CURL REDUCTION AND QUALITY AUGMENTATION OF PLAIN COPIER PAPER

R.B. Lakshmipathi Sakthi[1], F.Amjath Khan[1], S. Gokulakannan[1], R. Bhuvaneshwari[1], B.Mahesh[1]
[1]*Tamilnadu Newsprint and Papers limited, Kagithapuram, Karur-639136 Tamilnadu*
Email: rnd@tnpl.co.in

ABSTRACT

PAPER – An indispensable commodity made a great influence on Civilization and a significant impact on the course of human history. TNPL is eco-friendly bagasse based paper manufacturer across the globe. Customers look at TNPL as a prominent player in various applications of paper, with "TNPL Copier Platinum - An environmentally benign artifact product" a leader in photo copying plain paper market. The performance of any plain copier paper is challenged by commonly encountered problems like curling and jamming during commercial photocopying. Even though manufactured as per BIS norms, these challenges are more profound in TNPL Copier than other competitor products, the reason being usage of bagasse pulp to a large extent vise a vis wood pulps by the competitors. This paper describes how our team approached the customer end photo copying issues of curling and jamming using concepts of Manufacturing Excellence – A tailor made manufacturing concept embracing basic statistical tools and data driven improvement cycle DMAIC, a core tool used to drive Six Sigma projects. It also explains in detail the procedures followed in evaluation, analysis and standardization, which helped in identifying a sustainable solution to the key quality issues in copying paper and developing a SOP for the manufacturing of copier paper having excellent dimensional stability with reduced level of curl. The above systematic analysis has resulted in reduction of 43.8% in curling and 66.66% in TSO angle variation.

Key Words: Dry curl, Plain copier, Dimensional stability, Paper, Pulp, Manufacturing Excellence.

1. INDRODUCTION

In order to understand why paper curls, there are a few basic facts about paper that we need to know. If the relative humidity increases, paper absorbs water, and if the humidity decreases, it loses water. Though the paper is thin, paper has a separate top and bottom side and both are variant[1]. Differences in Co-efficient of Moisture Expansion (CME), fiber orientation, composition (fines, fillers, and coatings), draws, drying profile and uniformity in sheet moisture results in paper curl [3]. Most of the fibers are aligned in the web flow direction (i.e. Machine - Direction-MD) which is referred as "Long-grain". When the fibers swell due to increased humidity, the sheet usually curls along with the axis of curl in the MD[2].

"CURL" can be defined as tendency of paper to adopt a non-flat structure when exposed to changes in humidity or temperature during normal use. It occurs when sheet layers expand unevenly. The flatness and dimensional stability of paper relate to their ability to remain flat under the effects of humidity changes. Curl can also be defined as the inverse of the radius of curvature of the sheet, and is positive when the printed side is convex. There are various types of curl that can be observed in paper[3]. Based on the shape and the principle axis of the curl it can be defined as follows (Figure: 1)

- ✓ CD Curl (Cross-machine Direction)
- ✓ MD Curl (Machine Direction).
- ✓ Diagonal or Twisted Curl.

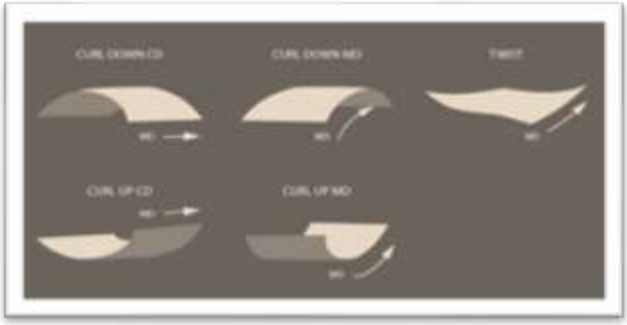

Figure 1.0

2. BACKGROUND OF PROBLEM:

When analyzing the inflow of customer complaints, it was evidently noticed that among all the varieties, highest number of complaints were registered in 70 GSM Copier with respect to Curling & Jamming. Accordingly most of the curling & jamming complaints were logged in while using in Electro photographic copiers and printers. Hence a quality circle project team was formed to solve this curling and jamming issue methodologically using data driven improvement cycle DMAIC[5] (Define, Measure, Analyze, Improve and Control)

3. USE OF DMAIC TOOL:

Define Phase:

The Process behind Electro photographic copier printer is copying of images on paper by transferring toner (resin particles) using static electricity. The fuser assembly in the printer heats the toner image to melt and adhere to the paper. By this, paper is exposed to high temperature (~100°C) instantaneously for about 0.05 sec[6], which in turn makes the paper to curl and comes out of the printer in an uneven manner. When the degree of curl is more, we would get paper jamming issue in double side printing and in case of single side printing the physical appearance & uniformity of paper gets disturbed, which makes the finishing processes like binding, cutting and packing more difficult.

