



IPPTA

Indian Pulp & Paper Technical Association

ZONAL SEMINAR CUM WORKSHOP 2023

Jointly organized with



— Giving Food a Future —

3rd - 4th August, 2023 at CFTRI Auditorium, Mysuru

REPLACING SINGLE USE PLASTIC BY PAPER WITH EMPHASIS ON FOOD PACKAGING

Enormous research work has been done by scientific fraternity to provide coating to paper to replace plastic lining with success.



Dr Dharam Dutt

Head of Department
Department of Paper Technology
I.I.T. Roorkee



ENVIRONMENTAL-FRIENDLY WATER-BASED COATING FORMULATION FOR PAPER TO IMPROVE THE REPULPABILITY AND RECYCLABILITY

Department of Paper Technology
IIT-Roorkee, (Saharanpur Campus)

By:
Dr. Dharm Dutt
Professor, HAG





MARKET SHARE OF DISPOSABLE CUPS

- According to IMARC Group latest published report, The India paper cups market reached 22.0 Billion Units in 2022, and is expected to reach 25.7 Billion Units by 2028, exhibiting a growth rate (CAGR) of 2.5% during 2023-2028.
- Indian paper cups market reached a value of INR 2,139 Crore in 2020.
- The poly-coated paper segment dominated, with a market share of around 38.47% in 2022. This growth is attributed to high demand from the food & beverage sector because of the growing demand for packaged food & beverages. Consumers prefer paper cups as they are lightweight and easy to dispose of.

ISSUES WITH PE COATED CUPS



**RECYCLING
ISSUE**

**SOCIETAL
ISSUE**

**ENVIRONMENTAL
ISSUE**



The impact of disposable cups [\[7\]](#)

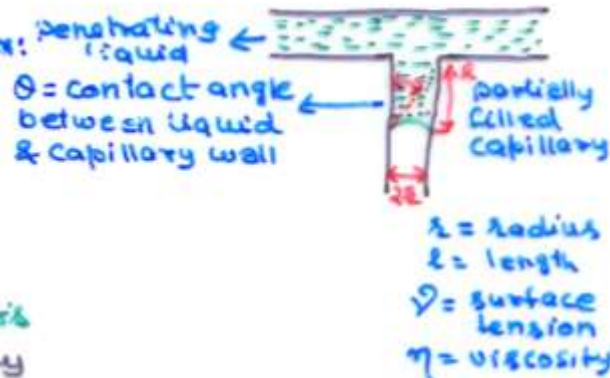
Mechanisms

- Liquid flow through capillary (Washburn equation):

$$\text{Time rate of penetration} = \frac{dl}{dt} = \frac{1}{4} \left[\frac{\gamma}{\eta} \right] \cdot \left[\frac{1}{r} \right] \cdot \cos \theta$$

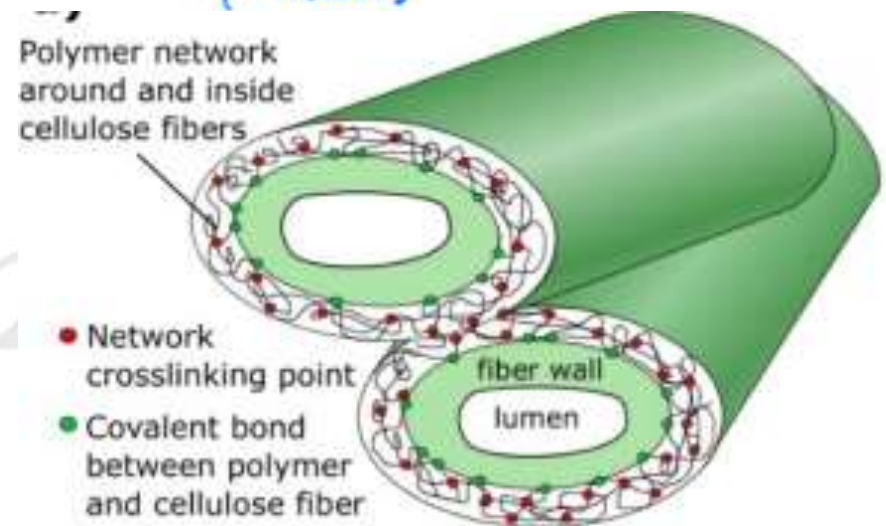
$\frac{dl}{dt}$ is determined by five parameters:

- Surface tension & viscosity of liquid is determined by the needs of ultimate customer
- The length & radius of capillary are controlled by paper maker's i.e. basis weight, bulk density & porosity of sheet.
- Contact angle (θ) is controlled by degree of sizing.

