 'steering' principle to avoid unnecessary apron stresses. Motorised linear actuators provide the pivotal motion, the remedial action quick and accurate with efficient sensing and precise actuator control.

The delivery apron of the Crosslapper can be operated in either:

- **'Continuous mode' –** the delivery apron operates at a continuous speed proportional to the average speed of the delivery carriage.
- **'Mapping mode' –** the delivery apron operates at a speed directly proportional to the carriage motion, incorporating a momentary pause at the extremities of the plaiting width.

The 'Mapping' function is particularly advantageous for the manufacture of lightweight Nonwovens where there is a combination of high delivery speed relative to a high plaiting speed. The system operates in conjunction with a Compensating Lattice assembly to provide optimum edge control at the extremities of batt formation, with the elimination of web wrinkling.

We now have the basis of a new design Crosslapper, built in a modular fashion, representing simplicity of mechanical design, having fewer parts.

The machine was now further developed adopting SERVOnet as the method of networking the distributed servo control.

With reference to figure 9, a central Machine Controller acts as a programme store, communications centre and scheduler to a number of networked axis modules which perform servo control on the range of AC servo motors. Such a design follows the successful management philosophy of effective delegation.

The system allows data and machine parameters to be stored in memory for recall, optimising operator efficiency. The controller would have a menu storage facility to provide fast recall and for programming machine control parameters for different fibre blends etc.

SERVOnet has the distinct advantage of:

- **Reduced wiring –** the ultimate benefit is to be able to place the drives and control local to the motors and sensors thus eliminating a large central cabinet and its associated cabling. Adding new features to an existing machine is simplified and overall machine reliability, due to reduced cabling, is increased.
- **Accurate synchronisation of all AC servo motors –** all the drives are controlled by a central Machine Controller ensuring that all motors remain in absolute synchronization.
- **Providing extensive diagnostics while running –** the performance of the Crosslapper can be monitored and adjustments made while the machine is running using Programmable Transmission System - PTS scope software.
- **Allowing further drives and expansion –** as a consequence of the modular nature of the system further drives and expansion can be added at any time. It has the capability for sequencing up to 60 servo control drives without sacrificing the overall strength of the system. It can therefore be used as a networking device for a complete Nonwoven unit.
- **Option to link to Ethernet and DeviceNet –** Ethernet and DeviceNet are incorporated into the machine controller enhancing the expansion capabilities and enabling the machine to be monitored and controlled remotely.

The Programmable Transmission System is incorporated to monitor Crosslapper performance to ensure correct machine operation. Remote fault diagnosis is via modem when critical timings can be quickly checked with remedial action implemented with the adjustment of parameters, reducing downtime and overall maintenance costs.

Each Crosslapper is equipped with its own individual 'Touch Screen' monitor for finite tuning and absolute control of machine operation. The control options are:

- Variation of machine speed
- Variation of 'plaited' width
- Variation of number of plaits for batt formation
- Variation of 'contour distribution'

The 'contour distribution' may be programmed at ten divisions across the plaited width to obtain the preferred distribution. The data is displayed on the Touch Screen monitor which also stores information and machine parameters etc. for recall at a later date.

What is fundamentally important on new high performance Crosslapper is the reduction in machine maintenance schedules and consequently downtime. Remote diagnostics facility via the modem assist with this objective. Reducing downtime was also an important requisite when considering parts replacement. An example would be that replacement conveyor aprons can be jointed on-site or alternatively supplied 'endless' requiring no on-site jointing. The latter ensures a perfect 'joint' with the work implemented in the suppliers factory rather than on-site.

In conclusion the features reviewed in this presentation may seem small and incremental in themselves but combined they produce a radical development to ensure the new Crosslapper is as revolutionary today as its predecessor in 1929.

Figure 1.

