Development of Specialty Papers is an Art: Wax Match Tissue Paper from Indigenous Raw Materials — Part I

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Received: 08 April 2002; accepted: 04 October 2002

Introduction

Wax match tissue paper is a highly specialized machine finished and unglazed paper used to manufacture ‘Vesta’, which is a kind of short match, especially with wax shaft for safety matches in 40/46 g/m², from low freeness pulp, but with high tensile strength and the absence of pin holes. Bleached Kraft pulp used for wax match is prepared from a blend of hardwood and softwoods. Softwood fibres give the mechanical strength where as hardwood fibres imparts softness to paper. The pulp must be a cleaned, free from speck and dirt particles and beaten to 45 °SR in order to develop toughness of wax shaft. The typical basis weight range is between 40-45 g/m². The wax match tissue paper is first passed through a bath of paraffin wax having melting point 57 °C and then the impregnated paper is subjected to cylinder discs where it is converted in to wax stemmed cylinder on a special vestas-manufacturing machine. The match head is put on in a separate operation for beading with various inflammable ingredients. When vesta is to set fire the paper may burn in very short time and cause serious accidents. No paper manufactured from cellulose fibre can be made fireproof; it will burn if sufficient heat is supplied. Paper can be made fire resistant so that it will not support combustion; it will burn if it is brought in contact with flame but it will cease to burn when flame is withdrawn. However, in the case of vesta the wax stemmed cylinder should burn at a very slow but controlled rate in order to avoid fire accident and other hazards.

Fire Retardants as Flame Proofing Material

The chemicals used as fire retardant are generally ammonium salts such as ammonium phosphate, ammonium sulphamate, polyphosphorylamine or ammonium sulphate, ammonium carbonate, aluminium hydroxide, zinc sulphate, magnesium sulphate, ammonium phosphate, zinc chloride, and urea. It was observed that borax-boric acid or boric acid and sodium borate mixture are a better fire retardant compared to chemicals like tetrais hydroxy methyl phosphonium chloride (THPC) and THPC with bromoform-triallyl phosphate polymer, metallic oxide plus chlorinated hydrocarbon or urea phosphate compound.1,3

Many more compounds are used as fire retardants, such as 5-15 per cent solution of phenolic resin containing oxyfluoroborate and a plasticizer, such as a water-soluble polyethylene glycol. Apart from borax and ammonium chloride, other flame proofing
agents are di-ammonium phosphate and di-ammonium ethyl phosphate. There are water-soluble resins about 15 per cent on the weight of the paper to give adequate fire protection and prevent after glow. A mixture of Boric acid and sodium borate require around 25 per cent to obtain fire retardancy, but it does not protect against after glow. Ammonium sulphate needs 15-20 per cent by weight of sheet and gives excellent fire retardancy and fair after glow characteristics. As all these agents have the disadvantages of being water-soluble and any severe wetting reduces or eliminates the retardant characteristics.

Flame retardant can also be formulated from chlorinated paraffin or antimony oxide and works only when the organic matter content and pigment is in the ratio of 1:1. Chlorinated rubber, applied from a toluene solution, has found highly successful.

Zinc borate developed during World War II has well fired retardant property and also exhibits water resistance and a definite fungicidal action against common cellulose degrading fungi. Sodium tungstate and sodium stannate, alum, mixture of borax and MgCl₂, MgBO₂O₃ and [Sn(ONa)₂]

\[ \text{Na}_3\text{B}_2\text{O}_3 + \text{MgCl}_2 \rightarrow \text{MgB}_2\text{O}_3 + 2\text{NaCl} \]
\[ \text{Sn(ONa)}_2 + 2(\text{NH}_4)\text{SO}_4 \rightarrow \text{Sn(ONH}_4)_2 + 2\text{Na}_2\text{Sn} \]
\[ \text{Sn(OH)}_2 + 4\text{H}_2\text{O} \rightleftharpoons \text{Sn(OH)}_4 + 4\text{NH}_3\text{OH} \]
\[ \text{MgCl}_2 + \text{MnSiO}_3 \rightarrow \text{MgSiO}_3 + 2\text{MnCl} \]
\[ (\text{H}_2\text{C})_2\text{N-PO-N(CH}_3_2)\text{-(CH}_2_2)-\text{N(CH}_3_2)\text{-PO-(CH}_2_2)+ \]