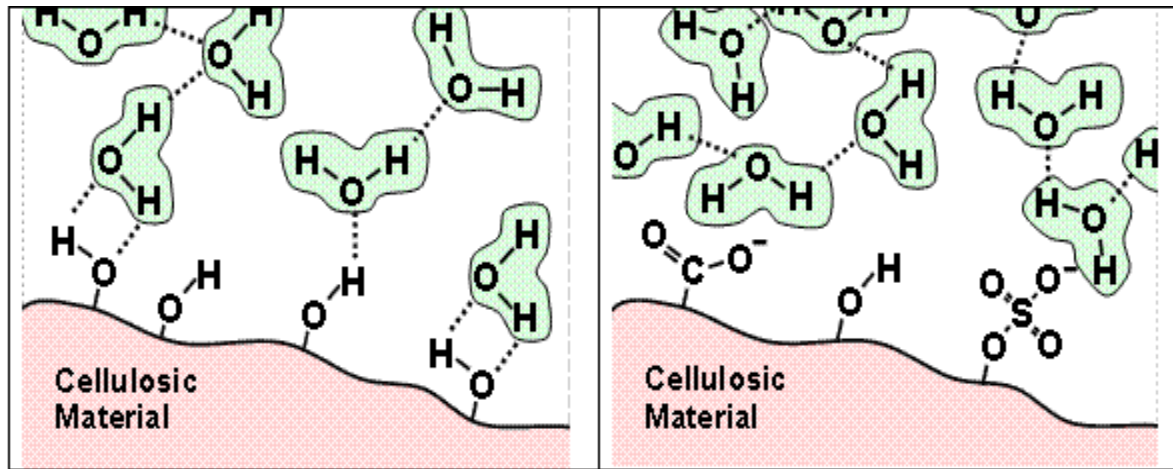


Capillary action

Cross-linking

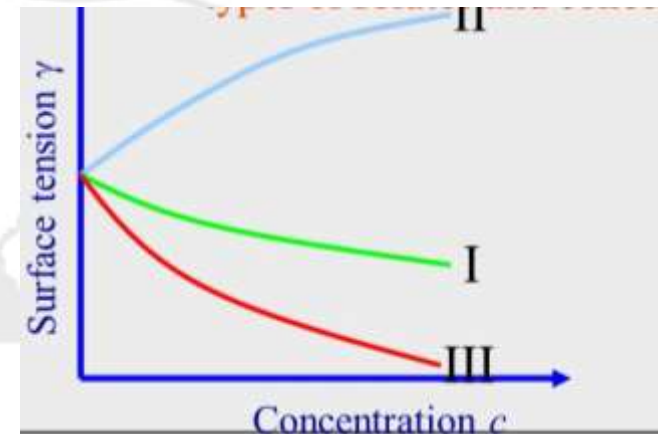
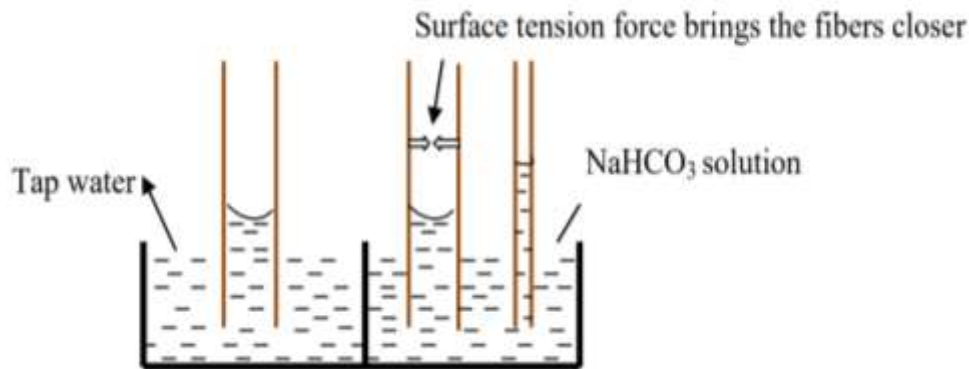


