EFFECTS OF FAST DRYING CONDITIONS ON MULTI-COLORED MOVING WEB(II)

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Abstract: In previous paper, a quantitative expression of wrinkles,which developed in multi-slot hot-air driers, has been introduced. Using the index, effects of fast drying conditions on wrinkle development were studied. In this report quantitative expression of time effects on wrinkle of stored paper as half-life period have been given. To know printing conditions on wrinkle development,effects of printing area and dot % on wrinkle were studied on various printing area and combinations of dot % of prints: the wrinkle index was just proportional to printing length,and dot% effects would be explained by dispersed-continuous phase concept. Other factors such as hot-air slot width and partial pressure of water vapor in drying hot air were mentioned. Significant results of these two reports were summerized at the end of the paper.

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Introduction: To understand the general concept of this study, an overview of the past studies is repeated here. Several studies on the surface heat transfer on the moving web have been reported by Sceuter and Dosdogru(1970,1971),Dosdogru (1974) and Black and Hardisty(1976), but their studies were limited in finding heat transfer coefficient distributions under arrays of various nozzles. These studies are useful to improve the heat transfer rate in dryers at shortest ink drying time. However, no study has been done on finding relations between drying conditions and dried web surface conditions(wrinkles), which are primary concern of most printers.

Traditionally these surface conditions have been evaluated by only human eyes, with such subjective methods little progress will be expected in improving the web drying processes. Thus, in last study, the effort was forcused on finding a quantitative expression of the wrinkles.

A new index for the web wrinkles has been introduced and various effects of drying condition (drying temperature, impinging hot air velocity, web speed,web tension,chill stand arrangement etc) ,time effects on wrinkles on stored paper and test pattern itself(printing area,dot percent and their combinations) were studied.

Through this kind of procedure, a scientific approach toward designing better drier and finding better operating conditions will be expected.

Numerical Expression of Wrinkles: Wrinkles were measured by a surface roughness instrument* with enlargement of one hundred times in vertical direction(ordinate) and four times in horizontal direction(abscissa), respectively. To find a correlation between surface roughness and human impression, a series of studies has been done on over forty printed samples and the following index has been introduced,

$$\text{Wrinkle Index}: \quad W=XY \qquad (1)$$

where $X=(\tilde{H}/\tilde{D})(\tilde{h}/\tilde{s})(100)$ and $Y=(1+0.02Z)^3$

H: height of a peak

D: peak-to-peak distance

h: bottom to peak distance

s: width at half height of a peak

Z: =summation of p_i

p_i: distance from top to inflection point

$\tilde{H}$: number average of H's, and so on

More detailed discussion was reported to TAGA'81 by the authers(1981).

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*Surface roughness instrument: Model SE-3C, Kosaka Research Institute,Inc.
Measuring velocity:0.5 mm/sec
Needle pressure:0.4 gf
Paper(web) used in this study was mainly SK COAT from Sanyo Kokusaku Pulp Co .,Ltd., Basis Weight 84.9 g/sm

Time Effects on Wrinkles: In previous paper, data were insufficient to know the quantitative time effects on wrinkles, so in this section additional data were added to the original data which have been reported in previous paper as shown in Fig.1.

Rather little effects were observed for sheets which had been stored as they were printed("uncut" sample);unprinted area surrounding the printed area works as a fixing frame. On the other hand the pieces taken-out from the original sheet("cut" sample size of 120mmx30mm) changed rapidly as shown in broken lines in the figure.

The time effects can be expressed in first order rate equation in term of time; wrinkle releasing rate dW/dt is proportional to the Wrinkle Index W at that time,or

