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OPTIMIZING THE PROCESSING OF OPEN-END COTTON YARNS BY USING THE EXTREME VERTICES EXPERIMENTAL DESIGN (EVED)

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Abstract

The regression equations for studying the effect of draft distribution, within draw-frames and open-end machine, on open-end yarn properties were determined. The significant equations were obtained by applying both Extreme Vertices Experimental Design (EVED) and stepwise regression. Twenty-two experiments were sufficient for the determination of Quadratic relation for eight factors. The conditions for the application of EVED on draft factors, were determined based on seven different experimental design. The yarn evenness and tenacity are sufficient parameters for optimization, and depends on draft distribution. The break draft at draw-frame affect them. Significantly, with oly ± 15 % variation in total draft. This indicates that when applying autoleveller redistribution of draft within drafting zone is required for attaining optimum condition.

or specially for optimizing spinning plans were applied on only 3 to 5 experiments [1-10].

It is of great importance in Textile industry to attain the optimal condition with a greater number of factors with lesser number of experiments. It is important to note that the significant factors in any optimization technique don't exceed 40% of the number of experiments [1,2,5,8,10,11], such a percentage decrease greatly with the increase of the number of factors and experimentation. In the mean time, the number of trails increase greatly with the increase of the amount of factors.

Special experimental design for first order regression was proposed, having the number of experiment lesser than the number of factors [7] to be studied, with the application of the stepwise regression, it is possible to determine the significant factors. For the first order regression, the mixture experimental design was applied in textile technology for the determination of optimum draft distribution within drawing frames [12].

Some factors in Textile industry are subjected to different constrains. These constrains can be transferred in some cases to sum constrain and the mixture experimental design can be applied [6,12]. The mixture design is applied in case of the following constrain [3,4].

$$\Sigma x_i = 1 \qquad 0 \leq a_i - b_i \leq 1 \qquad (1)$$

where: x_i = factors under investigation.

Applying such design enable the decrease of the number of experimentations to a great extent. [3,4]. Knowing that the constrain in draft distribution is in the form:

$$\pi\ x_i = ct \qquad 0 < x_i \qquad (2)$$

The log transformation and scaling of the equation (2) will tend to the constrain at (11). The product constrained can be obtained also in other factors concerning speed, twist factor [6]. In this case, great number of textile factors can be grouped in relation constrains and the decrease of number of experimentation to a great extent can be achieved.

It is remarkable to note that the range of these factors are always not within 0 to 1, but at the range a_i to b_i. For that, the application of conventional mixture experimental design will decrease the range of the factors and for that, the application of Extreme Vertices Experimental Design can enable the application of the whole experimental range [3,4], which will tend to a better representation to the regression relation.

The aim of this work consist of the determination of the regression relations characterizing the effect of eight draft distribution factors on different open-end yarn properties, with the application of seven different extreme vertices experimental design (EVED) with number of experiment varying from 13 to 49, for testing the ability of these experimental design. The significant regression relation will enable the determination of factor values which attain the optimal or required Quality level for different properties.

2. Experimental Procedure

Carded cotton sliver of counts ranging from 3.57 ktex to 4.08 ktex were obtained from the industry and processed on two draw-frame passage then through the open-end machine for obtaining yarn of count 40 tex. The factors under investigation consist of sliver count, break draft, main draft and doubling for both first and second drawing, then the main draft at the OE machine. The factors and their range of variations are shown in table 1.

Table 1

M/c	1st Drawing				2nd Drawing			OE M/c
Factor	Card Sliver Count	Break Draft	Main Draft	No. of Doubling	Break Draft	Main Draft	No. of Doubling	Main Draft
Symbol	X1	X2	X3	X4	X5	X6	X7	X8
Range	3.57 4.08 ktex	1.25 1.66	4.12 5.36	6 8	1.33 1.78	4.02 5.40	6 8	140.5 187.5
Ratio	1.143	1.328	1.301	1.33	1.338	1.343	1.33	1.335

The ratio of all the factors are from 1.3 to 1.34 only the sliver count has a ratio of 1.14 which is about 85% of the whole range. Factor 4 and 7 consist of the doubling at the draw-frame with only two levels, we have to take in mind that the level + 1 can not be used or we will not attain a constant yarn count. For that before taking the log transformation and scaling to transfer these factors to mixture