Measure Phase:

It is mandatory for us to maintain all the standards of BIS and TAPPI for not only Copy paper but any paper. The properties were verified at our In-house paper testing laboratory for every jumbo roll produced. Apart from Optical properties, Basis weight, Caliper, Directional properties such as tensile (Breaking length), Tear factor, Droop rigidity, Smoothness and Porosity were also measured.

Despite the fact that all the above said properties are maintained as per the BIS and TAPPI norms; curling issue still persists in our paper while photocopying. Hence it was decided to concentrate on evaluation of curl which was not carried out earlier. We explored the methods available for curl evaluation and we found a standard method in ISO as "ISO 14968 – Measurement of curl in a pack of sheets[7]. As per the standard, testing samples are to be collected only in final paper reams. Collected paper samples are to be processed only in photocopying printers to evaluate the curl angle using a standard image of curl angles. But, in practice as the Paper jumbo produced in Paper machine will tend to undergo some conversion process like winding, Cutting, Counting & Packing, checking of curl angle in packed reams could not help to take any possible corrective actions for improving quality, since it is the final stage just before delivering to customer. Rather it is better to check curl angle at manufacturing stage itself prior to conversion process. Hence our team decided to develop a new analogical curl evaluation method by creating printing environment similar to photocopying process.

Instead of taking samples from final reams, a sample has been taken from machine produced jumbo roll in cross direction. The strip of paper samples have been cut into A4 size (21.0 X 29.7 cm) samples with the help of standard A4 paper cutting template[8]. To create the same temperature similar to photocopying printers, an apparatus was designed. The apparatus consists of 6 nos of IR coated lamp with a door intact. As soon as the lamp glows, the optimum temperature will attain. By using Gauge R & R tool[9] the apparatus was standardized and calibrated accordingly. An SOP has been developed to evaluate the curl of paper as per the following steps (Figure 2.0)

Step: 1 Switch on the lights in dry curl tester just before 5 minutes of testing. Take 2 set of CD Strip samples from Paper roll and cut into A4 size template as short grain.

Step: 2 Condition the sample minimum for about 20 min. in a temperature of 27+/-1 ºC and 65 ± 2% of Relative Humidity[10]

Step: 3 Make a punch at top center of the samples. Suspend the sample inside the apparatus so that top side of the paper facing the light and close the door.

Step: 4 After 30 seconds release the sample to measure angle of curvature with scale provided in the STD ISO 14968[7]. Do the test for all samples in 1st strip and record.

Step: 5 By the same procedure measure curl in 2nd set of CD strip in which bottom side of the paper facing towards light

Lights off	Lights On	Suspending Sample	Deformation	Angle Measurement
				
a	b	c	d	e

Figure 2.0

By adapting the above procedure dry curl values of 3 consecutive runs have been evaluated and recorded during the production of TNPL 70 Copier as a base to keep a track for improvements. Figure: 3 denote that not only high average dry curl values but also range between minimum & maximum was high.