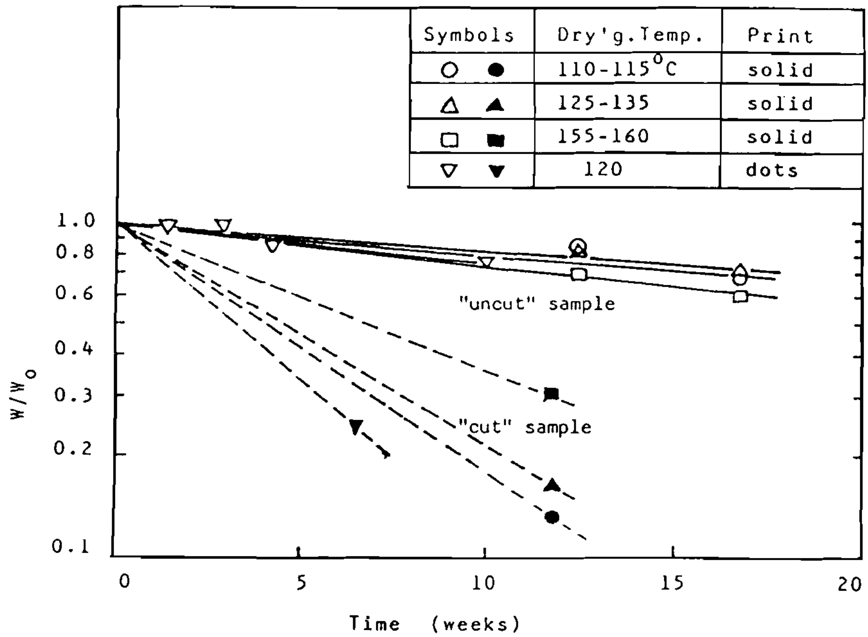

Fig.1 Time effects on wrinkles

$$dW/dt=-kW$$

or

$$W/W_o=\exp(-kt) \quad (2)$$

where, W_o is W at time t=0, and k is the proportional constant.

Average values of the proportinal constant k and half-life period(the time required for the wrinkle to be reduced to one-half of its initial value,or $W/W_o=0.5$) are shown in Table 1.

Thus it may be concluded that no time correction on measured wrinkle Index W is needed as long as the sheet is stored in "uncut" condition and measured in one or two weeks after printed.

Table 1 Proportional constants and half-life period for wrinkles

Sheet storage conditions	Proportional const. k (1/week)	Half-life period(wk)
"uncut"	0.026	26.7
"cut"	0.16	4.3

Effects of Printing Area, Dot Percent and Their Combinations:

Using particular test patterns, various effects of operating conditions on wrinkles are studies, so it is very important to know the effects of printing area,dot percent and their combination so that we can compare the results under different conditions and this information will gives useful guide to preparing test patterns.

For this purpose, a series of experiments was done on a test pattern(shown in Fig.2) and the results are shown in Table 2.

Following results are obtained

A) Wrinkle Index increases as printing area increases, the index was just proportional to the length of pattern(web moving direction) as shown in Fig.3.