Hydrogen bonding



Effect of solute on surface tension

Surface tension



I= Organic, II= Inorganic and III= Amphoteric

SYNTHESIS OF ACRYLIC-STYRENE CO-RESIN



Materials :-

1. MAA (Methacrylic acid)
2. BA (Butyl Acrylate)
3. ST (Styrene)
4. IPA (Iso propyl alcohol)
5. AIBN (Azobisisobutyronitrile)

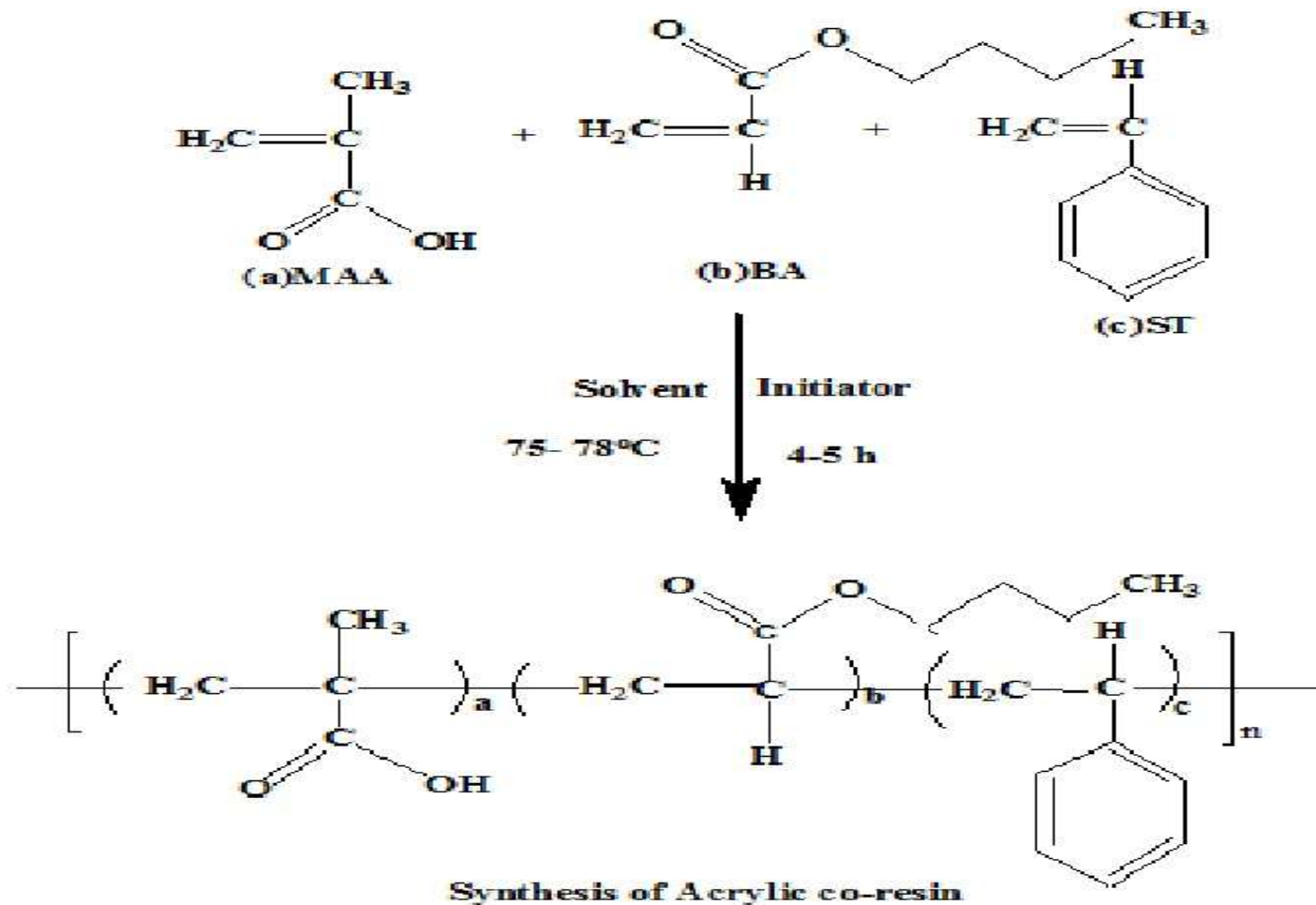
Butyl acrylate (BA) is a soft monomer, which enhances the chain flexibility of water borne resin and Methacrylic acid (MAA), is the functional monomers that enhances the solubility of resin in water and also binds resin to the substrate to achieve the required adhesion. Grafting of Styrene (ST) enhances the film forming property of resin with paper surface.