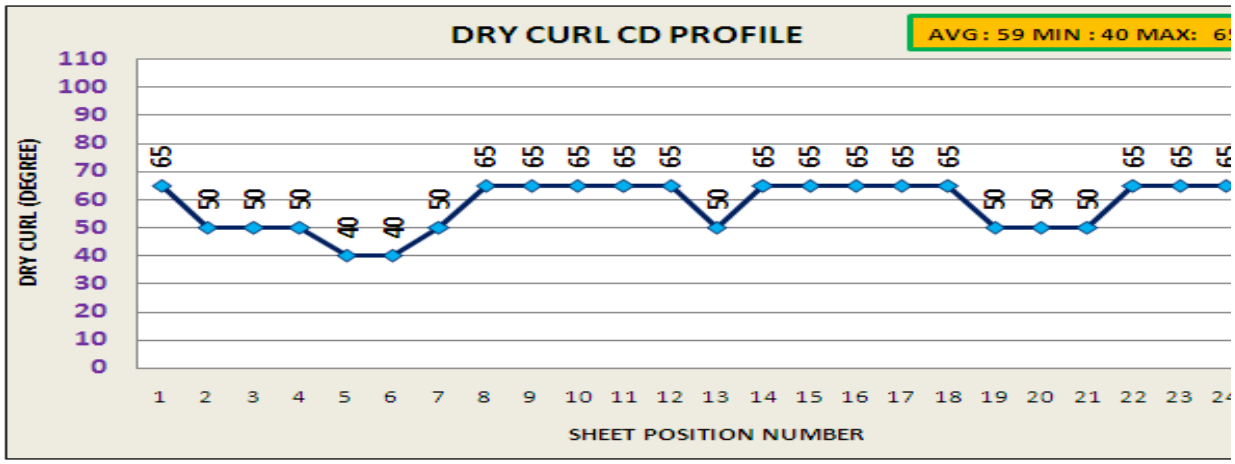

Figure: 3.0

Analyze Phase:

An acute discussion with operating crew & brain storming sessions with workmen have been carried out within the team to find variable factors which may influence curling tendency in paper. All the factors have been listed out, and a cause & effect (Fish bone) diagram has been made and the suitable factors were evaluated using risk priority numbering system. RPN system has been done based on Severity, Occurrence & Detection (SOD) score. To select the most critical factors from Score table Pareto chart QC tool has been used to categorize as vital few & Trivial many (Figure: 4.0)

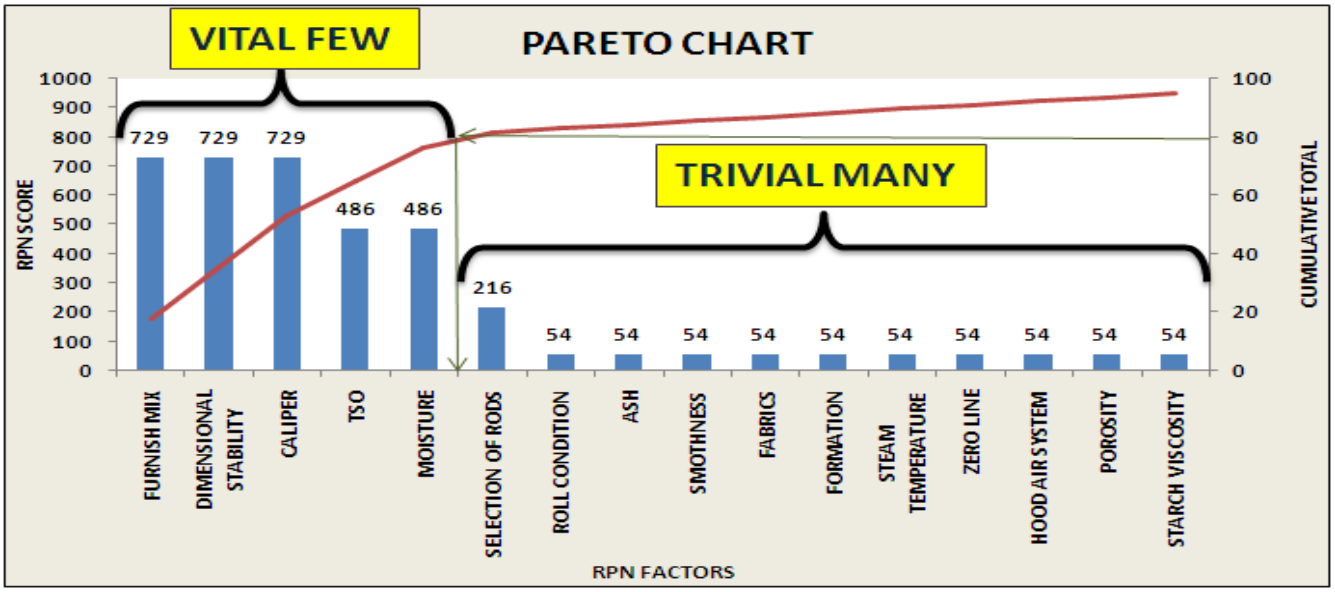

Figure: 4.0

Following Vital few factors were taken for next step of analysis

a. Furnish mix for Paper
b. Dimensional stability (MD/CD) of Paper
c. Caliper of Paper (Thickness)
d. Tensile Stiffness orientation (TSO) of fiber
e. Inbound Moisture in Paper

