High-Speed Trial Report on Mitsubishi Pilot Paper Machine

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Dryer and reel parts were added to a Mitsubishi pilot paper machine with a 1150 mm wire width and reel operation of 1750 m/min was achieved in March, 1999. This pilot machine enables close evaluation of sheet produced at high-speed. The high dewatering of the shoe press is effective in high-speed and stable operation. The all-top dryer arrangement works threading easy in high-speed-operation. Curl is controlled by using air cap drying. The next-generation paper machine will be for 2000 m/min operation developed on this pilot machine.

1. Introduction

Papermaking machine suppliers are always required to develop new machines incorporating innovative techniques to meet the need of the industry for high-speed and high-quality production. Mitsubishi Heavy Industries, Ltd. (MHI) has carried out papermaking tests on pilot machines after completing basic studies of each process part and determining the basic concept of the actual machine. These papermaking tests on pilot machines to evaluate their performance are also useful for researchers and machine designers to evaluate the actual operating performance of machines being designed. This article gives an outline of a Mitsubishi pilot paper machine and the results of trials for high-speed papermaking operation.

2. Outline of pilot machine

2.1 Development of Mitsubishi pilot paper machine

In 1985, MHI constructed a 650 mm-wire width pilot machine (#1 Machine) that was composed of a series of parts from headbox to press, and allowed verification of the web at the wet end, and started to develop a paper machine that would be accepted by the papermaking industry in Japan.

The progress of the maximum running speeds attained by the MHI pilot machines is shown in Fig. 1. The operation of the #1 pilot machine allowed papermaking tests using the Fourdrinier process and a Bel Form former, which were conventionally popular. The maximum operating speed of the Bel Form former was 1200 m/min. As hybrid-type formers like the Bel Form former seemed to have reached the limit of increase of the operating speed, MHI shifted its efforts to the development of a twin-wire former and constructed #2 pilot machine in 1993, that was a unique twin-wire former (MH Former) with 1150 mm wide wires from headbox through press. On papermaking tests using the pilot machine, sampling at 1500 m/min or higher speed was found difficult, because the web was still wet after being pressed due to the machine arrangement, and was not strong enough to be reeled up. In 1996, the press part was improved by installing a shoe press on the 3rd nip position of tri-nip type press and by using a ceramic MH Rock for the center roll and top roll of the 4th press. In 1997, a dryer part and reel were added to the pilot machine to allow dry sampling for evaluation of paper quality. Furthermore, a soft nip calender and a basis weight profiler were installed in 1998 and an unreeler for calender test in 1999, to complete the present pilot machine.

Thus, the pilot machine described in this paper was completed by employing the latest techniques, and by improving each part every time a new technique was applied.

2.2 Specifications of pilot paper machine

The #2 pilot machine is intended for papermaking tests of newsprint and fine paper. It is designed to run at 2000 m/min and to be capable of continuously winding a dry sheet sample of about 600 mm width. Previously, wet web were collected after pressing and then dried individually. However, addition of downstream equipment to the dryer of the pilot machine has made it possible to wind sample sheet in a similar manner to actual machines and evaluate...
behavior on the dryer.

For papermaking tests, pulp sheet and wound log prepared from actual machine operation are used and papermaking materials for test are prepared by slushing and refining on stock preparation equipment. Papermaking testing using additives such as talc and retention aid is also possible. The pilot machine has a capacity of 8 tons/day and can be made trials of 2 days/week.

Fig. 2 shows the layout of #2 pilot machine and Fig. 3 illustrates the main sections. Concept IV-MH Headbox has been developed to meet users' needs for high-speed, high-quality production and profile improvement [Fig. 3 (a)]. Use of a specially designed tube in the headbox ensures uniform and steady flow across the entire width and keeps jet flow always stable, even during high-speed trial. The former is a twin-wire type MH Former consisting of a forming board with dewatering blades positioned on a curvature of large radius, together with a forming shoe and a suction box. The MHI-developed serrated shoe is used for the forming shoe. The press is a combination of a tri nip type and a 4th press and uses a shoe press for 3rd press to improve dewatering capability. Furthermore, MH Rock (ceramic coated) rolls are used for the center roll and top roll of 4th press [Fig. 3 (b)]. Transfer felt is placed between the center roll and 4th press to minimize the draw. The dryer part is made up of all-top arrangement with air caps. Threading performance and running performance are improved by eliminating bottom group components and curl from dryer section is controlled by air caps (hot air impingement system) [Fig. 3 (c)]. The calender part is a single nip soft calender consisting of a large-diameter induction heating roll and a soft nip calender of elastic roll and has a basis weight profiler on the exit of the calender [Fig. 3 (d)]. The pilot machine also has unreel equipment to allow independent calender test. The MH reel allows both surface- and center-winding operations.