PREPARATION OF ACRYLIC-STYRENE BASE RESIN



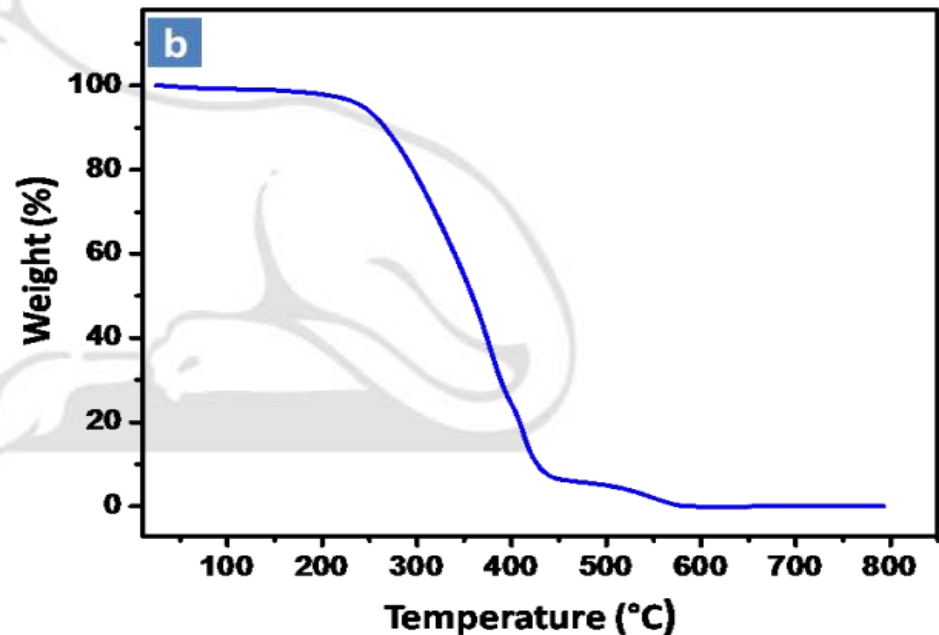
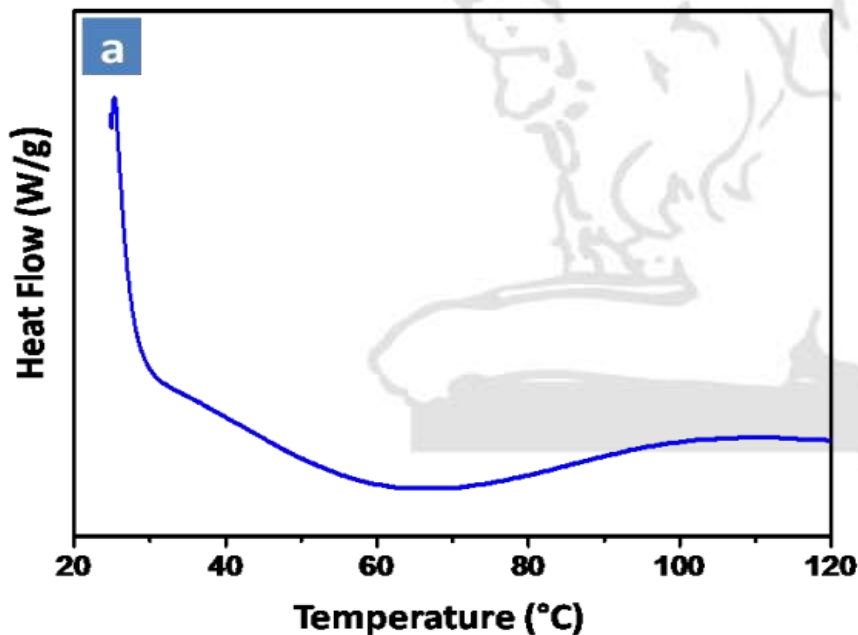
Reaction Setup for synthesis of Acrylic-Styrene Co-resin