Exper. Set	Exp. No.	X1	X2	X3	X4	X5	X6	X7	X8	SUM
	1	0.132	0.103	0.198	0.132	0.146	0.139	0.133	0.014	0.997
	2	0.216	0.105	0.198	0	0.146	0.123	0.133	0.078	0.999
	3	0.132	0.221	0.198	0.132	0.018	0.102	0	0.198	1.001
	4	0.132	0.281	0.281	0.132	0.018	0.028	0	0.13	1.002
	5	0.132	0.103	0.281	0.132	0.046	0.074	0	0.233	1.001
	6	0.132	0.103	0.281	0	0.018	0.102	0.133	0.233	1.002
I	7	0.132	0.103	0.198	0.132	0.06	0.225	0	0.147	0.997
	8	0.132	0.103	0.198	0	0.146	0.139	0.133	0.147	0.998
	9	0.132	0.103	0.198	0	0.046	0.074	0.285	0.163	1.001
	10	0.18	0.042	0	0.236	0.108	0.085	0.236	0.134	1.021
	11	0	0.236	0.215	0	0.011	0.385	0	0.141	0.988
	12	0.18	0.133	0.215	0.236	0.065	0.188	0	0	1.017
	13	0.18	0.042	0	0.11	0.311	0.072	0.236	0.07	1.021
	14	0.216	0	0.284	0	0.146	0.251	0	0.103	1
	15	0	0.161	0.281	0	0.146	0.265	0	0.145	0.998
	16	0	0.161	0.281	0	0	0.285	0.133	0.142	1.002
	17	0.216	0	0.278	0	0.278	0	0.131	0.101	1.004
II	18	0.131	0.284	0.197	0	0.046	0.343	0	0	1.001
	19	0	0.236	0	0.11	0.108	0.396	0	0.137	0.987
	20	0	0.183	0.215	0	0.084	0.374	0	0.132	0.988
	21	0	0.133	0.215	0.11	0.011	0.385	0	0.133	0.987
	22	0	0.133	0.215	0	0.065	0.327	0.11	0.133	0.983
	23	0.132	0.103	0.198	0.132	0	0.285	0	0.147	0.997
III	24	0.131	0.104	0.198	0.133	0	0.285	0	0.147	0.998
	25	0.129	0.104	0.193	0.275	0.143	0	0	0.155	0.999
	26	0.132	0.103	0.281	0.281	0.046	0	0	0.158	1.001
	27	0.127	0.274	0.274	0.127	0	0.069	0	0.127	0.998
IV	28	0.216	0.052	0	0.285	0.047	0	0.286	0.105	0.991
	29	0.131	0.104	0.283	0	0.046	0.311	0	0.125	1
	30	0.129	0.102	0.193	0	0	0.144	0.277	0.155	1
	31	0.216	0	0.284	0	0.075	0.19	0.133	0.103	1.001
	32	0.216	0.221	0.198	0	0.046	0.224	0	0.094	0.999
	33	0.132	0.221	0.198	0	0.146	0.169	0.133	0	0.999
	34	0.132	0.221	0.198	0	0.046	0.269	0	0.133	0.999
	35	0.132	0.281	0.281	0	0.018	0.102	0	0.186	1
	36	0.132	0.103	0.281	0	0.146	0.21	0	0.125	0.997
	37	0.132	0.221	0.281	0	0.018	0.102	0	0.248	1.002
	38	0.132	0.103	0.198	0	0	0.285	0.133	0.147	0.998
	39	0.132	0.103	0.198	0	0.146	0.268	0	0.15	0.997
V	40	0.132	0.103	0.198	0	0.286	0.128	0	0.15	0.997
	41	0	0.221	0.198	0.132	0.018	0.267	0	0.163	0.999
	42	0	0.161	0.281	0	0.06	0.225	0.133	0.142	1.002
	43	0.131	0.104	0.198	0	0.046	0.373	0	0.149	1.001
	44	0.216	0.051	0	0.132	0.283	0	0.283	0.034	0.999
	45	0	0.183	0.149	0.11	0.084	0.312	0	0.183	1.021
	46	0	0.133	0.215	0	0.12	0.277	0.11	0.166	1.021
	47	0	0.133	0.215	0	0.194	0.311	0	0.168	1.021
	48	0.18	0.042	0	0.11	0.084	0.408	0.11	0.087	1.021
	49	0.18	0	0.215	0.11	0.011	0.182	0.11	0.213	1.021

factor condition a dummy ratio of 2.81 was proposed and the factor condition for experimentation were determined by applying the Extreme Vertices Experimental Design (EVED), the level of these factors are shown in table 2 In table 2, five sets of experimental trail are shown.

