A model of the stuffer-box crimper which can be easily handled and exploited by the industry has been fabricated. A critical study of the process technology of the crimper and a practical approach to see the mode of crimp formation have also been made.

The machine design of stuffer-box crimper and the processing of material through the crimper are very complex and, therefore, this machine has found limited industrial use. Certain modifications in the machine design and processing parameters have been carried out with a view to exploring the possibility of use of this machine in industry, but very little work has been published and the rest is in the form of patented information. Among the latest advances in design is Sahm's super-speed draw texturing model exhibited in ITMA '75. In the present investigation, a suitable model of the crimper which can be easily handled and exploited by the industry has been fabricated. A critical study of the process technology of crimper and a practical approach to see the mode of crimp formation have also been made.

**Experimental Procedure**

*Fabrication of crimper*—The present model (Fig. 1) is a modification of the previous model using the process of preheating the filament, buckling and setting in a tube, post-setting to stabilize the crimp, and winding in a continuous operation.

A lappet is introduced to control the balloon size due to nose-end unwinding of filament from the package. The preheater tube is made longer for effective heating and for running the machine at high speed. The impelling rolls are made bigger in size (diam., 50 cm and length, 50 cm). This modification has been effected to avoid roller lapping. If at all any lapping occurs, it is easily removed from the larger diameter roll. A part of the length of one roller is used for measuring the pressure between the rolls by providing a flat spring in the previously cut groove and, when required, it may be connected to the strain gauge.
SINGH et al.: STUDIES ON STUFFER-BOX CRIMPER: PART II

gauge system for recording the pressure. A check-nut is provided for raising/lowering the pressure level. The rollers used are quite heavy and, therefore, the vibrations are almost completely avoided. The surface of the rollers is corrected (accuracy, $2.5 \times 10^{-3}$ cm). Because of the large diameter rolls, the surface speed is higher even for low rpm rate.

Several stuffing tubes of brass of 4-10 mm inner diameter and 30-80 mm length were prepared. The lower end of the tube was ground by a pair of roller grinders equal in size and shape to those of impelling rolls, and finally well polished to make the surface very smooth. The fitting of the tube on the impelling rollers was so adjusted that it remains in contact with the rollers but does not exert any pressure on them. The top end of the tube carries a flange for providing the seat to the egress tube. The stuffing tube is surrounded concentrically by a large chamber (diam., 6 cm, and height, 4 cm) filled with chilled water and having a continuous flow from the water cooler.

The design of the inner passage of the egress tube has been changed by introducing the curvature at the openings. This facilitates yarn movement without extra stretching which used to disturb the crimp angle in the previous model.

The withdrawal rollers are added to the crimper to enable continuous withdrawal of crimped yarn at a given tension; the postheater is provided to stabilize the crimp. A long cooling zone is also provided between the heater and the package winding head.

Autothermo control units are provided at the pre- and post-heating systems and also to the cooling chamber. If the water temperature rises abruptly, the flow rate of water also increases.

An extra pair of roller $R_1$, which may be replaced by a pair of godgets $G_1$, is provided for use when the crimper is to be used for draw-texturing. These rollers may be replaced by other flexible rollers while applying plasticizer, lubricant, etc. to the filaments. The total assembly is fixed on a cast iron frame which is grouted on the wall to avoid any vibrations. The driving arrangement with the help of two electric motors is provided at the back of the frame with left side opening in the wall. All the drive is provided through gears, except winding unit $R_3$ and $R_4$ which are connected with a variable speed motor.

Testing and measurements—The cross-sectional study of processed and unprocessed filaments was done by dry-section cutting of filaments embedded between the plates. The projection microscope ($\times 200$) was used for tracing the shape of the cross-section on transparent paper over the screen. Dry-sectioning was preferred to avoid any kind of swelling, etc.

Tensile testing was done on Instron tensile tester keeping the chart and head speeds 30 and 20 cm/min respectively with the sample mono-filament yarn (length, 5 cm; and denier, 12). All the testing was carried out at 25°C and 62% RH.

For measuring the pressure in the yarn, a nozzle was fitted about 1.5 cm below the exit of the glass tube and a manometer was attached with the nozzle through a rubber tube. The manometer was calibrated in mm scale and filled with xylol (sp. gr., 0.9 g/ml). The difference in the readings was taken as the air pressure in the yarn plug region. The manometer assembly is shown in Fig. 2.