REACTION MECHANISM OF ACRYLIC-STYRENE RESIN



DSC and TGA

- The DSC curve of **acrylic-co-resin** shows one glass transition temperature around **58°C**, which indicates that the **product does not contain any homopolymer and all the acrylic monomers are involved in the co-polymerization**
- The thermal degradation behavior of the acrylic copolymer resin shows that the **resin started to be volatilized at 100°C**,
- The significant **weight loss appeared in the range of 330 - 430°C** due to the degradation of the main polymeric chain
- The resin decomposed completely at 600°C



DSC curve of acrylic-co-resin (a), and TGA curve of acrylic-styrene *co*-resin (b)



Testing

- ❖ **Molecular weight (Mw):-** Weight average molecular weight of acrylic co-resin is determined by Gel Permeation Chromatography (GPC)
- ❖ To determine the Mw, first prepare the solution of (15 mg resin dissolved into 15 ml of THF) and 3-4 ml of solution injected into a GPC Sample holder, and the test was carried out at constant pressure and temperature 25°C.
Results, **the molecular weight of acrylic-styrene co-resin was 1768 g/mol**
- ❖ **Solid content:** To determine the % of the solid content, 2 gm of acrylic co-resin is cast into a petri dish, and sample is dried to a constant weight at 105 °c.
- ❖ The % of solid content is determined by using the formula

$$\% \text{ of solid content} = (w_2/w_1) \times 100 = 35 \%$$

Where,

w₂ is the weight of resin after drying

w₁ is the weight before drying.

- ❖ **Surface energy of acrylic resin**

The surface energy of the prepared Acrylic co-resin is measured using a Tensiometer equipped with rectangular platinum plate.

The samples are performed at 25°C in the triplet.

The surface energy of the resin medium was **28, 27, 29 dyne** respectively

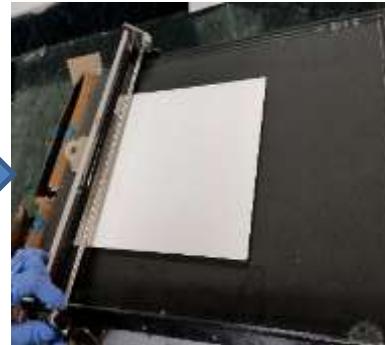
STEPS FOR COATING SHEET



a) Placing sheet on the AFA



b) Selecting coater rod



c) Mounting rod on the rod holder



d) Taking Resin in the beaker



g) Coated sheet



f) Pour resin from one end to another end



e) Pouring resin on the sheet



PHYSICAL PARAMETERS

- **GSM Test**: GSM, also known as grammage, stands for ‘**Grams per Square Meter**’. It is used to measure the weight or heaviness of paper products.

Formula :- $\text{Weight of Paper} / \text{Area of Paper}$

- **Thickness Test**: The thickness of paper is often measured by calliper, which is typically given in thousandths of an inch in the United States and in micrometres (μm) in the rest of the world.
- **Water Absorbance Test (Cobb60)**: The Cobb test determines the amount of water absorbed into the surface by a sized (non-bibulous) paper, paperboard, and corrugated fibreboard paper or paperboard sample in a set period of time, usually 60 or 180 seconds (Cobb60 or Cobb180). Water absorbency is quoted in g/m^2 .



RESULTS OF PHYSICAL PARAMETERS

| Physical Parameters | Base | After Coating with bar of (36-36 micron) | Difference |
|--------------------------------|------|--|------------|
| GSM (g/m ²) | 180 | 202 | 22 |
| Thickness (μm) | 210 | 224 | 14 |
| Cobb Value (g/m ²) | 30 | 1.1 | 28.9 |

| Physical Parameters | Base | After Coating with bar of (6-6 micron) | Difference |
|--------------------------------|------|--|------------|
| GSM (g/m ²) | 180 | 189 | 9 |
| Thickness (μm) | 210 | 218 | 8 |
| Cobb Value (g/m ²) | 30 | 1.1 | 28.9 |