Yarn strength, evenness and imperfections were determined for the study using the standard methods of testing.

3. Results and Discussion

Seven experimental designs with different factors combinations were constructed from the proposed experimental sets. These experimental trials are shown in table 3.

Table 3

CONSTRUCTION AND SPECIFICATIONS OF DIFFERENT EXPERIMENTAL DESIGNS

Experimental Design No.	1	2	3	4	5	6	7
Experimental Set Combination	I	I, II	I-III	I,II,IV	III-V	V	I-V
No. of Exp.	13	22	25	27	27	19	49
Max Variance for straight line relation	81.9	17.2	13.9	11.9	20.4	39.1	7.0
Max variance for special Quadratic relation	—	134814.8	129627	477008	654061	8.4E8	29296.3
Number of factors at lower level	1	3	3	3	2	2	3

The results of different experimental designs are shown in table 4, while the regression relations are demonstrated in table 5. From these tables, it is possible to attain the following:

3.1 General consideration

All the proposed experimental trails determines the regression relations with high significance, the coefficient of correlation varies from 0.943 to 0.999, this indicates that the obtained relation describe to a great extent, the effect of different factors on the tested yarn properties. One or more interactions effects were obtained in all the significant regression except the regression determined by first experimental set for the yarn neps. This enable us to say that the factors affect the tested yarn properties in Quadratic form.

3.2. Effect of Experimental Design

The coefficient of correlation of all experimental designs are highly significant, while the significant factors differs in some circumstances. If we consider that the existance of a factor in linear or interaction form is a measure of design efficiency for detecting the factor effect. The number of factors determined by every experimental design are shown in table 5. From this it can be seen that the experimental designs 2,3,4,7 had the greater abilities for the detecting of factor dependence. This can be explained from table 3 by both the range of variation of the factors and maximum variance in Variance matrix. For that, it is important to have the whole range of the factor within the experimental trials and the 30% 40% of the factors be at the lower level at every experiment with an homogeneous

Yarn -\ Prop.-/	Yarn Strength			Yarn Evenness & Imperfections			
	Tenacity g/tex	Tenacity ct*lea st.	Elong. %	C.V.%	Thick per 1000 meter	Thin per 1000 meter	Neps per 1000 meter
Exp.No.							
1	9.35	1678.1	7.15	16.81	144	274	430
2	9.72	1714.3	7.17	18.34	394	1542	900
3	9.63	1664	7.08	16.29	138	530	630
4	9.78	1602.6	6.55	16.11	104	440	540
5	9.14	1638.2	7.16	17.16	184	572	662
6	9.68	1691.7	7.27	16.93	190	562	706
7	9.6	1744.2	7.65	15.84	48	174	280
8	10.04	1729	7	18.91	216	846	874
9	9.19	1524.4	6.76	17.4	84	510	440
10	9.26	1577.6	6.53	16.8	140	554	682
11	9.76	1748.8	7.17	17.03	84	276	302
12	8.7	1864.1	8.5	16.12	154	400	726
13	8.21	1331.1	6.44	17	148	578	702
14	9.8	1539.7	6.59	17.35	280	480	770
15	10.21	1838.2	6.9	18.4	138	404	400
16	9.12	1568.1	6.65	17.17	68	386	432
17	9.54	1516	6.54	18.9	400	1600	892
18	9.6	1626.4	7.09	16.57	180	456	694
19	10.31	1773.3	7.02	17.84	117	454	602
20	9.92	1615.1	6.7	17.73	112	424	474
21	9.64	1561.9	6.43	18	146	380	432
22	9.71	1716.2	7.3	16.66	50	274	368
23	10.01	1837.6	7.24	16.65	168	466	628
24	9.73	1904.5	7.51	15.58	40	170	306
25	9.45	1673	7.08	17.18	132	288	566
26	9.26	1627	7.26	17.05	124	504	510
27	9.24	1602.6	6.79	17.73	112	424	474
28	9.26	1577.6	6.53	17.13	84	276	302
29	9.68	1691.7	6.43	16.93	190	562	706
30	10.73	1767.5	6.78	18.08	48	479	358
31	9.66	1652	6.68	18.81	354	1762	964
32	9.59	1671.3	7.1	17.28	212	504	730
33	9.66	1742.1	7.05	16.74	200	660	780
34	9.61	1633.7	6.94	16.21	152	398	720
35	9.53	1690.3	7.42	16.84	84	350	420
36	10.32	1908.3	7.11	17.32	57	414	354
37	9.64	1764.2	7.99	15.86	122	416	760
38	9.35	1608.8	6.84	17.68	64	454	420
39	10	1728	6.69	16.7	182	660	614
40	9.21	1492.5	6.61	16.8	100	420	594
41	9.13	1487.4	6.7	18.61	158	506	580
42	9.64	1561.9	6.43	18	146	380	432
43	9.81	1694.6	6.8	16.94	136	486	586
44	8.21	1331.1	6.44	17	148	578	702
45	9.13	1487.4	6.7	18.61	158	506	580
46	10.21	1838.2	6.9	18.4	138	404	400
47	9.12	1568.1	6.65	17.17	68	386	432
48	9.45	1669.5	6.77	16.8	122	580	674
49	9.53	1532.3	6.7	16.33	48	204	344

