

HIGHLIGHTS

- China applied 63% recycled fiber in all paper products. Recycled fiber can produce quality products
- China mills kept positive on market demands and facility investments
- Newsprint and paperboard containing recycled fiber from U.S. & China mills are investigated, strength and weakness seen on both sides
- Recycled fiber applied in U.S. mills has better quality than those in China peers
- U.S. is good on paper recycling, but weak on recycled fiber utilization

INTRODUCTION

The Facts of Pulp and Paper between U.S. and China

- China becomes the largest paper/board manufacturer, both capacity and productivity are still increasing.
- U.S. paper/board capacity and productivity were keeping shrinking since late 1990’s
- Chinese has extremely low natural resources in terms of per capita
- Paper recycling is the most successful sustainable program in U.S.
- U.S. has advantages in manufacturing experiences and techniques, and China has advantages in new facilities and processes

| Items | U.S. | China |
|--|---------|-------|
| Paper machine average ages, years | > 35 | 15 |
| New PM installations, 2000-2010 | 9 (N.A) | 431 |
| Forest cover | 33% | 20.4% |
| Domestic consumed paper/board recycled | 67% | 43.8% |
| Recycled paper for export | 42% | - |
| Recycled fiber in all new paper products | 37% | 63% |

Note: Data are cited in 2010 and 2011; N.A refers US and Canada

Attitudes on Recycled Fiber Utilization

- Recycled fiber is the largest fiber source in China, up to 63%. U.S. only applied 37% recycled fiber into new paper products.
- China applied recycled paper in all grades of products, U.S. only focus on paperboard, tissue, newsprint
- U.S. exports 42% of recycled paper in 2011, and is the largest recycled fiber supplier to China

METHODOLOGY

Samples Sources

- Newsprint paper (NP) and one-side-coated paperboard (PB) samples were coming from four mills in U.S. and China

| Items | CNP | UNP | CPB | UPB |
|-----------|-----------|--------|-------------|---------|
| Grammage | 45/48 gsm | 48 gsm | 250/350 gsm | 350 gsm |
| Recycle % | 100% | - | 100% | - |

Tested Paper Properties

- Fiber quality, ash content and hot water extract pH & conductivity
- Paper mechanical and surface properties
- Optical properties and lightfastness