By keeping the previous dry curl data as blank, trials have been carried out by changing each factor arrived from Pareto chart. The details of the trials & results have been discussed. Trials were carried out by keeping most of the machine parameters & variables constant for 24 hrs and altering any one factor in each trial. To avoid switch over errors, sampling was done in jumbo rolls produced during middle of the trial for 8 nos. An average dry curl values have been evaluated and recorded for each trial.

a. Furnish mix of paper

In general for manufacturing of copier 70 GSM, furnish mix is followed as wood Pulp – 50%, Bagasse Pulp – 40 %, recycled Pulp – 5% and mechanical pulp – 5 %. Since, competing market samples manufactured using only wood pulp (100%) and wood furnish is susceptible for less curl[11], percentage of wood pulp was increased in furnish mix as per the table.

Experiment No	Furnish Mix in %				Avg Dry Curl in Deg
	Wood pulp	Bagasse Pulp	Recycled pulp	Mechanical pulp	
Blank	50	40	5	5	59
1	70	20	5	5	45
2	80	10	5	5	40
3	100	0	0	0	35

Table 1.0. Effect of wood pulp on dry curl

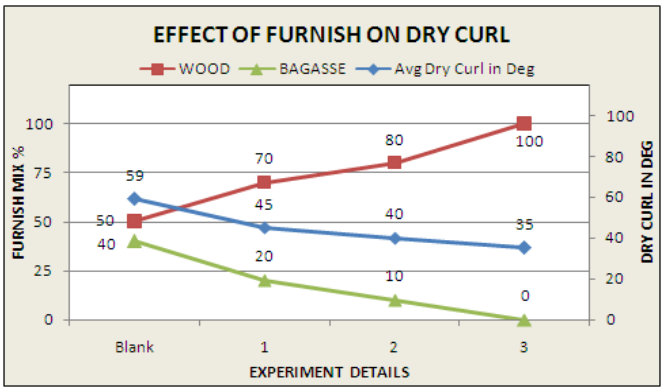

Figure: 5.0

From above Figure 5.0 it can be concluded that wood pulp was inversely proportional & CBP was directly proportional to dry curl values. TNPL is committed to be the eco friendly paper maker across the world by replacing wood pulp with Bagasse pulp, hence increase of wood pulp is being limited in the furnish mix though the results are encouraging.

b. Dimensional stability (MD/CD) of Paper

Balance (Ratio) between the directional properties such as Tensile strength, Tearing strength, bending stiffness, shrinkage (MD & CD) is termed as Dimensional stability of paper. If the ratio is less, the paper has squaring in nature[11]. The ratio can be adjusted by varying the Jet to Wire speed difference. In normal the ratio will be 2.2: 1 for a jet wire difference of 23 mpm. To improve the squarness of paper, Jet Wire difference was varied at different levels by adjusting head box pressure.

Experiment No	J/W Speed Diff. mpm	Avg. Dry Curl Deg.	Breaking Length in Meters		
			MD	CD	Ratio
Blank	23	59	5150	2450	2.10 : 1
1	18	52	4750	2500	1.90 : 1
2	13	43	4450	2530	1.76 : 1
3	8	62	4800	2490	1.93 : 1

Table 2.0 Effect of Jet wire speed ration on Squareness of paper

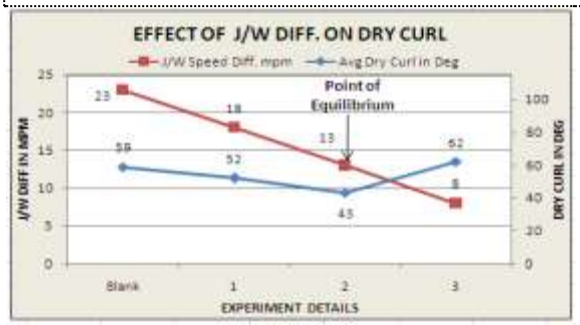

Figure 6.0(a)