Table 5

DIFFERENT REGRESSION RELATIONS

ED / Yarn Properties	1 Fact	1 Coeff.	1 Sig	2 Fact	2 Coeff.	2 Sig	3 Fact	3 Coeff.	3 Sig	4 Fact	4 Coeff.	4 Sig	5 Fact	5 Coeff.	5 Sig	6 Fact	6 Coeff.	6 Sig	7 Fact	7 Coeff.	7 Sig
Tenacity Single-End Strength	X1	24.1	**	X3	8.7	**	X8	30.0	**	X8	54.8	**	X8	48.4	**	X3	25.6	**	X8	48.6	**
	X36	82.6	**	X6	16.8	**	X6	27.6	**	X6	14.0	**	X1	41.4	**	X14	174.5	*	X1	27.5	**
	X28	102.3	**	X18	97.9	**	X68	-98.5	*	X1	35.3	**	X18	-243.6	**	X6	13.5	**	X18	-158.4	**
	X7	14.9	*	X17	42.2	4.6	X17	98.1	**	X18	-225.9	**	X6	11.3	**	X15	64.4	*	X6	19.5	**
	X34	38.5	3	X24	74.7	**	X34	53.3	**	X68	-67.3	3.1	X35	81.7	**	MR	0.996		X68	-95.2	**
	MR	0.9985		X5	10.8	**	X35	53.6	**	X25	51.3	3.6	X56	-77.1	*				X5	5.7	**
				X23	24.6	1.6	MR	0.996		MR	0.996		X28	-52.2	*				X37	16.7	4.8
				MR	0.9994								X27	31.9	*				MR	0.995	1
													MR	0.998							
Tenacity Lea Strength	X1	7158.7	**	X3	5754.9	**	X3	4647.8	**	X3	3388	**	X8	4756.3	**	X3	4435.2	**	X3	5825.6	**
	X36	16605.2	**	X45	39060.3	**	X47	4053.8	7.2	X6	3725.2	**	X1	6593.4	**	X14	18890.4	*	X47	12264.7	**
	X28	12726.1	2.4	X2	5163.6	**	X25	11483	**	X36	-7990.8	**	X18	-35144.5	**	X6	2326.9	**	X6	3526.7	**
	MR	0.996		X23	-17144.4	**	X8	6208.1	**	X1	6472	**	X6	1330.8	**	X15	11235.1	*	X36	-12051.3	**
				X34	-9151.8	*	X38	-18450.1	**	X13	-10114.9	**	X3	2460.9	**	MR	0.995		X45	11644.7	*
				X28	8322.8	2.8	X16	4533.2	1.4	X15	-34687.2	**	X28	-2434.6	*				X17	5835.2	1.3
				MR	0.997		X26	4397.7	**	X5	6734	**	X14	5466.3	4.1				MR	0.995	
							X45	11886.6	*	X56	-13915.8	**	MR	0.997							
							X17	5538.5	1.1	X67	4828	**									
							MR	0.997		X48	4255.8	*									
										MR	0.999										
Yarn Evenness C.V.%	X1	107.1	**	X3	30.1	**	X8	58.7	**	X8	118.4	**	X3	105.8	**	X3	60.2	**	X3	59.5	**
	X2	128.8	**	X6	22	**	X5	20.5	**	X5	31.1	**	X6	65.7	**	X45	416.8	**	X6	19.5	**
	X12	-797.3	**	X17	139.3	*	X2	20.9	**	X2	21.8	**	X65	-414.2	**	X6	32.6	**	X36	-46	*
	X26	-151.6	1.2	X48	128.1	**	X1	44.2	**	X7	5.1	7.6	X57	179.9	**	X36	-51.8	1.4	X57	65	**
	MR	0.999		X5	23	**	X18	-258.3	*	X3	47.3	**	MR	0.997		MR	0.998		X3	61.4	**
				X24	70.8	**	X36	54.6	**	X38	-317.9	**							X38	-227.7	**
				X78	61.7	1.6	X37	64.4	*	X25	-193.2	**							X17	117.8	2
				X2	6.8	3	X4	12.8	*	X58	-163.2	1.1							X45	62.9	1