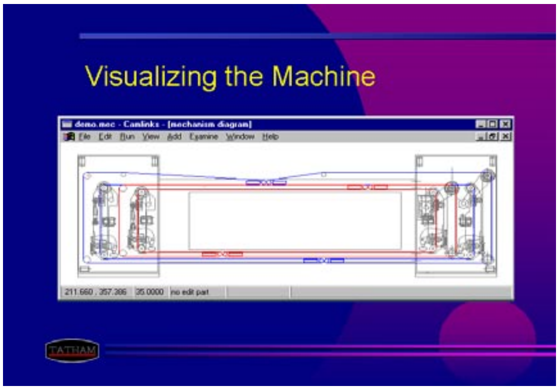

Figure 2.

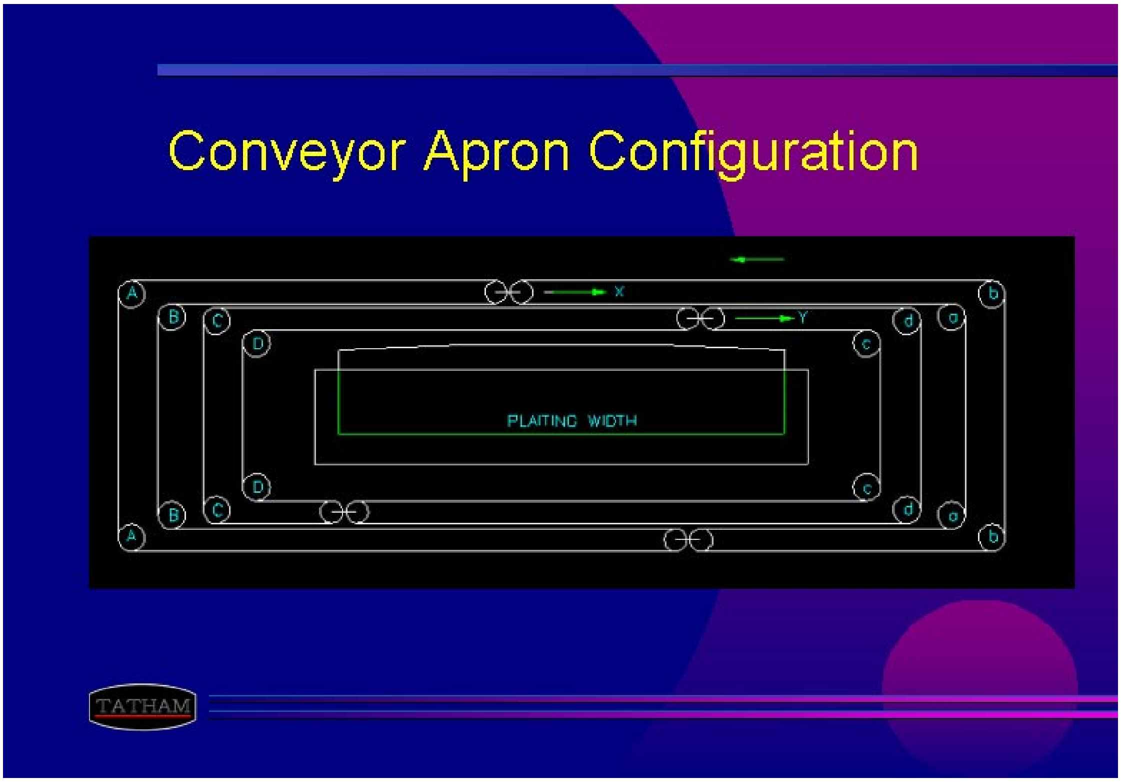

Figure 3.

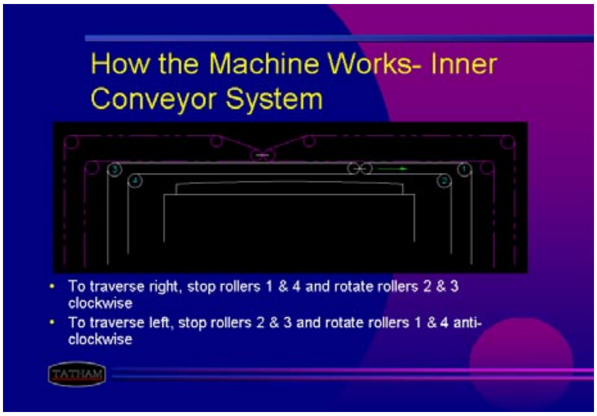

Figure 4.