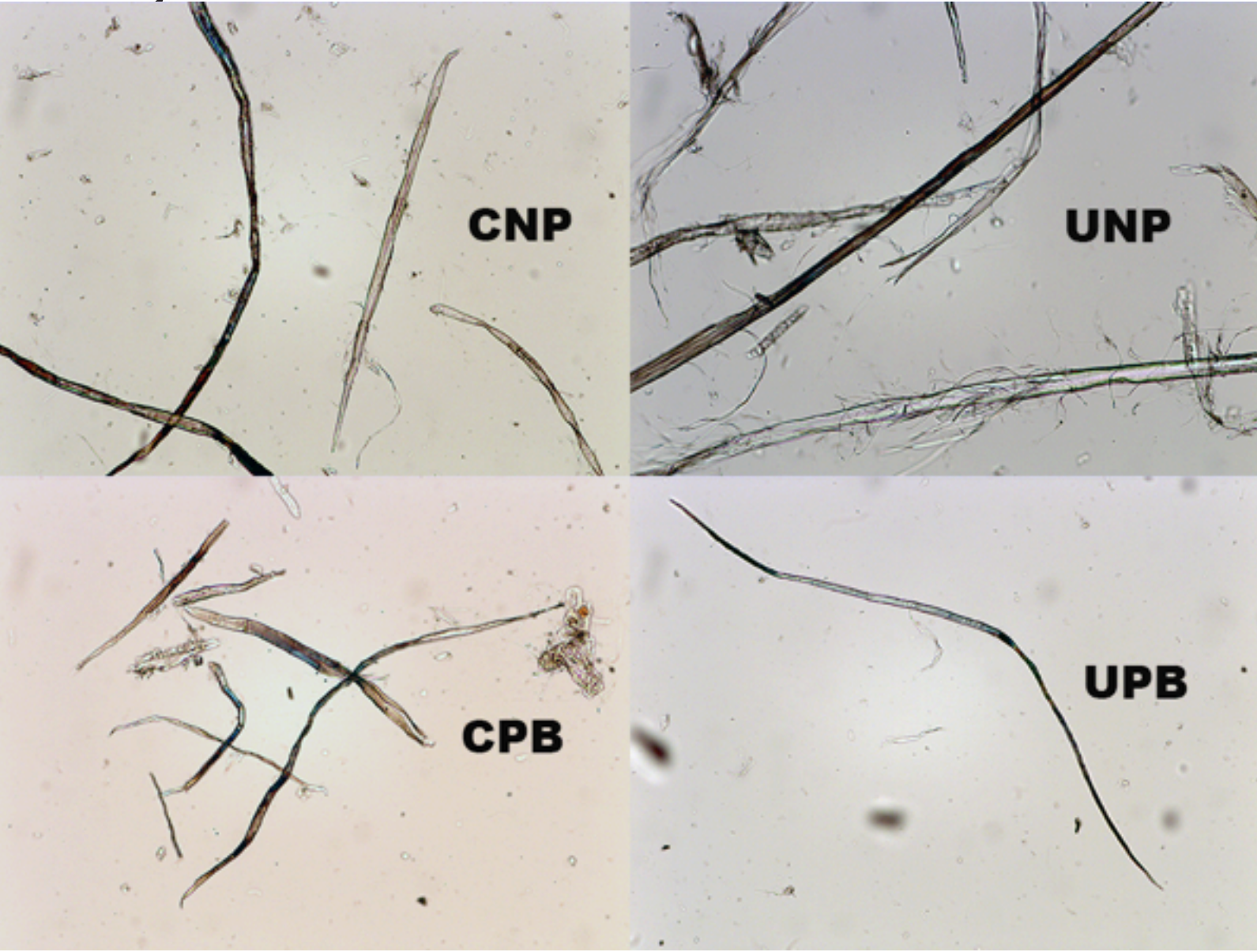
Standards

- TAPPI

RESULTS AND DISCUSSIONS

Fiber Analysis

- Recycled fibers (tinted) were found under 50X microscope



| Specimens | CNP | UNP | CPB | UPB |
|-------------------------------------|------|-------|-------|-------|
| Fiber length (weighted, mm) | 1.12 | 1.56 | .94 | 1.68 |
| Fiber width (mean, micron) | 21.3 | 29.13 | 17.73 | 22.97 |
| Curl index (Arithmetic) | 0.10 | 0.05 | 0.09 | 0.09 |
| Kink index (1/mm) | 1.66 | 0.53 | 1.59 | 1.34 |
| Zero span tensile (corrected, N/cm) | 26.3 | 26.9 | 23.8 | 20.9 |

- Fiber quality assessment
All fibers are short and straight.
Fibers from U.S. mills are longer and wider, indicates Chinese mills use lower grade fiber.
Zero span tensile indicates the mills in China uses additional binders to offset fiber weakness.
- Ash content, pH and electrical conductivity
UNP adds extra fillers than those in CNP, which help to obtain bulk and opacity. It saves fiber but weaken paper mechanical properties, e.g. tensile strength.
CPB applies near double mineral pigments percentage (e.g. CaCO₃) than those in UPB so that it reduces the paperboard functional properties.
UNP solution shows acid that it indicates an outdated papermaking process; CNP is made in alkaline environment.
UNP and UPB have high electrical conductivities. It refers high level impurities in pulp, or poor washing effectiveness.
New facilities help Chinese mills in recycled paper utilization.

| Specimens | CNP | UNP | CPB | UPB |
|--------------------------------------|------|-------|------|------|
| Paper hot extract conductivity (mho) | 86 | 129.9 | 71.7 | 80.2 |
| Paper hot extract pH | 9.09 | 3.72 | 8.82 | 7.66 |
| Ash contents (525 °C, %) | 19.3 | 24.5 | 40 | 21 |

Mechanical and Surface Properties

- UNP has high bulk and caliper which are good on readability
- High filler contents decrease mechanical properties. Long fiber in UNP can offsets the loss of tensile strength. However, the tensile energy absorption (TEA, or toughness) and stretch are still decreased.