Discussion

Critical assessment of impelling rollers—The present model, in general, worked very smoothly, although the noise level was rather high. The introduction of fibre wheels as a carrier wheel in the gearing assembly reduced the noise considerably.

The yarn quality may be assessed in terms of buckling length, crimp angle and crimp uniformity. The buckling length and the crimp frequency can be represented by a single parameter, i.e. crimp height, but its direct measurement is not possible. Therefore, the buckling length alone may be taken as the most suitable parameter for assessing the yarn quality. The buckling length depends upon the modulus of yarn, end load compression, and the extent of filament segregation, particularly in the case of multifilament yarns. Apart from the previous processing history of the yarn, its modulus is affected by preheating and by the lateral pressure exerted by the impelling rollers. Therefore, the preheater efficiency and magnitude of lateral compression do contribute to the process at their own levels.

The end load compression is the resultant effect of the impelling force generated into the yarn and the resistance offered by the yarn plug, egress tube and wall friction together in terms of back pressure. The impelling force has to be slightly greater than the back pressure to support the yarn plug, so that the gravitational fall of yarn plug through the stuffing tube slit is avoided.
Segregation is essential in multifilament yarn to facilitate the buckling of individual filaments and it is introduced by the lateral pressure of the impelling rollers. In case the condition of segregation is met in the process, the buckling length of the individual filaments would vary considerably for the same segment of the yarn. The inner and outer filaments in the bent portion would have different set of compressive and tensile forces. For the segregation to occur, the pressure of impelling rollers is increased to the extent that the cross-sectional shapes of the filaments are deformed and reorganized.

From the above discussion it is clear that the activity of the impelling rollers is interesting and it looks as if the complete phenomenon of buckling inside the tube is pre-decided by their action. The conclusion can also be derived regarding the role of stuffing tube and the previous concept seems to be negated. It has been reported \(^{18}\) that crimp size and crimp frequency are based on the size of the stuffing tube, but probably the role of the impelling roller was either misunderstood or not considered relevant while assessing crimp size.

The action of the impelling roller has partly been reported \(^{19}\), but the changes in the structure of filament were not practically accounted for. For understanding the same, the stuffing tube assembly was removed and mono-filament yarn, delivered by the impelling roller, was wound directly into the package. The values of filament cross-section and changes in it due to lateral pressure at room temperature and softening temperature of the monofilament yarn are given in Fig. 3. The cross-sectional deformation is given in terms of filament ratio as applied to the lobal fibres. The filament cross-section has undergone drastic changes in its shape, particularly when it is heated to its softening temperature. In such structures, the mass shifts away from the axis of the filament, facilitating buckling. The reduction in the modulus of the filament with rise in pressure between the impelling rollers is shown in Fig. 4. The value of the tensile modulus of the filament further decreases with heating for the corresponding pressures. The loss in tenacity and increase in elongation indicate that the filament structure as a whole has undergone drastic changes, the loss of orientation being a major change.

Phenomena occurring inside the stuffing tube—To understand the phenomenon responsible for buckling of yarn segments inside the stuffing tube due to end load compression, a modification was introduced in the crimper. A glass tube was fitted over the stuffer used in the previous model \(^{19}\) and the assembly was put over the impelling rollers. The rollers were run with cold mono-filament at the surface speed of 100 m/min. Leakage of air at the joints of stuffer and glass tube was observed; it was confirmed by sprinkling fine powder in its surrounding. This indicates entry of air into the tube along with the filament. The egress tube was controlled mechanically for holding it up at a certain height. A thin yarn plug was allowed to form just below the egress tube and the winding operation was started. A sequence of events of buckling was observed in the visible region of the tube (Fig. 5). The segments of filament have been shown to illustrate the buckling phenomenon. It is observed that the completion of the buckle is preceded by half-built
buckle. Also, the straight segment of the filament was seldom at the centre of the stuffing tube and every change in its position was initiated by torque generation, as if some torsional force has thrown the filament to the other radial position of the tube. The unevenness of the lower surface of the plug is a well known consequence and, therefore, the plug density varies accordingly. The air current and filament enter the tube simultaneously but act in different directions and escape through the egress tube. The tangential feed of air current through the impelling rollers converts it into a rotational flow which strikes the vertical filament continuously. Also, the fresh buckled yarn is deposited within a region of the plug. While shifting, the end of the vertical filament also shifts, being in contact and simultaneously, the air currents take advantage of the transition phase of the filament and generate torsional force onto the yarn segment.