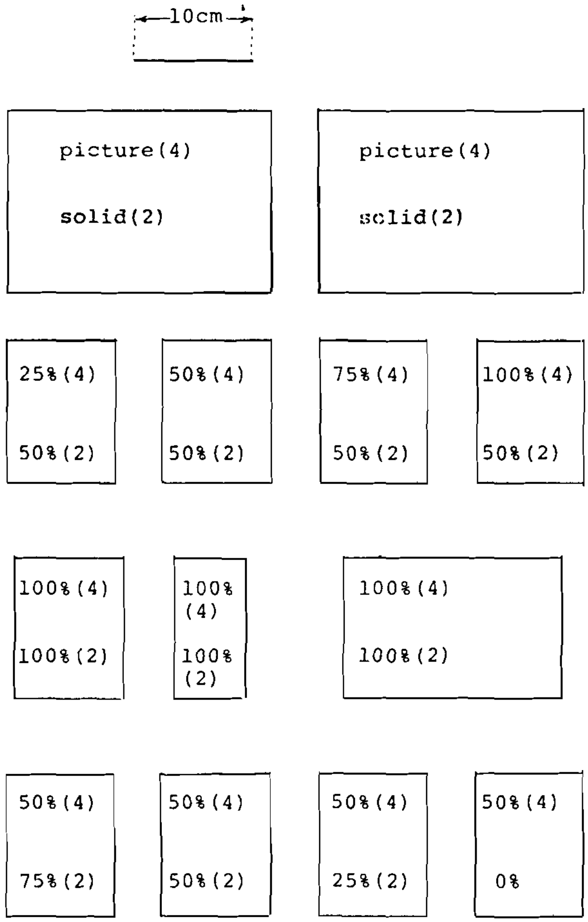

Fig.2 Layout of test pattern to know the effects of printing area and dot % on W

Table 2 Effects of printing area,dot % and number of ink layers on wrinkle

#	Dot %(*)	Print area widthxlength	W
1	solid(4)-solid(2)	120 x 180 mm	37.7
2	" "	" 90	24.8
3	" "	" 60	21.8
4	75%(4) "	" 90	20.8
5	50%(4) "	" "	24.0
6	25%(4) "	" "	15.0
7	50%(2)-solid(4)	" "	12.2
8	75%(2)- 50%(4)	" "	38.4
9	50%(2)- "	" "	25.0
10	25%(2)- "	" "	14.0
11	0% - "	" "	1.7

* Figures in parenthesis mean number of ink layers

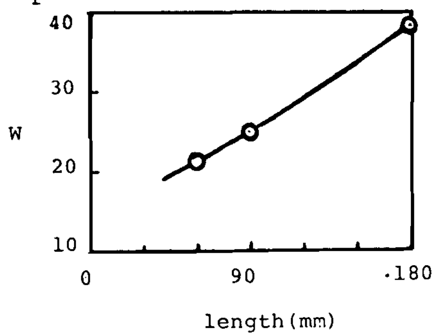

Fig.3 Effects of printing area on wrinkles. Width was fixed at 120mm.

B) In Fig.4, wrinkle index was plotted to the dot %; there were two series of data: The first group was expressed in solid line with circles, changing dot % from zero to 100%(two ink layers) on one side of the web,and the other side of the web was fixed 50%(4)---#5 and #8 to 11.

The second group was expressed in brocken line with triangles changing dot % from 25 % to solid fixed the other side solid(2)---#2 and #4-6.

Though some data were scattered,it may be concluded that the two groups behave identically; wrinkle index increases proportionally to dot % until 50 %, then the value keeps plateau. This critical value of 50 % of dot can be understood by disperesed and continuous phase concept which is discussed in D).

C) The effects of base conditions less than 50 dot% were shown in Fig.5. Combining the results of B) and C), general profile of these effects are expressed as Fig.5.

D) As mentioned in B), 50 dot% seems critical value. Just thinking dot distribution in print as shown in Fig.6, with less 50 dot% they are disperesed and wrinkle increases as dot% increase and with over 50 dot%(Fig.6-c) they become continuous phase,then ink layer effects on wrinkle formation remaines constant. Or beyond 50 dot % the wrinkle remaines at a same level(plateau)

Findings in previous and this sections are useful to design test patterns and measuring time after printed. Also comparison of wrinkles of different patterns and different print time would be possible in some extend using this information.