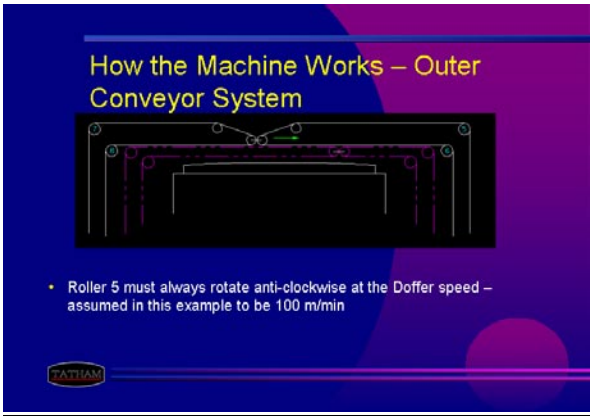

Figure 5.

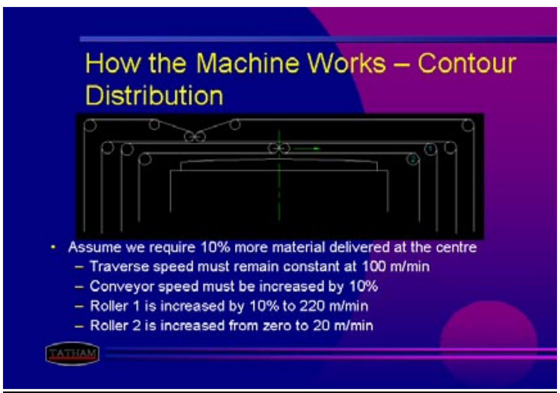

Figure 6.

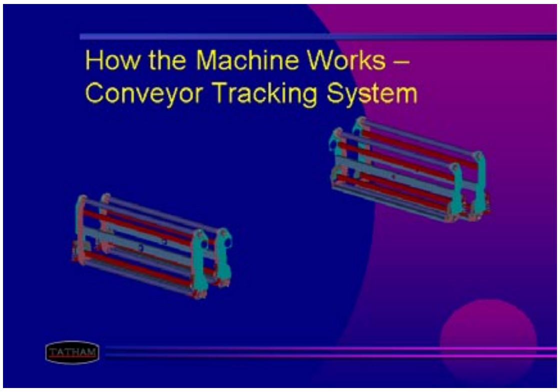

Figure 7.

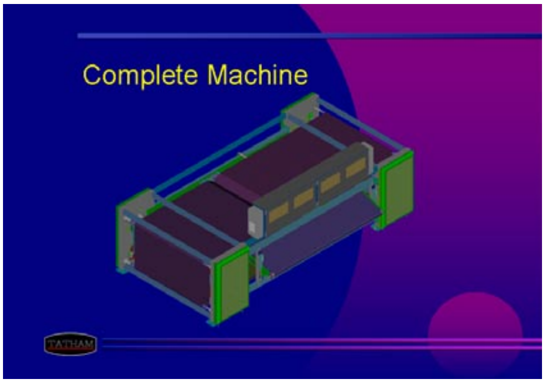

Figure 8.

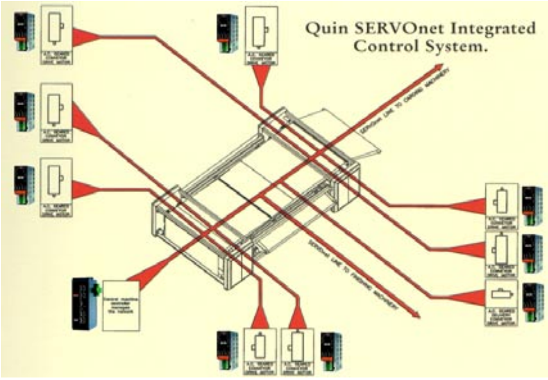

Figure 9.