				MR	0.9995		MR	0.999		MR	0.998								X37	-43.4	*
																			MR	0.997	
Thick Places Per 1000 Mt	X1	1468.7	**	X1	787.6	**	X1	694.1	**	X1	929.5	**	X3	329.2	**	X3	1053.3	**	X1	232.6	8.3
	X14	-3294.7	2.3	X35	2590.5	*	X35	3170.1	**	X35	2497	**	X26	1506.7	**	X26	4919.3	**	X3	331.9	**
	MR	0.952		X68	1500.8	2.1	X26	991.4	**	X26	719	1.1	X15	3182.4	**	X45	3692.1	**	X15	2719	*
				MR	0.95		MR	0.95		X14	-5129.7	1	X25	-2333.7	1.8	X23	-2565.6	**	X26	492.6	*
										X9	608.3	4.2	MR	0.958		X36	-3602.7	*	MR	0.938	
										MR	0.958					X48	-2540.6	3.6			
																MR	0.986				
Thin Places Per 1000 Mt	X1	5746.6	**	X1	1311.4	8	X35	8601.9	*	X1	2523.1	**	X1	1833.7	**	X26	7252.6	**	X1	1814.1	**
	X14	-15825.6	*	X35	10676.4	*	X28	13799.8	**	X35	7431.8	*	X56	5762	**	X1	1649.5	**	X26	2973.6	**
	MR	0.961		X28	8598.6	*	X15	14313.1	**	X28	9767.6	**	X37	4532.6	*	X12	-3312.5	*	X35	6914	**
				X17	8345.1	5	MR	0.94		X14	-8044.7	*	X24	14009.5	*	X5	850.5	*	X37	4537.6	1.1
				MR	0.944					X57	6841.3	1.8	X26	2975.3	**	MR	0.99		X57	4233.2	3
										MR	0.952		X48	-7490.6	1.4				MR	0.95	
													MR	0.988							
Neps Per 1000 Mt	X1	4169.7	*	X1	3252.5	**	X1	2219.1		X1	2178.1	**	X3	1032.2	*	X3	2356.9	**	X1	3672.3	**
	MR	0.966		X68	5832.8	*	X6	500.8		X6	478.8	2.4	X15	7441.4	*	X1	4010	**	X6	1235.7	**
				X2	746.9	3.3	X58	12082.1		X58	12194.5	**	X6	708.1	*	X13	-15695	**	X16	-7406.9	**
				MR	0.977		X2	938		X2	955.3	*	X1	987.1	2.9	X26	1364.2	*	X47	-5027.4	*
							MR	0.969		MR	0.975		MR	0.971		X78	-11253.5	1.4	X5	601.8	3.5
																MR	0.983		MR	0.974	
Yarn Elongation %	X1	33.4	**	X3	25.2	**	X3	18.7	**	X3	12.9	**	X8	28.4	**	X3	28.7	**	X3	9.1	**
	X36	30	1	X45	76.8	*	X45	64.8	**	X46	10.7	5.4	X1	35.1	**	X45	155.4	**	X6	12	**
	X8	35.3	**	X2	27	**	X2	24.8	**	X25	52.1	**	X18	-195.7	**	X6	13.6	**	X45	30.5	*
	X18	-210.7	**	X23	-92.7	**	X17	47.1	**	X8	38	**	X3	9.5	**	X36	-57.2	*	X1	21	**
	X24	36.7	2	X7	13.1	*	X23	-75.8	**	X38	-47.3	*	X28	-12.7	**	MR	0.997		X16	-19.9	6.1
	X35	28.2	4	X37	-47.2	6.9	X36	15.9	**	X1	27.3	**	X46	24.7	*				X8	30.8	**
	MR	0.999		MR	0.998		X14	30.8	*	X18	-179.4	**	MR	0.998					X38	-37.8	2.1
							X58	50.8	*	X33	-26.7	**							X68	-46.6	**
							X35	-17.8	4.4	MR	0.999								X18	-84.5	*
							MR	0.999											X26	-3	4