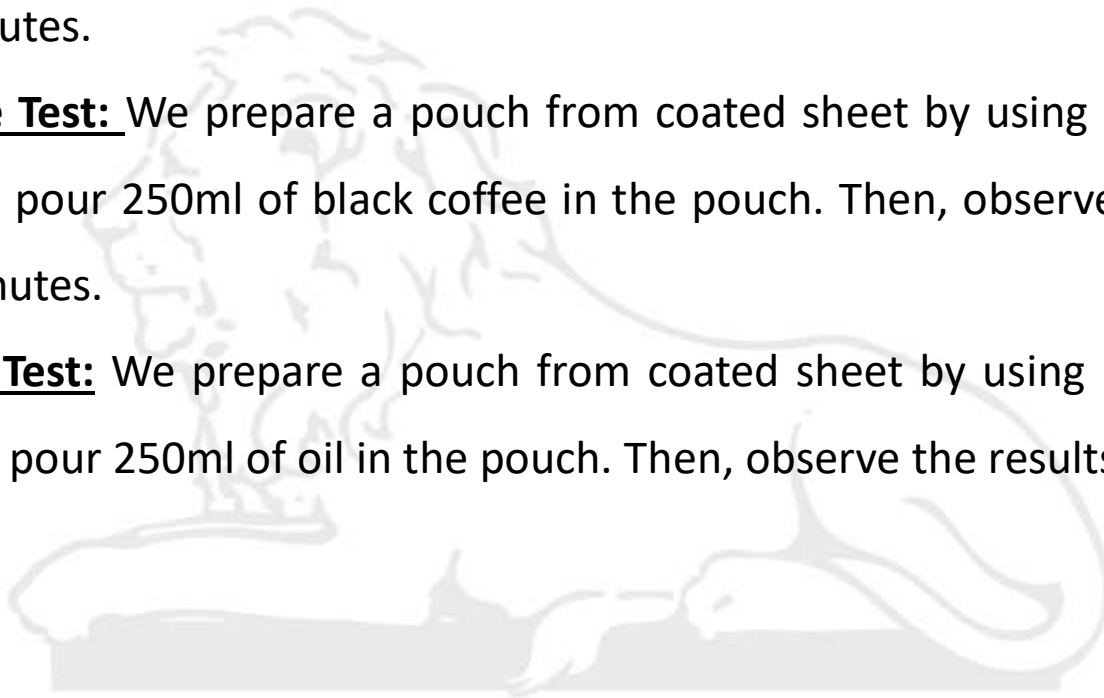


LEAKAGE TEST OF SAMPLE

❖ **Hot Water Test:** We prepare a pouch from coated sheet by using heat sealing method. Then, pour 250 ml of boiled water in the pouch. Then, observe the results for next 45 minutes.

❖ **Black Coffee Test:** We prepare a pouch from coated sheet by using heat sealing method. Then, pour 250ml of black coffee in the pouch. Then, observe the results for next 45 minutes.

❖ **Oil Leakage Test:** We prepare a pouch from coated sheet by using heat sealing method. Then, pour 250ml of oil in the pouch. Then, observe the results for next 45 minutes.



SAMPLE PREPARATION FOR HOT WATER LEAKAGE TEST



a) Cut the sheet to make a pouch



b) Seal the one end



c) Now, seal the another end



d) Sealing third end of the pouch



g) Leave the pouch for 45 min.

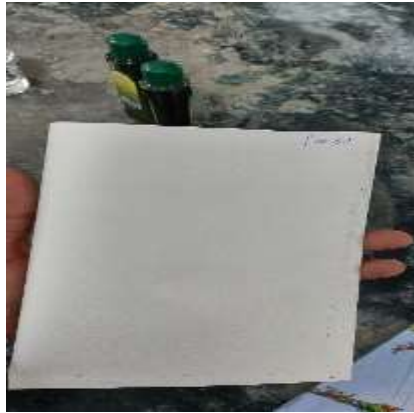


f) Fill the pouch with 250 ml of hot water



e) The pouch is prepared

OIL LEAKAGE TEST



a) Prepare a pouch



b) Take a pouch for KET Test



c) Pour oil in the pouch



e) Leave the pouch for 45 min.