• Optical
• Tensile strength
• Even thickness must be maintained. Paper should be free from lumps as it is directly linked to runnability of special vestas-manufacturing machine.
• Optical properties, like brightness and opacity are of utmost importance for wax match tissue paper. No shade variation is accepted. Shade of the paper should be bright and white.
• The paper should be free from specks, pinholes, dirt particles and two sidedness. Anything which tends to form pinholes, like air in stock, dispersed air in the form of bubbles, foam, poor sheet release from wire, press rolls, dryers, therefore, should be avoided.
• High tear strength is frequently used to evaluate toughness. While stress/strain curve and TEA (Tensile energy absorption) are also equally important.
• Tensile strength is another criterion, as cylinder formation operation requires high MD/CD strength ratio. This is possibly with highly oriented fibres. This gives a good CD elongation, which allows the wax stemmed paper to follow the shape of a cylinder.
• As the wax match tissue paper is subjected to impregnation with wax, water klemm values (penetration of melted wax through capillaries into the paper) and castor oil penetration (paper able to retain melted wax in it) are essentially required.
• Wet strength resin is frequently used in order to keep relatively strong the rather low strength displayed by this base paper after wetting.
• In order to retain resins and micronized soap stone alum (Al₂(SO₄)₃ 14-18 H₂O) is added to pH 6-5. The alum must be free from iron as Fe⁺⁺ turns paper into blackish or bluish while dipping in wax.

A mixture of ferrie pyrophosphate and Ti, Zr, or Sb oxide can be used as fire retardant. But wax match tissue paper along with the above retardants when impregnated with paraffin wax turns in to black or bluish colour. These chemicals are dissolved in water and applied either at size press or at the calendar. It can be used in heater in some situations.

The test for fire retardancy consists of burning paper in contact with a flame produced by burning gas with a specified energy content in a burner with requisite characteristics. After 12 s the flame is withdrawn and the time during which it continues to glow is measured along with the length of char that is produced. The paper is supplied in the form of reels or narrow bobbins on customer requirements. The most important properties for wax match tissue paper are as follows:

- Uniform formation of the paper is very important as it influences many other important properties, like compressibility, porosity, opacity and surface smoothness.
- Water content is most important for wax match tissue paper. No shade variation is accepted. Shade of the paper should be bright and white.
- The paper should be free from specks, pinholes, dirt particles and two sidedness. Anything which tends to form pinholes, like air in stock, dispersed air in the form of bubbles, foam, poor sheet release from wire, press rolls, dryers, therefore, should be avoided.
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The study aims at developing wax match tissue from indigenous hardwoods, like *Eucalyptus tereticornis* with some proportions of *Dendrocalamus strictus* (Bamboo) and *Pinus roxburghii*. In order to develop water klinn values, hardwood pulp is blended with softwood pulp; the former gives formation and smoothness and later develop strength. The important properties required for wax match tissue paper strictly fulfill the requirements of end users.

**Experimental Methodology**

**Pulp Characteristics**

Bleached mill pulp of brightness 82.0 °PV (Photo volt) is undertaken for study. The approximate composition of Pine: Bamboo: Eucalyptus being 1:2.3:11.