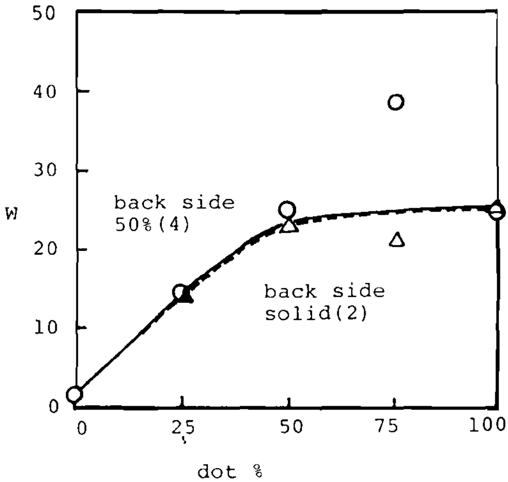

Fig.4 Effects of dot area and their combinations on wrinkles

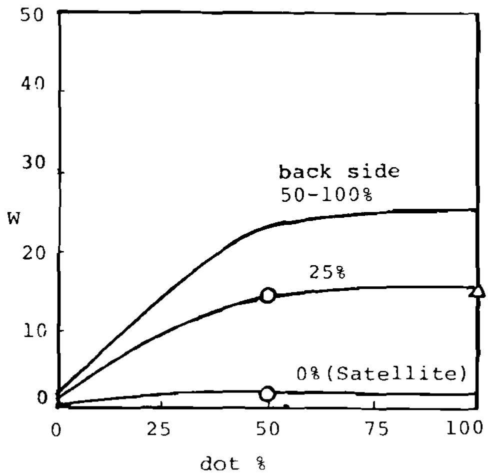

Fig.5 Effects of back side dot% on wrinkle development

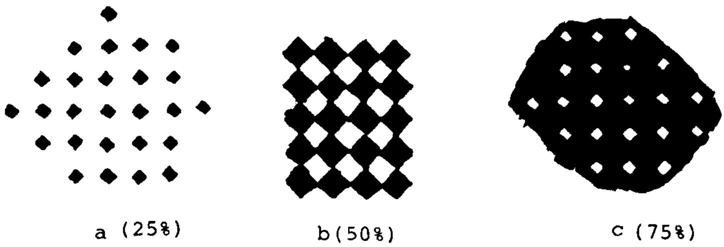

Fig.6 Dispersed and continuous phase:
a:dispersed phase, b:critical phase
c:continuous phase for inked zone

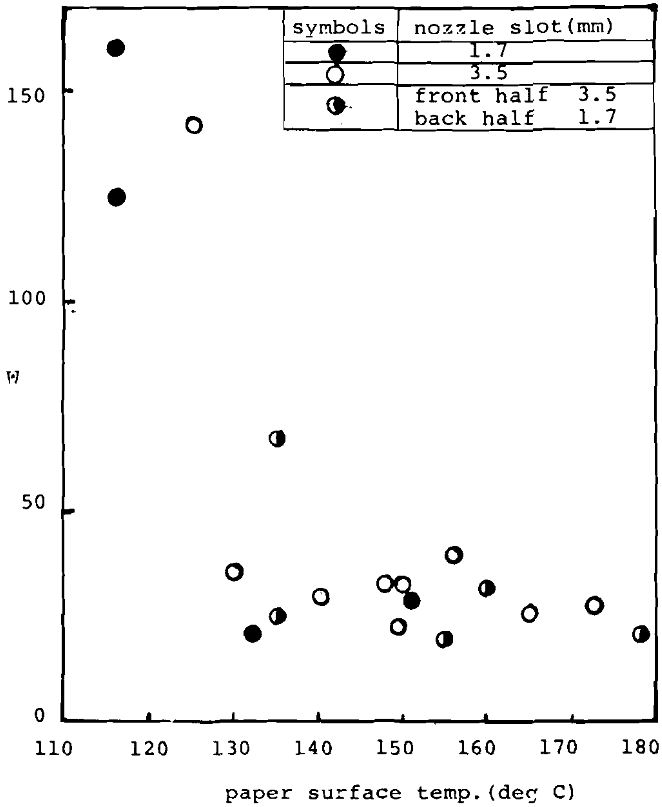

Fig.7 Effects of hot air slot opening on W
paper-nozzle distance was 4mm,paper SK Coat 79.1 (g/sqm). Air vel:65-70(m/s) for 1.7mm,30-45(m/s) for 3.5mm slot. Nozzle units:13+13

Effects of Slot Opening: A series of experiments on different slot opening of hot air impinging unit has been done on a fast hot air drier which was directly connected to blanket-to-blanket web offset press. The number of nozzle unit was 13 pairs, effective drier length was about 3.6m, and slot opening was 1.7mm and 3.5mm respectively. Other conditions are explained in Fig.7.

As shown in Fig.7, it is very difficult to find any difference between the two different slots. Very long distance between press and chill stand (almost 6m from the end of the press to chill stand) could overshadow the effects of slot opening. Drier length seems play very important role in wrinkle development,but it is rather difficult problem to carry out any experiments on different driers of different length.

Partial Pressure of Water Vapor: At higher hot air recycle inside the drier, wrinkles were a little improved and wave length(D) became larger and peak density was reduced(less number of peaks in certain distance), and rather soft dried web was obtained. This might be resulted by slower water evaporation from the web surface at higher vapor pressure and avoided excess water evaporation.

Effects of Chill Stand Conditions:

A) On the first chill cylindersurface, thin aluminum tapes were fixed in parallel V shape so that the winding web was stretched to outsides as they run, a conceptual sketch is shown in Fig.8. Using this chill cylinder, wrinkle index was improved by around 20%.