3. Trials of high-speed operation

3.1 Issues and solutions for high-speed operation

With the aim of achieving high-speed operation exceeding the general papermaking speeds of...
Commercially operated machines in Japan, MHI conducted trials and succeeded in reeling up newsprint at 1750 m/min in March 1999\(^\text{1}\). There were some limitations on papermaking trials because of pilot machine factors such as short operating time and insufficient conditioning of papermaking devices. However, issues arising from these limitations were solved by adopting appropriate countermeasures to gradually increase the maximum operating speed.

The sources of such issues can be classified into (1) Equipment, (2) Adjustment, and (3) Maintenance. The following are the issues solved up to the present time and the adopted countermeasures. Some pieces of operation-related information which were new to machine suppliers have also been obtained through the trials, and have been useful data to enhance the MHI product, though they may include some matters already widely known in the paper industry. The most important factors for high-speed operation are considered to include the following five points:

1. Complete cleaning of machine and facilities (equipment and maintenance)
2. Stable wet-web running at pickup section (equipment and adjustment)
3. Web release of center roll in press part (equipment)
4. Prevention of web sticking to dryer rolls (equipment and adjustment)
5. Smooth threading of dry end (equipment and adjustment)

The main issues and countermeasures with regard to the above-mentioned points are summarized in **Table 1**.

### 3.2 Results of papermaking trials

#### 3.2.1 Press part

The press part has been a bottleneck to the recent attempts to increase the operating speed of paper machines. In particular, improvement in smooth running of wet web to 4th press or to the dryer part from 3rd press can reduce the frequency of occurrence

### Table 1 Issues and countermeasures for high-speed operation

<table>
<thead>
<tr>
<th>Part</th>
<th>Issue</th>
<th>Equipment</th>
<th>Countermeasures</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock piping</td>
<td>Prevention of slime and sludge generation inside pipe</td>
<td>Polishing inside of pipe and correcting flute mating face.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headbox</td>
<td>Improvement of jet smoothness</td>
<td>Employing small-dia. breast roll.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Former</td>
<td>Improvement of paper trimming and cutting performance</td>
<td>Using double-hole nozzle and increasing vacuum in suction box.</td>
<td>Adjusting nozzles for position and angle.</td>
<td>Checking nozzles (incl. strainer) for choking.</td>
</tr>
<tr>
<td>Press</td>
<td>Stable running of sheet in pickup section</td>
<td>Revising unit weight of pickup felt.</td>
<td>Adjusting clearance between save-all and felt.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prevention of felt watering</td>
<td>Installing high-pressure washing system.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cleanliness of felt</td>
<td></td>
<td>Chemical cleaning and caustic soda washing.</td>
<td></td>
</tr>
<tr>
<td>Dryer</td>
<td>Prevention of sticking in 1 group</td>
<td>Reducing clearance between dryer and vacuum roll and using sheet release chemicals.</td>
<td>Controlling dryer surface temperature and regulating draw between press part and dryer part.</td>
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</tr>
<tr>
<td></td>
<td>Improvement of threading performance in 1 and 2 groups</td>
<td>Installing tail chute plate around vacuum roll.</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Stabilization of sheet running</td>
<td>Optimizing dryer felt air permeability.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reel</td>
<td>Improvement of threading performance between dryer part and reel part</td>
<td>Adjusting conveyor setting position, installing chute plate and straightening paper runway.</td>
<td>Adjusting air jetting direction and conveyor speed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prevention of paper break during turn-up</td>
<td>Changing materials and shape of sheet cutting blade.</td>
<td></td>
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</tbody>
</table>

of sheet break and is said to be the key to increase of productivity. MHI adopted the undermentioned measures to improve the runability and confirmed their effect on stable high-speed operation.

(a) Improvement of wet-web dryness and also reduction of draw by employment of a shoe press on 3rd press.
(b) Reduction and stabilization of draw by employment of a ceramic center roll for lowering the wet-web separation force.
(c) Reduction of open draw and stabilization of runability from center roll to 4th press by installing transfer felt.

(1) Example of application for fine papermaking
When 70 g/m² PPC paper and 53.5 g/m² rotogravure paper were made using a shoe press for 3rd press instead of a conventional roll press, wet-web dryness at the exit of 3rd press was found improved by 6% and 4% respectively, as shown in Fig. 4. At the same time, despite that the blending rate of long fiber (NBKP) was lowered by 10% in both cases, wet-web strength increased by a factor of two and about 10% respectively, as shown in Fig. 5.