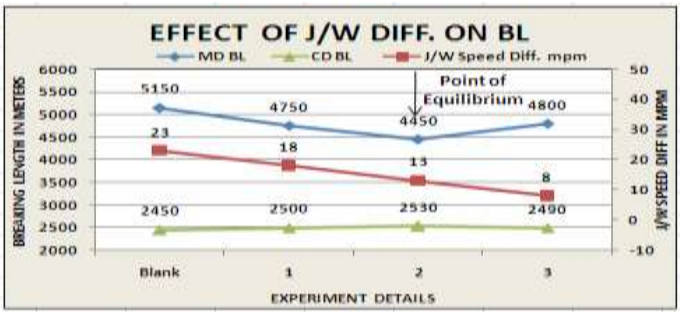

Figure. 6.0 (b)

From above Figure.6.0 (a) it was evidently clear that squaring nature of paper will impact on dry curl to a certain level, but it got reversed at a certain point of equilibrium. Consequently, while attempting the squareness, MD breaking length of the paper got disturbed and dropped below the norms mentioned in the BIS copier specification Figure.6.0 (b).

c. Caliper (Thickness)

When comparing to 80 GSM Copier, 70 GSM Copier tends to curl more during photocopying [12]. The reason is that basis weight is reduced upto 10 g/m^2 and thus the thickness of the paper maintained around 98 micrometers in 70 GSM, whereas 106 micrometers in 80 GSM. Hence, an experiment was carried out to increase the caliper of 70GSM by 2-4 micrometers from existing 98 micrometers.

The above said uplifting was achieved using mechanical pulp which is having lower density than chemical pulp[13]. Mechanical pulp has been replaced by corresponding bagasse pulp and evaluated the thickness and dry curl values. From the table 3.0 and the Figure.7.0 indicates that the addition of BCTMP have significant impact on caliper and marginal impact on dry curl.

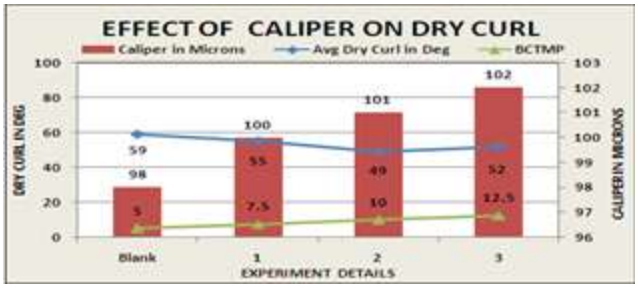

Figure.7.0

Experiment No	BCTMP % in Furnish Mix	Caliper in Microns	Average Dry Curl in Deg
Blank	05	98	59
1	7.5	100	55
2	10	101	49
3	12.5	102	52

Table 3.0 Effect of Mechanical pulp on caliper and dry curl

d. Tensile Stiffness orientation (TSO) of fiber in Paper

Though the TSO is an indicative parameter to understand the machine directional behavior of paper [14], it is important to have a view on it. Experiments have been taken after TSO optimization by adjusting the spindles in Head box Slice lip.

Experiment No	TSO Min. Deg	TSO Max. Deg	Average Dry Curl in Deg
Blank	-21	25	59
1	-15	10	48
2	-10	8	45
3	-4	5.5	40

Table 4.0 Effect of TSO on dry curl

Figure 8.0 denotes that there was an improvement in dry curl values with respect to TSO. Also it was observed that improvement of dry curl in CD profile along with better fiber orientation. But the average dry curl values were still higher.

e. Inbound Moisture in Paper

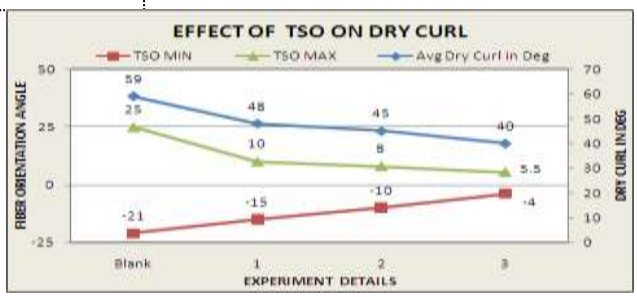

Figure. 8.0

In nature, the paper manufacturing process mostly comprises removal of water from pulp. For fine papers, starch in the form of cooked viscose liquid is coated on both sides of the paper through a pair of rubber covered sizer rolls after drying the paper [15]. Since this intermediate process makes paper damp, it is mandatory to remove the moisture in paper after soup application. Hence paper will pass through a series of dryer cylinders to dry [16]. During the drying, moisture profile of the paper may get affected. Here trials have been taken by limiting the flows of soup solution by various metering rod profile which may influence inbound moisture.

