The Prediction of Yarn Strength of Sirospun Yarns From AFIS Fiber Properties By Using Linear Regression Analysis

Tuba BEDEZ ÜTE, Prof. Dr. Hüseyin KADOGLU
Ege University, Izmir

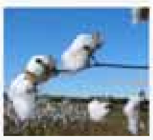
- Introduction
- Sirospun system
- Experimental
- Results
- Conclusion

2

- Modelling and prediction of the yarn properties has been very attractive for the textile engineers, therefore several mathematical, statistical and empirical models have been developed to yield limited success in terms of prediction accuracy and general applicability.
- As the raw material costs constitute the majority of the yarn production costs, it is critically important to know the desirable fibre characteristics that we need, for the selection of the suitable cotton blend.

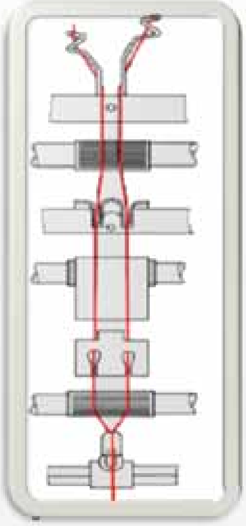
3

- Previous researches showed that, yarn properties are particularly influenced from fibre properties and this effect becomes more influential in the case of finer yarns.
- Obviously, fiber strength, length parameters and fineness are the most important factors for yarn tenacity.
- In recent years, due to the demand of quality improvement studies, some of the developments are subject to certain modifications of the ring spinning frame to produce yarns with different structures using modern spinning systems which improves yarn properties.



4

Sirospun system



- The Sirospun technology was developed in the 1970s at CSIRO laboratories.
- In 1980 Zinser, was licensed to sell Sirospun spinning frames and to convert old frames to the new system.
- Traditionally, two-fold yarns are used for worsted weaving, because twisting binds the surface fibres into the structure of the yarn.
- The essence of Sirospun is the combination of spinning and doubling in one process.
- System enables to produce a special spin-twisted yarn directly on a conventional ring spinning machine.

Sirospun system

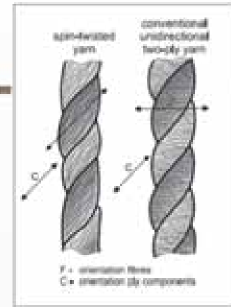
Sirospun system

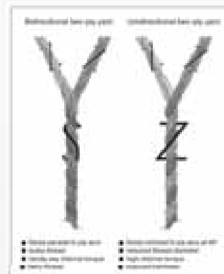
- ✓ can be installed on ring spinning machine with low investment costs.
- ✓ offers advantages such as eliminating doubling and twisting processes.
- ✓ provides production increase, lower energy, air conditioning and production costs,
- ✓ provides savings on place and staff due to eliminating some processes,

6

Sirospun system

- In terms of fiber orientation, the fibers of plied yarn are orientated at right angles to the axis whereas fibers always have an incline to the axis of the sirospun yarn. Therefore sirospun yarn surface will closely resemble a single yarn.
- Conventional plied yarns have opposite direction of twist but spin-twisted yarns have identical direction of twist in the single and in the plied yarn.
- Sirospun yarns are less hairy and more extensible compared to two-plied yarns.
- It has better evenness, hairiness, abrasion resistance and tenacity compared to single yarns with same linear density.





7

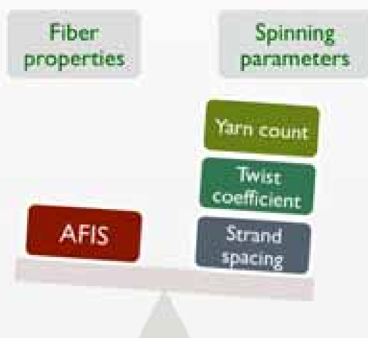
Yarn strength

- Since the tensile properties of a yarn directly affect the winding, knitting and weaving efficiency, they are very important in determining the quality of the yarn.
- For this purpose, it is important to know which fiber and yarn production parameters influence yarn tensile properties.
- Yarn strength depends upon various fiber parameters. The inherent breaking strength of individual cotton fibers is considered to be the most important factor.
- But fiber strength cannot be measured by AFIS. Instead of strength, mean fiber length and fibre fineness become the leading properties among those of AFIS.

8

Materials and Methods

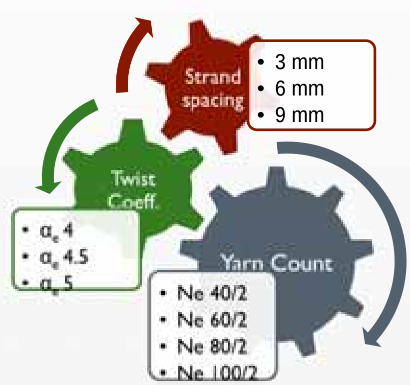
- In this research, different cotton blends were selected from different spinning mills in Turkey.
- Yarn count, twist coefficient and <u>strand spacing</u> were also selected as predictors because of their considerable effects on the yarn properties.