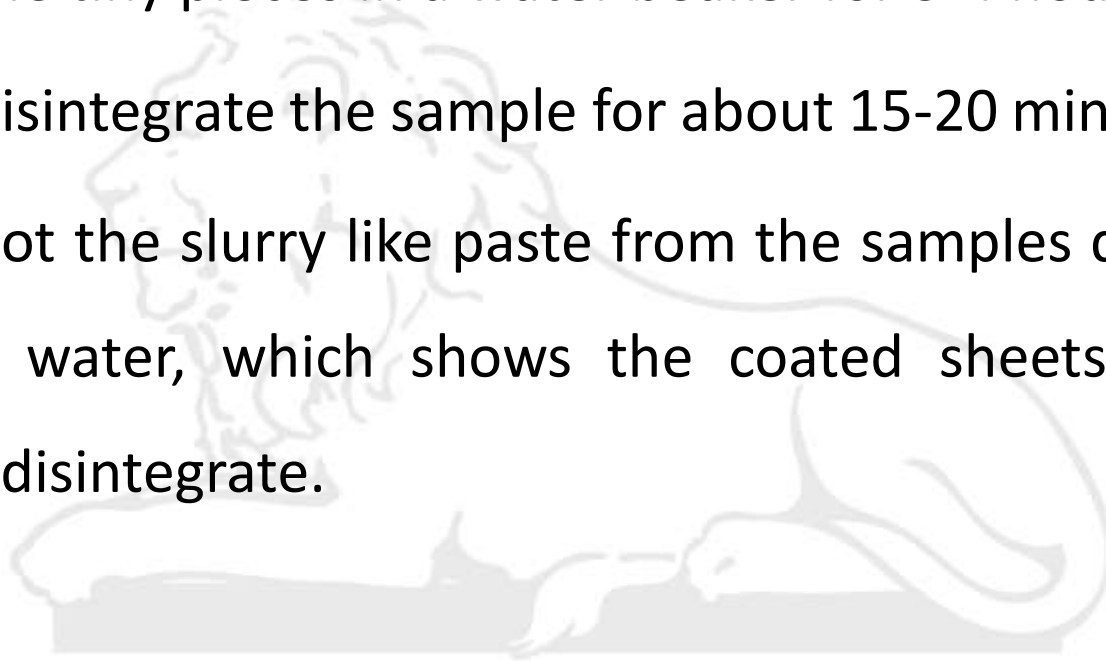


d) Pouch filled with oil

RECYCLING PROCESS OF COATED SHEETS



1. Cut the coated sheets into tiny pieces.
2. Keep the tiny pieces in a water beaker for 3-4 hours.
3. Now, disintegrate the sample for about 15-20 minutes.
4. Now, got the slurry like paste from the samples dipped in the water, which shows the coated sheets were totally disintegrate.



STEPS FOR RECYCLING PROCESS OF COATED SHEETS WITH HOT WATER



a) Cut the sheets into tiny pieces



b) Take 20g of tiny pieces of sheets



c) Add tiny pieces into Hot Water



d) Stir the mixture with glass rod



h) We got whitish slurry by disintegration process



g) Now, Stir the mixture with mechanical stirrer with the speed of 900rpm for 30 min.



f) Add 1L Hot water for disintegration process



e) Leave the mixture in the hot air oven for 1h.

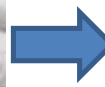
SHEET FORMATION BY HOT SLURRY



a) Take 300ml of normal slurry



b) Add slurry into round sheet former



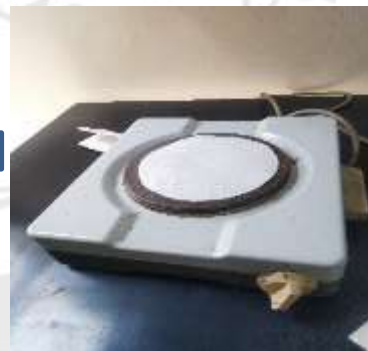
c) Now, mix the solution stirrer rode



d) Fresh round sheet formed



h) We got Hot water recycled sheets



g) Now, transfer the sheet on the hot sheet dryer



f) Now, rolling the weighted roll over the fresh formed sheet



e) Now, transfer the sheet with placing bloating paper over the fresh sheet



CLAIMS UNDER PATENT APPLICATION

- Formulation of developed water-soluble resin for coating on paper sheet used for making paper cups and other applications
- Quantity of different monomers used for resin preparation
- Percentage of resin and solvent
- Additives used for functional properties like anti-foaming, anti-settling etc
- Type of coating methods and parameters of coating cylinders

THANK YOU