Experiment No	Metering Rod Profile used in Sizer	Soup Flow in ml/min. /Sqm	Average Dry Curl in Deg	Droop Rigidity in mm

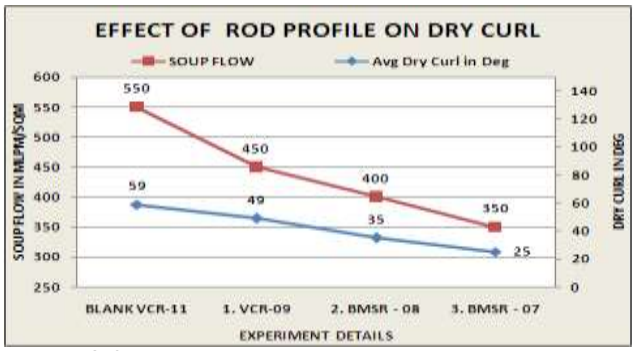

Figure 9.0

Blank	VCR-11	550	59	112
1	VCR-09	450	49	112
2	BMSR - 08	400	35	113
3	BMSR - 07	350	25	114

Table 5.0 Effect of paper moisture on dry curl

From the above table 5.0 and figure 9.0, it shows that lesser soup flow to paper results in reduced dry curl values. This gives clarity about role of inbound moisture in optimizing the curling issue. Also it was observed that droop rigidity/ stiffness of paper also improved during this trial. This trial responds more than any other experiments conducted without deviating remaining basic paper properties.

Improve Phase:

As a result of the trial – "Inbound Moisture in Paper" consecutive manufacturing of Copier 70 GSM were carried out by maintaining soup solution at minimum flow along with lower profile metering rods. To verify the actual performance of Copier 70 GSM, the reams were collected from final conversion section. All the samples were tested in commercial photo copying machines of various customers irrespective of speed & model of the photo copying machines. Also single & double sided printing was done in all photo copying machines to find the difference in degree of curling tendency.

Before

After Improvement

Figure: 10.0

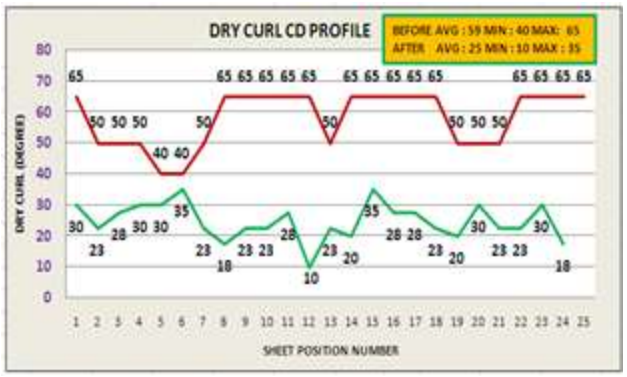

Figure 11.0

It was observed that all paper samples performed well in all photo copying machines without any curling & jamming issues (Figure 10). Also all samples showed good average dry curls values along with low deviation in minimum and maximum (Figure 11.0).

Control Phase:

An SOP was implemented by Standardizing metering rods which were used at the time of manufacturing Copier 70 GSM. The procedure includes documenting of metering rod details like make, flow and running hours. Regular Measurement of dry curl values at the time of manufacturing itself was incorporated. In addition to that printing performance of final paper samples from finished reams were checked randomly at in-house photo copying machines.

4. RESULTS & DISCUSSION

After a span of six months since we made this effect, we looked at the inflow trend of customer complaints and it took us by surprise that no complaints were logged in Copier variety (Fig 12.0). The result of our project ended not only in improved printing without curling and jamming issues, but also a remarkable increase in monthly production of TNPL copier 70 GSM (Fig 13.0). On top of it, we reaped additional benefit of increased ash by 1% due to improved rigidity of paper as per the new process (Table no 6).

