Standardization of RDA Conditions for the Simultaneous Analysis of Retention, Drainage and Uniformity of Papers

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Abstract
In order to manage the papermaking procedure in an effective way, it is inevitably required to measure and estimate the various changing parameters of wet-end process control. This content is devoted to the explanation of lab scale new investigating method regarding wet-end process of paper machine by using RDA.

Keywords papermaking, RDA, retention, drainage, uniformity

Three important factors in papermaking

Drainage property in wet-end stage means the degrees of dewatering and consolidating of paper stock, which is ejected from headbox at the consistency of about 1% usually. If drainage is bad, insufficient dewatering may cause the serious problem like the reduction of paper making productivity and also it can be a reason of poor physical properties of paper.

Retention means the ratio of solid portion retained on paper web versus total solid amount in headbox stock. When the retention is bad, suspended solids in paper stock can pass through the forming fabric and this results in the accumulation of fines and other contaminants in white water. There will be excessive loss of raw materials. In order to promote the retention of fine solid materials, various kinds of chemicals are added to wet-end as you can expect. In that case, you should concern about certain degrees of coagulation, floculation of small particles in paper stock compensating for retention of them.

Although, addition of retention chemicals or increase of headbox consistencies can be

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suggested sometimes as a solution for bad drainage and low retention, it may induce the deterioration of the uniformity of paper, bad formation as a result of increased fiber flocculation. Wood fibers are slender shape (1 to 4 mm length with narrow width 20 - 40 μm, in case of Sw-BKP). Therefore, wood fibers have a strong tendency to flocculate each other. The degree of flocculation is generally proportional to consistencies of paper stock and fiber length. Flocculation gives rise to deterioration of uniformity, paper formation and consequently, lowering of other properties of paper like strength, printability and opacity could be induced by bad formation. Retention, drainage and formation are almost always critical to good papermaking, but usually are opposed to each other in their control.

Managing Retention, Drainage and Formation

How do papermakers control retention, drainage, and formation to optimize all three without harming any one of the three? In order to get a balance of three to meet paper quality parameters we should find the best solution for specific wet-end case and use effective tool to optimize the wet end for maximum performance and ultimately helps the papermakers meet their goals.

If someone wants to produce paper efficiently, formation of paper, with the drainage and retention properties, should be considered as important factors of papermaking procedure. In particular, comprehensive understanding about wet-end part of paper machine (PM), the main decisive stage of important properties of paper and paperboard, is the important key of PM operation. Appropriate control for this stage with regard to drainage, retention and formation of sheets could be made by RDA.

Limits of Conventional Testing Instruments

Many kinds of instruments were developed with views to measure the drainage, retention
properties and to make paper samples representing actual machine-made one as possible as they can. The most well known testing instruments for drainage is Canadian Standard Freeness Tester (CSF Tester). And instrument for retention is Dynamic Drainage Jar (DDJ).

The existing equipments like CSF tester or DDJ generally do not adapt vacuum in dewatering stage and depends entirely on gravity for the sake of convenience. However, it is different from actual PM's condition which use usually vacuum in wet-end part at the suction power of 0.25 bar or more than. Although DDJ can measure the retention of fine particles, it doesn't form the fiber web and so filtration effect on retention can not be analyzed. Coagulating or flocculating power of additives can be measured in this case.

Circular handsheet former has been standardized and the most well known one is TAPPI standard handsheet former. Rapid Köthen Former is also an official standardized one. Other similar formers exist but they all obtain the same result: handsheets with through-look as good as possible, the perfect sheet. This is possible because there is water-flow under the wire and the usual consistency is about 0.2 g/L. The consistency in paper machine is about 5 - 13g/L. The handsheet former may allow to test pulp, but not paper. Although it allows to check the degrees of refining or the effect of pulp composition, the drainage speed of handsheet former is so slow that it can't reproduce the real PM's sheet forming process. Although it allows to have uniform specimen, and to get some optical and physical test results with that uniform sheets, users can't evaluate the changes of retention, drainage, and degrees of fiber flocculation caused by the addition of wet end chemicals. All these reasons don't make the actual forecasting possible with regard to the wet end of PM.

Swedish equipment, Dynamic Drainage Analyzer (DDA), is a new instrument developed later. DDA doesn't make handsheets, but gives information about drainage & retention. Nevertheless the drainage condition is not so harsh compared to the actual PM. Usually the dewatering time required for DDA is more then 5 seconds. PM at the slow operating speed of 500m/min may have dewatering time less than 1 or 2 seconds. Therefore, based on the above-mentioned aspects, it could be concluded that although automatic vacuum dewatering can be performed by DDA, the use of it is confined to the relative comparison of dewatering tendencies between different paper stocks and wet end additives.