The yarn plug level was raised at this stage by reducing the winding rate, which was again increased to the previous value after achieving the specified height of the plug. The sequence of events of buckling remained the same, but they were occurring more rapidly. This was due to increased effectiveness of the impelling force. The kinetic energy goes on falling with distance from the impelling roller and, therefore, the impelling force is inversely proportional to the height of the filament which causes increase in the end load compression at this stage. The air column is also reduced, but the effectiveness to hold up the yarn plug is increased because of the hindrance in the air escaping, as the plug density is comparatively high (Fig. 6).

In the last stage, the mechanical manipulation of the egress tube was stopped and the yarn plug was lowered considerably due to the weight of the egress tube. At this instance, the events were not visible, but the air volume was negligible in the tube and it was escaping along with the impelling rollers while maintaining a constant pressure through the stuffing tube slit. The position of the filament was radially stable at the steady state and crimps available at this stage were more uniform than in the previous two stages.

The impact of preheating the filament does not change the sequence of events, but its low flexural rigidity allows the events to occur very close to the tube slit near the contact point of the impelling rollers.

A limiting contact exists between the impelling rollers and the arcs of the stuffing tube. If this contact is increased, the friction would generate heat, resulting in fusion of the filament. On the contrary, if the wider gauge is introduced, the air currents would escape along with the peripheral speed of the rollers, resulting in pressure drop inside the tube which would cause the filament to follow the path of the escaping air along with the roller periphery and the yarn mass would gradually start falling down onto the rollers and lap around them.

The size of the slit, where the impelled yarn enters the stuffing tube, has an important bearing on the working of stuffer-box crimper. It can be controlled on the small size impelling rollers, e.g. 2.5 cm diameter, but the large diameter rollers used in the present model do not allow a slit hole diameter less than 2.5 mm, which is rather high. The slit fork has to enter deep up to the roller contact point to control the flyaway of the yarn. Also, the nozzle of the preheater tube enters deep enough into the other side of the roller contact for avoiding any lateral movement of the yarn, which facilitates entry of the yarn into the tube.

The above discussion indicates that air pressure is the major force which holds up the yarn inside the tube. So, the previous concept of Banlon process\(^1\) that the impelling force due to filament propulsion is balancing the back pressure resulting from the weight of yarn plug egress tube and friction due to tube wall is negated; this conclusion is substantiated by the above discussion that the back pressure is balanced not only by filament propulsion but is also supported by air pressure.

Yarn withdrawal rollers—The pair of rollers \(R_3\) (Fig. 1) consists of a metallic fluted roller and a synthetic cot covered roller to ensure flexibility at the contact points. The crimped yarn, while passing through the pair of rollers, comes in partial contact with the peripheral arc of the metallic rollers and is in closer contact with the flexible synthetic cot, which protects its characteristic features.

The withdrawal rollers are provided exactly above the exit of the egress tube unlike in the conventional machines where the crimped yarns are withdrawn at a certain angle from the axis of the egress tube. In the latter case, the bend causes extra strain on the yarn which affects the crimp angle, sometimes to the extent of loss of crimp. In the present crimper, the rollers are fitted only a few millimetres above the egress tube and this does not put any strain on crimped yarn during withdrawal; rather it becomes very smooth and the processing is perfect.

The construction and functioning of preheater stuffing tube cooling arrangement and winding package are the same as in the previous model\(^1\). The main changes are the introduction of a long preheater and an independent winding unit.

Conclusion

The role of the impelling rollers seems to be important and the crimps are pre-decided by their action and previous history of the filament yarn. Inside the stuffing tube, air pressure plays an important role;
air pressure and filament jointly oppose the back pressure generated by the weights of the yarn plug and the egress tube and tube wall friction. The increase in plug height increases the effectiveness of the impelling force and air pressure below the level of yarn plug increases. The claim of Banlon 1 that the impelling force through the filament yarn holds up the yarn plug at a certain level has been modified by explaining the role of air pressure along with the force of filament propulsion.

References

2 Stowell E, Text Ind, 124 (1960) 91.
5 Man-made Text, (1965).
10 Int Text Bull (Spinning Section), 4 (1975).