- CPB has same tensile as UPB has. But it has high TEA and stretch regardless of the short fiber and high mineral pigment contents. Extra binders are integrated.
- UPB has very good performance in stiffness, which is very important to packaging.

| Specimens | CNP | CNP | UNP | CPB | CPB | UPB |
|--------------------------------|-------|-------|-------|--------|--------|--------|
| Grammage (g/m2) | 45 | 48 | 48 | 250 | 350 | 350 |
| Caliper (mm) | 0.06 | 0.06 | 0.08 | 0.27 | 0.40 | 0.45 |
| Bulk (cm3/g) | 1.32 | 1.25 | 1.68 | 1.14 | 1.19 | 1.36 |
| Tensile strength (MD, N/m) | 2,630 | 2,670 | 2,631 | 13,333 | 15,337 | 15,798 |
| TEA* (MD, J/m2) | 28.5 | 25.5 | 19.5 | 236.3 | 289.4 | 192.7 |
| TEA STD (J/m2) | 2.2 | 1.2 | 2.8 | 14.7 | 45.9 | 16.7 |
| Stretch (Elongation, %) | 1.77 | 1.60 | 1.36 | 2.72 | 2.84 | 1.98 |
| Taber stiffness (MD, def. 15°) | - | - | - | 78.5 | 73.3 | 201 |
| Smoothness (PPS, microns) | 3.6 | 3.8 | 3.6 | - | - | - |
| Porosity (PPS, ml/min) | 243.8 | 201.9 | 548.2 | - | - | - |

*TEA: Tensile energy absorption

Optical Properties and Lightfastness

- All newspapers have closed optical properties, e.g. brightness, gloss and CIE L*, a*. UNP shows yellowish tint.
- CNP has lower opacity than UNP
- No Fluorescence is found in all of samples.
- UNP has poor lightfastness, which indicates high lignin content. Virgin pulp is included.

| Specimens | CNP | CNP | UNP | CPB | CPB | UPB |
|--------------------------------|------|------|------|------|------|------|
| Grammage (g/m2) | 45 | 48 | 48 | 250 | 350 | 350 |
| Paper brightness (Directional) | 55.7 | 56.8 | 55.7 | 82.3 | 80.4 | - |
| Fluorescence | 1.6 | 1.0 | 0 | 1.3 | 1.4 | - |
| Paper Gloss (MD, 75°) | 11.6 | 11.4 | 11.3 | 34.0 | 51.2 | - |
| Paper Gloss (CD, 75°) | 9.8 | 9.9 | 9.6 | 32.5 | 51.7 | - |
| Paper opacity | 90.2 | 90.2 | 92.3 | - | - | - |
| CIE L* (D50, 2°) | 79.5 | 80.0 | 79.8 | 90.6 | 90.6 | 89.6 |
| CIE a* (D50, 2°) | 1.0 | 1.7 | 1.5 | 2.3 | 2.0 | -0.4 |
| CIE b* (D50, 2°) | 1.5 | 0.6 | 4.1 | -2.4 | -1.8 | 0 |
| Lightfastness (CIE ΔE) | 10.7 | 12.6 | 21.9 | 0.9 | 1.7 | 0.7 |

CONCLUSION

- Recycled fiber is the main fiber source of China pulp and paper industry
- China mills apply 100%, relative low grade recycled fiber produce quality paper products
- U.S. has very good paper recycling program, but need to invest on recycled paper utilization.
- U.S. mills need to find solutions to overcome current facility shortage, especial for recycled paper.