Different from the above-mentioned testers, the objective of FRET was to make handsheets that can be similar to machine made paper, especially with regard to filler-retention, flocculation and formation. Actually, this objective seemed to have been obtained by FRET but there still exist serious gap between its formation and actual one. After the introduction of paper stock, center located agitator in stock tank of FRET is programmed to stir it in order to give sufficient mixing action to the varied chemicals added to stock. Introducing of stock into forming tank follows the stock preparation and just before suction dewatering, there is an
introduction of air bubbles in order to disperse the stock again.

At this moment, the dispersed state of stock should be sustained sufficiently until the finish of vacuum dewatering not only enough to get a uniform formation of sheet but also to insure the exact reproduction of actual PM's sheet forming performance. Unfortunately, it is impossible for FRET to sustain the proper dispersed state of stock in forming tank. Dispersion of pulp stock could be achieved by maintaining sufficient turbulence. However, turbulence has a strong tendency to be decayed fast if there is no more additional agitation or other kinds of mixing action, which can induce shear force. When the agitating impeller of FRET is stopped, decaying of turbulence is started. And during the paper stock is introduced into forming tank, certain degree of fiber flocculation is unavoidable. This means that the condition of FRET's handsheet forming is different from that of actual PM which can provide enough turbulence without interruption from headbox to couch roll by continuous vibrating action and pulse of suction. How can we analyze and estimate the wet-end properties based on the lab scale simultaneous test of three influencing factors? We need universal test machine for wet-end now.

Developing Story of RDA

Fig. 1 RDA, Commercial Model (2002).

Fig. 2 Fiber Orientation According to Different Stirring Actions,
By adapting the new agitating system consisted of six impellers, rotating with counter
direction each other, RDA can give unoriented shear force to stock until the finish of stock
introduction into forming tank without interruption. Due to the remaining turbulence of
introduced stock, more uniform sheet formation at high consistency could be realized by RDA.
If it were not for six impellers, continuous stirring of stock might not be possible because of
the unintentional circular orientation of fiber caused by the mixing action of center located
mono stirrer. If the strips for tensile strength test are prepared with above-mentioned handsheet,
showing circular fiber-orientation, test results may represent significant variation according to the
place where the strips are taken. For example, strips taken at the edge of sheet may have the
machine directed fiber orientation. On the contrary, strips taken at the center of sheet may have
the cross machine directed one showing low strength.

The dispersed state of paper stock, introduced into forming tank is determined by the strength
of agitating action in stock tank and by the (turbulence decaying) period of stock introducing
and wave subsiding. Basically closing cone should be opened as much as possible without the
excessive wave or bound. The height of stock tank should be adjusted according to the volume
of stock, based on the simple standard, as low as possible. By lowering the position of stock
tank, generation of unwanted wave by introducing stock can be minimized consequently.

RDA is also superior to other existing equipments in an aspect of adapting syringe revolver
instead of chemical pump as an automatic injector of chemical additives into stock tank. The
comparison of varied wet-end chemicals should be made based on the simultaneous analyses of
drainage, retention and formation of paper at the varying addition levels and kinds of chemical
additives. In case of automatic chemical pump, cleaning of chemical reservoir should be preceded before the change of additives and it consumes lots of time and labor consequently. However, by adapting revolver injector for RDA, disposable syringe can replace the conventional reservoir and so test time could be reduced consequently.

The year 2002 KRICT developed a novel handsheet former RDA (Retention Drainage Analyzer) with a view to overcome the lots of faults made by existing equipment. Different from previous machine, RDA can provide and control the intensity of turbulence during paper stock introduced into forming tank. RDA is superior to the other existing handsheet making equipment, in particular, in an aspect of sheet forming consistency, uniformity of sheet and reliable reproduction of actual paper machine’s dewatering procedures.

Sheet Molding Procedure of RDA

Set Consistency or Volume of Stock Corresponding To Target Uniformity

RDA needs at least 750mL volume of stock in order to mix it properly. If the volume of stock is less than 750mL, it may cause the incomplete mixing of additives and stock. Actual consistency of paper machine headbox is around 0.5 to 1.3%. However, so high consistency for RDA forming is not desirable due to the bad formation of sheet. Although RDA can bring a mixing action until the finish time of the stock introduction into “Forming Tank”, turbulence generated by (stirring) shear force is to be decayed at a millisecond of “Delay Time” (time for the introduction of stock from “Stock Tank” to “Forming Tank”) and “Forming Time” (time for the subsidence of waves in “Forming Tank”).
Dilute Headbox Stock with Same Conductivity Water without Anionic Trash

Hence the consistency of stock should be diluted in order to adjust the degrees of fiber flocculation of RDA sheet according to the target formation. Here 750mL of 0.3% consistency stock is corresponding to the basis weight of RDA sheet o.d. 75g/m2. Maximum volume of “Stock Tank” is 1,500mL. If there is a trial regarding the choice of wet-end chemicals, first of all, RDA operator should take the mixing or machine chest stock and short circulating white water from silo separately in order to prepare the blank headbox stock without any introduction of wet-end chemicals. And then one should dilute the prepared stock with the water having same conductivity of actual headbox while the anionic trash is not included in order to adjust the formation RDA sheet as similar as that of actual target paper.