**Blending and Stock Preparation**

Softwood bleached pulp of brightness 87.5 °PV was beaten to 34 and 45 °SR, respectively, in laboratory valley beater. In the similar manner, bleached mill pulp was beaten to 34 and 45 °SR, respectively. Bleached mill pulp and imported softwood pulp of similar freeness level was mixed in the ratio of 4:1. The blended pulp is now divided into four sets:

**Set 1** — In the first set of pulp having freeness level of 34 °SR one per cent melamine formaldehyde, 0.1 per cent tetra-4-hydroxyl methyl phosphonium chloride (THPC) with bromoform-triallyl phosphate polymer were added to retard the burning rate. 0.1 per cent sodium hexa meta phosphate also added for uniform mixing of non-fibrous additives. A final pH level of 0.5 was maintained with the help of non-ferric alum by thoroughly mixing in laboratory disintegrator with controlled rpm of the rotor.

**Set 2** — In second set of pulp having a freeness level of 34 °SR, all the non-fibrous additives, as mentioned in set 1, along with 10 per cent micronized soapstone powder of brightness 95 °PV were added. A pH level of 6.5 was also maintained with the help of non-ferric alum by uniform mixing.

**Set 3** — In the third set of pulp having a freeness level of 45 °SR, all the non-fibrous additives were added according to set 1.

**Set 4** — In the fourth set of pulp, having a freeness level of 45 °SR, all the non-fibrous additives were added according to set 1.

**Sheet Preparation and Evaluation**

The chemicals were thoroughly mixed with the pulp in laboratory disintegrator prior to sheet forming. Laboratory hand-sheets of basis weight 45 g/m² on British sheet former were prepared. The hand-sheets were air dried, conditioned and tested as per BIS specification. The properties of laboratory hand-sheets are reported in Table I. The results are compared with mill made wax match tissue papers obtained from those Indian mills and shown therein.

**Results and Discussion**

In the present study, a pulp blend having 40 per cent imported softwood fibre and 60 per cent mill pulp of composition of pine, bamboo and eucalyptus in the ratio 1:2.3:11 was found suitable to impart optimum properties for wax match tissue paper. This composition can give high strength properties like tear and tensile strength (to form shaft), elongation and toughness (to give proper shape to cylinder of a vesta).

Microscopic examination shows that some wax match tissue samples consist of 40 per cent jute fibre, 10 per cent softwood fibre, and remaining 50 per cent hardwood fibre. In other wax match tissue paper samples the softwood fibres are found up to 70 per cent. The rest might be hardness and other fibres.

Table 1 shows the comparison of laboratory made wax match tissue paper with mill made wax match tissue paper. When the chosen pulp blend is beaten to 34 °SR separately and thoroughly mixed with 1 per cent melamine formaldehyde to develop sufficient wet strength during impregnation, 0.1 per cent tetra-4-hydroxyl methyl phosphonium chloride with bromoform-triallyl phosphate to slow down burning of vest shaft, 0.1 per cent sodium hexa meta phosphate for uniform distribution of non-fibrous additives and non-ferric alum to maintain pH 6.5 to enhance interlink with MF resin with fibres. The converters require 4.5 per cent ash in wax match tissue paper and sufficient opacity and brightness after impregnation with paraffin wax. Therefore, it is necessary to add micronized soapstone in to the furnish and the vesta becomes brighter after impregnation with paraffin wax.
### Table 1 — Comparison of laboratory made wax match tissue with mill made wax match paper