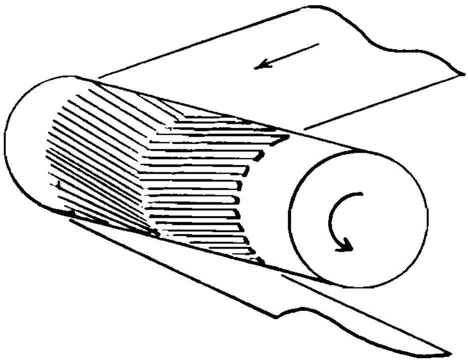

Fig.8 First cooling drum with shallow V stripes to give side stretch on moving web

B) Tape winding at the edges of the first cooling cylinder gave only worse results as shown in Fig.9.

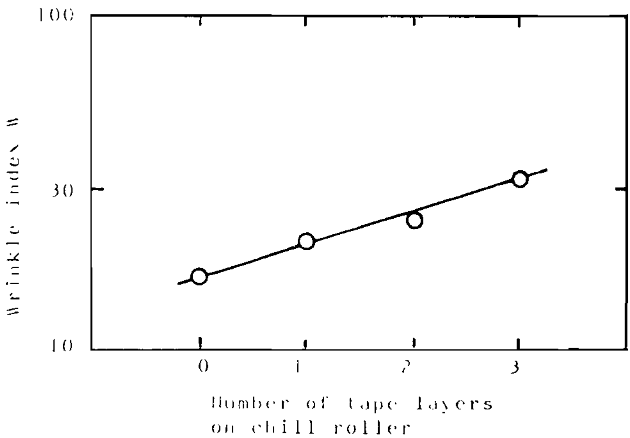

Fig.9 Effects of tape winding on the first cooling drum at both edges

Conclusions:

1. Time effects on wrinkles are expressed as Table 1.
2. Effects of printing area and dot percent are shown in Fig.5.
3. Slot opening effects were not observed on the long drier(Fig.7).
4. Effects of cooling cylinder surface conditions are shown in Figs.8 and 9.
5. As mentioned in previous paper, major factors on wrinkle development in drying process are hot air impinging velocity, drying temperature and probably water partial pressure. Others, such as web tension, web speed and chill stand conditions are not primary factors.
6. More intensive studies must be done on drier length,or press to chill stand length. Since faster press tends result longer drier which means longer cylinder-roll distance and unfavorable condition for wrinkles.

References:

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APPENDIX

Wrinkle Index Calculation Program(N-BASIC)

```
5    REM *** WRINKLE INDEX CALCULATION ***
8    REM *** N-BASIC(NEC MODEL-8001) ***
10   INPUT "TOTAL DATA VOLUME.  Y=";Y
20   INPUT "NUMBER OF PEAKS.  Z=";Z
30   PRINT "NO    HEIGHT    SHARPNESS    PITCH
               W          N":PRINT
35   LPRINT"NO    HEIGHT    SHARPNESS    PITCH
               W          N":LPRINT
40   DIM A(Y,4,Z+1),B(Y),C(Y),D(Y)
50   FOR I=1 TO Y:FOR J=1 TO 4:FOR K=1 TO Z+1
80   READ A(I,J,K)
90   ON SGN(A(I,J,K))+2 GOTO 510,120,100
100  ON J GOSUB 210,240,310,410
110  NEXT K
120  NEXT J
130  W=H*S/P*100:S$=""
150  PRINT USING"##    ##.##          #.####
          ###.##     ###.##     ##";I,H,S,P,W,S$,N
160  NEXT I
170  END
200  REM**HEIGHT**
210  B(I)=B(I)+A(I,1,K):H=B(I)/K:N=K:RETURN
300  REM**SHARPNESS**
310  C(I)=C(I)+A(I,2,K)/A(I,3,K):S=C(I)/K:RETURN
400  REM**PITCH**
410  D(I)=D(I)+A(I,4,K):P=D(I)/K:RETURN
500  REM**RIDGES WITH INFLECTIONS**
510  READ F:
520  DIM E(F)
530  ZZ=0:S$="*":FOR L=1 TO F:READ E(L):ZZ=ZZ+E(L)
570  NEXT L
580  W=H*S/P*100*(1+0.02*ZZ)^3
590  ERASE
600  GOTO 150
1000 REM**DATA**
1010 DATA 21.5,18,26.5,4.5,40.5,0
```