ED = Experimental design Fact = Factor Coeff = Coefficient Sig =Significance distribution of lower level for all factors within the experimental design.

3.3 Yarn Strength and Elongation

The regression equations for yarn tenacity of single of lea ends are shown in table 5. From which, the coefficient of correlation for proposed regressions exceed the value of 0.995 for all regressions obtained. In case of tenacity of single-end strength, all the tested factors are presented in most of regression obtained. The relation obtained by the second and third sets are the most representable of the results, same condition is obtained for the count strength product, in which the number of experiment are lesser than the other experimental design except the first one. In case of yarn elongation, the coefficient of correlation is within 0.998, also second and third experimental sets show a tendency to better representation of data.

All the regression obtained involve an interaction factors which indicate that a Quadratic relation represent the dependence of yarn strength and elongation on factors under consideration. The most adequate factors, on yarn strength and elongations are break and mean draft, and doubling at the first draw-frame, break draft of the second draw-frame and draft at the open-end spinning machine.

3.4 Yarn imperfections

The regression equations of the four measures characterizing the yarn imperfections are shown in table 5. The value of coefficient of correlation is greater than 0.990 in case of yarn evenness. For that, the yarn evenness can be considered the most influenced by the factors under study. As in case of yarn strength and elongation, the second, third and also the seventh experimental set realize mostly the results obtained. In the same time a Quadratic relatioh is also obtained for almost of the regression accomplished.

The most satisfactory factors on yarn imperfections are card sliver count, main draft of first draw-frame, break draft and draft for second draw frame.

3.5 Optimum Conditions

Specified values of any yarn property under study can be determined by solving any of the proposed relation. The most representative are that of set 2,3,4,7. Since no significant difference were obtained when solving such relations, the most optimal design can be considered that of the lower number of experimentation which are set 2 or 3.

VI. Conclusion

1. The application of Extreme Vertices Experimental Design enable the determination of different regression equations concerning the dependence of yarn properties on draft distribution with great accuracy.

2. The regression equations can be obtained with minimum number of experimentation by using the stepwise regression. A significant Quadratic relation for eight factors can be obtained by only twenty-two experiments.

3. The most effective experimental design is that in which the lower

level exist in the design for all factors in a homogeneous form and within 25% - 40% of the total number of factors.

4. Most regressions obtained are significant for Quadratic relation, which has to be taken always in consideration when proposing an experimental design.

5. The yarn tenacity, evenness and imperfections are mostly affected by break draft and main draft of the drawing frames.

6. The yarn evenness and tenacity of single-end yarn can be considered the most sufficient parameters for optimization of open end processing.

7. The break draft in both first and second draw-frame are always significant in both yarn imperfection and strength since this variation is only within ± 15%. This is within the level of any autoleveller. For that, a redistribution of draft within the drafting zone is needed when a variation in total draft is produced on the autolevelling system.

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