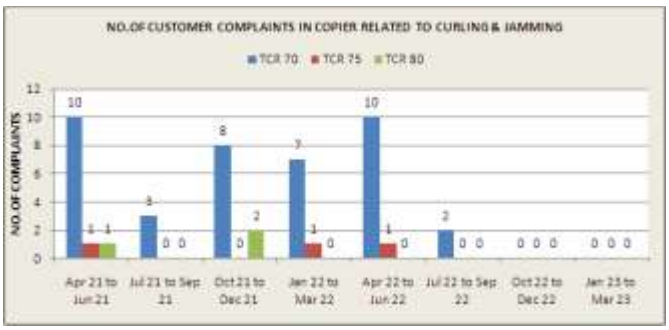

Figure 12.0

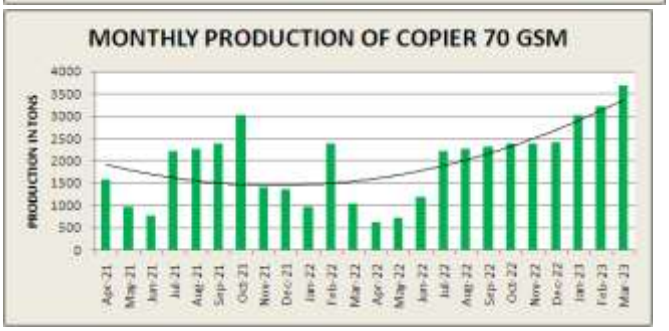

Figure 13.0

Calculation for Cost Benefit per Annum	
Cost reduction/ ton of Paper in Rs.	**309.5**
Average yearly production of Copier 70 GSM	**25631.82**
Cost Benefit per Annum	**79 Lakhs**

Table 6.0 Cost implications

5. CONCLUSION

By picking a parameter which is not in the existing regulation norms and with team's endeavor, a detailed systematic study and research, we were able to optimize it by controlling the unwanted or excess water addition with soup solution. Hence the famous quote "Cost cutting is no longer the solution to sustainable profitability, the key to success is finding creative ways to prevent wasteful

activities" was proved again. The following benefits were noticed by this innovative approach for sustaining quality.

Tangible benefits:

1. TNPL Copier 70 GSM demand increased exceptionally in market.
2. Profit of 79 Lakhs per annum earned because of increased ash by 1%
3. Elimination of customer complaints

Non tangible benefits:

1. Goodwill & Brand value sustained
2. Customer's perception towards the product turned good

ACKNOWLEDGMENT

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REFERENCES

1. Green, C. and Atkins, J., "Curls Aren't Always Cute", Paper360° Magazine, November 2007, TAPPI Press, Atlanta.
2. The problem of paper curl. Paper 360-Jan/February 2012.
3. Page D. H.; Barbe M. C.; Seth R. S.; Jordan B. D. "The Mechanism of curl creation, removal and retention in pulp fibres", Tappi International Mechanical Pulping Proceedings (1983).
4. R. Duane Smith.,The roll and Web defect terminorlog 2nd Edition 2012.
5. Miguel, Paulo Satolo, Eduardo, Andrietta, João, Calarge, Felipe Benchmarking the use of tools and techniques in the Six Sigma programme based on a survey conducted in a developing country, Benchmarking: An International Journal 2012/10/19 VoL - 19
6. https://www.bu.edu/simulation/classes/505classnotes/PhotoCopier.pdf
7. ISO 14968:2022 Paper and board — Cut-size office paper — Measurement of curl in a pack of sheets, 2022
8. ISO 11556, Paper and board — Determination of curl using a single vertically suspended test piece, 2015
9. https://www.isixsigma.com/tools-templates/measurement-systems-analysis-msa-gage-rr/making-sense-attribute-gage-rr-calculations/
10. ISO 187, Paper, board and pulps — Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples.
11. Handbook of Paper and Board. H. Holik (Ed.) 2006 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim ISBN: 3-527-30997-7
12. W. Kogler, W. J. Auhorn and M. Tietz, "Coating of Paper and Board," in Handbook of Paper and Board, H. Holik (Ed.), Wiley-VCH Verlag GmbH & Co. KGaA, 2006.
13. P. Bajpai, Pulp and Paper Industry - Chemicals, Patiala, Punjab, India, Punjab: Elsevier Inc., 2015.
14. Biermann's Handbook of Pulp and Paper (Third Edition) Volume 2: Paper and Board Making-Paper making chemistry 2018, Pages 207-236
15. P. Bajpai, "Chapter 6 - Paper Manufactured - Dry End Operation," in Biermann's Handbook of Pulp and Paper: Paper and Board Making, vol. 2, Kanpur, Patiala, Índia, Elsevier Inc., 2018, pp. 137-158.