As a result, the draw generated between presses 3rd and 4th was reduced to between 3.2% and 3.4% from 4.3%, and both web-running smoothness and steadiness were remarkably improved.

(2) Application to newsprint making
Fig. 6 shows the relation of wet-web dryness and press speeds when newsprint is made using 3rd press in the same way as for fine papermaking. The graph shows that wet-web dryness decreases with increase of press speed in both cases of roll press and shoe press. At a press speed of 1500 m/min, wet-web dryness is about 34% when a roll press is used for 3rd press, but it rises to 44 to 47% when a shoe press is used; that is, about 10 points higher than in the former case. These data prove that a shoe press has sufficient pressing capability, even in high-speed operation.

The rate of generation of draw in the area between presses 3rd and 4th rises with press speed, as shown in Fig. 7. This graph indicates that the difference in the rising rates of draw between the two types of press used for 3rd press increases to about 1.5 points at a press speed of 1500 m/min from 1.0 point at 1000 m/min. It is obvious that use of a roll press for 3rd press causes the draw rate to rise to 3% and or higher when press speed exceeds 1100 m/min, and decreases sheet threading and running performance. However, use of a shoe press limits the draw rate to 3% or lower, even at a press speed of 1500 m/min, and maintains good sheet threading and running performance.

\[\text{Fig. 4 Web dryness vs. press type at 3rd press (outlet of 3rd press)}\]

Wet-web dryness at 3rd press exit is improved by using shoe press instead of conventional roll press for 3rd press.

\[\text{Fig. 5 Wet-web strength vs. press type at 3rd press}\]

Use of shoe press increases wet-web strength even though blending rate of long fiber (NBKP) is reduced by 10%.

\[\text{Fig. 6 Web dryness vs. machine speed with different press type at 3rd press}\]

Wet-web dryness decreases with increase in press speed, but it stays higher by about 10% when shoe press is used.

\[\text{Fig. 7 Draw vs. machine speed with different press type}\]

Use of shoe press at 3rd press substantially improves wet-web dryness and reduces draw.
Curling can be reversed to wire side from felt side by setting thermal load between 35% and 40%. Thus, the combined effect of the improvement in wet-web dryness using a shoe press, and wet-web release performance using a ceramic roll has made it possible to considerably reduce the generation of draw for stable high-speed operation.

3.2.2 Dryer part

To maintain high-speed machine operation, the dryer part is also required to have higher drying efficiency, suppression of fluttering at open draw, smooth threading in wet end, prevention of sticking and blowing, easy disposal of waste paper after occurrence of sheet break, and so on.

As one measure, a single-deck dryer was developed in 1970. As each vacuum roll is positioned as close as possible to the neighboring cylinder driers, it can keep the generation of draw to a minimum and allow stable runability. In addition, dryer felt runs continuously supporting the wet web so that occurrence of fluttering is prevented.

Recently, all-top arranged dryers have been increasingly adopted for papermaking machines because of the easy disposal of waste paper resulting from sheet break, and sheet tail at the time of threading. Due to the structure of such all-top arranged dryers, one side of the web dries naturally and causes the web to curl on the felt-side, convex to the dryer surface. Although some attempts are being made to correct the curl by size press and calender operation, it can be solved easily by installing a hot-air impingement system (air caps) on dryers to apply hot air to the web through the dryer felt, as illustrated in Fig. 8. Uniform both-side drying is particularly important because the curl produced in after-dryers following gate roll and rod coating remains in dry sheet in the form of residual stress. Fig. 9 shows the relation between thermal load applied by air cap and irreversible curl. From this graph, it is obvious that curl can be reversed to wire side from felt side by applying a 35 to 40% thermal load.

If an attempt is made to replace an existing 2 deck dryer type with a single deck dryer, it will normally make the overall machine length longer. However, it can be done without changing the existing machine length by adding air caps that improve both curl controllability and drying efficiency.

4. Conclusion

An outline of the Mitsubishi pilot paper machine and the results of high-speed trials and papermaking tests have been described in this article. MHI will continue to make efforts to improve their pilot paper machine, aiming at higher stability in high-speed operation, including evaluation of the functions of the former and press parts, and will proceed with the development of a 2 000 m/min machine utilizing the techniques verified by the trials.

Further development of various functions, including high-speed capabilities, must be pursued by understanding more clearly the users' needs and the issues to be solved to meet such needs, without causing any inconsistency with the threading performance required for actual machines. In addition, considering that the functions of papermaking devices and chemicals will become more important for high-speed, high-quality machines, especially in regard to their maneuverability and performance, MHI hope to continue their research and development activities in cooperation with the paper industry and the component suppliers.

Reference