Considerations Given to the Design of RDA (Preserve Turbulence of Stock In Forming State)

RDA is designed with the concept of preserving turbulence of stock during dewatering by reducing the duration times for introduction of stock into forming tank as short as possible. As already mentioned in previous explanation, turbulence decay can occur during the short period of introducing, even at the very short time, millisecond. If the introducing period is too long, fiber flocculation and deterioration of paper formation are unavoidable. The introducing time of stock depends on the volume of stock (basis weight of handsheet & stock consistency) and opening gap of closing cone. After stock preparation, pulp stock is to be introduced by opening the closing cone of stock tank. At this stage, the opening gap of closing cone determines the introducing time of stock.

Adjust the Height of Stock Tank and Opening Gap of Closing Cone

If the gap is increased excessively, bounded stock can overflow the forming tank and generate waves on the stock surface. On the contrary, excessively narrow gap can cause the delay of introduction of stock and results in fiber flocculation. Conclusively, closing cone should be opened as much as possible without the excessive wave or bound. Hence the height of stock tank should be adjusted according to the volume of stock, based on the simple standard, i.e. as low as possible. By lowering the position of stock tank, generation of unwanted wave by introducing stock can be minimized consequently.
Application of Post Dilution Water

If RDA needs additional dilution of stock in order to enhance the formation of RDA sheet more, introduction of post dilution water in “Stock Tank” and pre-filling water in “Forming Tank” could be considered. Post dilution water means additional water for dilution of stock where the whole additives are already added. Although excessive dilution of stock before the introduction of additives could result in insufficient mixing of wet-end chemicals, the additional introduction of dilution water after additives introduction may not cause the above mentioned error. If the total volume of slurry in “Forming Tank” exceeds 2,500 mL, installation of extension ring on “Forming Tank” could be suggested in order to prevent the overflow of stock.

Application of Pre-Filling Water

With a view to dilute the stock at “Forming Tank”, forming tank could be filled with certain amount of dilution water called “Pre-Filling Water”. According to the introduction of slurry from “Stock Tank”, mixing of stock and “Pre-Filling Water” is to be made consequently. Here the volume of “Pre-Filling Water” should be smaller than that of introducing stock from “Stock Tank”. Otherwise sufficient mixing by falling action could not be made due to the deficiency of mixing power. Existing equipments can not provide any controlling ways for above mentioned delicate setting however RDA provides appropriate conditions for the more reliable reproduction of actual PM’s paper forming performance.
Choose Mesh Size and Stirring, Suction Condition Corresponding to Target Retention

After adjusting the uniformity (formation) of RDA sheet by dilution, consideration about the retention could be followed with a view to set the fines retention level of RDA sheet as similar as that of actual paper. Retention level of RDA sheet could be checked by measuring the o.d. weight of sheet or turbidity of filtrate water. The most influential way of adjusting the retention of RDA is changing wire mesh. Here the bigger wire mesh means the less retention of RDA sheet. Stirring time, rpm and suction vacuum could be suggested as influencing factors on the retention of RDA sheet. However, these factors are the operating characteristics of paper machine and intentional or unnatural setting of them is not desirable.

Table 1. RDA conditions to analyze the drainage of test stock

<table>
<thead>
<tr>
<th>Papergrade</th>
<th>Unit</th>
<th>Corregated Board</th>
<th>Newsprint</th>
<th>woodfree office</th>
<th>Decor paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials</td>
<td></td>
<td>50% News + 50% OCC</td>
<td>50% News + 50% LWC</td>
<td>80% hardwood + 20% softwood + 20% Filler</td>
<td>100% hardwood euca + 40% Filler TiO2</td>
</tr>
<tr>
<td>Grammage</td>
<td>g/m²</td>
<td>220</td>
<td>100</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Step1</td>
<td>sec</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Sub</td>
<td>RPM</td>
<td>700</td>
<td>800</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Step 2</td>
<td>sec</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Sub</td>
<td>RPM</td>
<td>700</td>
<td>800</td>
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### 참고문헌


2. 전창훈, 류정용, 송봉근, 서영범, 정성현, 보류, 탈수, 지합을 종합적으로 고려한 Retention and Drainage Analyzer (RDA) 활용 보류양상계의 선정사례, 펄프·종이기술, 제42권 제3호, 7-13, (2010).