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Laboratory made hand-sheet</th>
<th>Mill made wax match tissue paper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pulp with 1 per cent</td>
<td>Pulp with 1 per cent</td>
</tr>
<tr>
<td></td>
<td>M F resin + 10 per cent MSS</td>
<td>M F resin + 10 per cent</td>
</tr>
<tr>
<td>Basis weight, g/m²</td>
<td>43</td>
<td>45</td>
</tr>
<tr>
<td>Thickness, μm</td>
<td>80</td>
<td>84</td>
</tr>
<tr>
<td>Bulk, cm³/g</td>
<td>1.86</td>
<td>1.87</td>
</tr>
<tr>
<td>Burst index, kPam²/g</td>
<td>3.43</td>
<td>3.04</td>
</tr>
<tr>
<td>Breaking length, m</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Average</td>
<td>4320</td>
<td>3260</td>
</tr>
<tr>
<td>Tear index, mN²/m²</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Average</td>
<td>7.747</td>
<td>7.159</td>
</tr>
<tr>
<td>Double fold, no</td>
<td>34</td>
<td>18</td>
</tr>
<tr>
<td>Brightness, per cent</td>
<td>81.2</td>
<td>83.4</td>
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<tr>
<td>Opacity, per cent</td>
<td>77.0</td>
<td>79.2</td>
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<tr>
<td>Water kelnm, mm/4min</td>
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<td>—</td>
</tr>
<tr>
<td>Average</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Air porosity</td>
<td>8</td>
<td>8</td>
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<tr>
<td>Gurley, s/100 mL</td>
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<td>—</td>
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<tr>
<td>Wet strength, g/cm</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Average</td>
<td>120</td>
<td>113</td>
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<tr>
<td>COP, seconds</td>
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<td>—</td>
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<tr>
<td>Average</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Ash, per cent</td>
<td>2.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>

*MSS = Micronized soap stone, MD = Machine direction, CD = Cross direction, TS = Top side, WS = Wire side

In set 2, ten per cent micronized soapstone of brightness 95 °PV was added along with other non-fibrous additives as stated in set 1. However, all other properties are remained constant but breaking length drops sharply from 4320 to 3260 m. It is generally observed that approximately 10-15 per cent of strength properties of laboratory made hand-sheet reduces in paper machine operation due to mixing of broke and white water.

In another set the pulp was beaten to 45 °SR to enhance strength properties. In set 3, all non-fibrous additives except micronized soapstone in the similar proportions were added. A breaking length of 4833 m, tear index 7.355 mN²/g, double fold 62 numbers, water kelnm values 13 mm/4min, COP 12/10 s and wet strength 133 g/cm were obtained in the laboratory made hand-sheets.
In set 4, ten per cent micronized soapstone along with other non-fibrous additives was added. However, all other strength properties, like COP, wet strength and water kelin remained almost constant but breaking length decreases from 4833 to 3650 (24.5 per cent) and tear index 7.355 to 6.57 mN/m/g (about 107 per cent).

There is no BIS standard for wax match tissue paper available. Therefore, paper could not be compared with the specification stipulated by the regulatory authorities. In this situation comparison can be made only with the results of the leading wax match tissue paper manufacturers. In the present study the laboratory made results are compared with samples from different mills. The results show the close proximity with mills made wax match tissue paper. In some cases the laboratory made paper is superior to mill made wax match tissue and fulfil the requirements of end users.

Conclusions

1. A pulp blend having 40 per cent imported softwood fibre and 60 per cent mill pulp of composition of pine, bamboo, and eucalyptus in the ratio 1:2.3:11, beaten to 45°SR, was found suitable for wax match paper.

2. Ten per cent loading of soapstone to get 6±1 per cent ash in paper, 1.0 per cent melamine formaldehyde resin, 0.1 per cent tetra-hydroxy methyl phosphonium chloride with bromoform-triallyl phosphate to slow down burning of vest shaft, 0.1 per cent sodium hexa meta phosphate for uniform distribution of non-fibrous additives, and non-ferrie alum to maintain pH 6.5 to enhance interlink with MF resin with fibres was found suitable for wax match tissue paper.

3. Non-ferrie alum dosing to get 6.5 pH was added as a retention aid to entrap fillers and to enhance resin cross-linking without any adverse effect.

4. The properties of laboratory made hand-sheet were found to be excellent with those from machine made papers. In some cases, even superior properties are obtained. The results are found very promising.

References

1. Jackson J, Can Pat 564042, September 30, 1959
4. Tappi Testing Procedures, T461, 1972