9

Materials and Methods

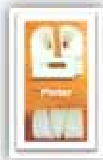
- Sirospun yarns were produced with 10 different blends at a yarn count of Ne 20, Ne 30, Ne 40 and Ne 50.
- Each yarn count was spun at 3 different twist multipliers.
- For each yarn count and twist multiplier, 3 different strand spacing (3mm, 6mm and 9 mm) were adjusted.



10

Materials and Methods

- All samples were spun into yarns on a Rieter Model G30 ring spinning machine



11

Materials and Methods

- Spinning operations can affect fibre properties in different ways, depending on the machinery line and adjustments etc. For the elimination of these effects, fibre properties were measured from rovings by using an Uster AFIS instrument.
- Yarn strength and breaking elongation tests were performed on an Uster Tensorapid.

Materials and Methods

Table 1. AFIS fiber properties of different blends.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
Nep Cnt/g	4	19	24	8	5	7	152	12	19	25	17
L(W) (mm)	29,5	28,1	25	30,3	26,8	27	24,8	26,1	26,3	28	25,5
UQL (w)	35,2	33,9	30,7	36,6	32	32,6	30,9	31	31,2	33,9	30,6
SFC (w) %	2,3	3,7	6,2	2,4	3,8	4,6	9,9	3,7	4,6	3,9	5,1
L(n) (mm)	25,8	24,2	21,5	26,4	23	23,3	20,2	22,9	22,7	24,3	22,2
SFC (n) %	8,5	11,6	15,1	9	11,3	13,2	25,5	11	12,8	11,4	14,2
5.0% (mm)	40,9	39,9	36,7	42,4	37,3	38,2	35,6	36,1	36,9	39,1	35
Total Cnt/g	8	11	14	7	29	16	84	5	14	9	9
Trasg Cnt/g	0	0	0	0	0	0	11	0	2	0	2

13

Modeling

- Regression analysis is widely used for prediction and forecasting and to understand which among the independent variables are related to the dependent variable.

  Y : ➤yarn strength

  X : ➤fibre properties (AFIS)

  ➤yarn production parameters (yarn count, twist coefficient, strand spacing)

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon$$

- The multiple regression analysis and ordinary least squares method was selected to learn the relationship between several independent variables and a dependent variable.

14

Modelling

- Initially, the types of relationship between independent and dependent variables were checked by using curve estimation and correlation analysis.
- Statistical analysis demonstrated that there was a nearly linear relationship between fibre properties measured in AFIS and sirospun yarn properties, so, the linear multiple regression analysis method was chosen for this study.
- Statistical analyses were performed using Gretl and Minitab softwares.

15

Modelling

- Collinearity which is defined as a linear relationship between two explanatory variables is tested.
- It is found that there is an exact linear relationship between some variables such as length measurements by weight and number based values. Besides, upper quartile length by weight and 5% span length parameters were highly correlated with mean length by weight.
- As a result, upper quartile length by weight, mean length by number, short fiber content by number and 5% span length parameters, were omitted due to exact collinearity.

16

Results and Discussion

- Another important diagnostic test was applied for seeking if there is a heteroskedasticity in the regression models.
- The presence of heteroscedasticity can invalidate statistical tests of significance that assume that the modelling errors are uncorrelated and normally distributed.
- White test was used to establish whether the residual variance of a variable in the regression model is constant (that is for homoscedasticity).

17

Results and Discussion

- Best Subsets Regression, which is a method used to help determine which independent variables should be included in a multiple regression model, was used.
- This method involves examining all of the models created from all possible combination of predictor variables.
- Adjusted R^2 is used to measure the goodness of fit in the model. A good model should have a high R^2 and adjusted R^2, small S, and a Mallows' Cp close to the number of predictors in the model and the constant.
- Possible regression models for prediction yarn strength were given in Table 2.

18

Table 2. Possible regression models for predicting yarn strength with AFIS fiber properties.

Number of indep. variable	R^2	Adj. R^2	C-p	S	Strand spacing	Yarn count (Ne)	Twist coeff. (αe)	Nep Count	L(w)	SFC (w)	Total Count	Trash Count
1	69,9	69,9	3243,6	1,7553					X			
1	41,6	41,5	8648,6	2,4466						X		
2	81,8	81,8	985,3	1,3664		X			X			
2	74,7	74,7	2335,3	1,6103			X		X			
3	84,3	84,3	507,1	1,2687		X	X		X			
3	82,6	82,5	836,5	1,3367		X			X		X	
4	85,1	85,1	361,0	1,2371		X	X		X		X	
4	84,3	84,3	501,9	1,2674		X	X	X	X			
5	86,5	86,5	88,3	1,1761		X	X		X		X	X
5	85,8	85,8	217,7	1,2053		X	X		X	X	X	
6	86,6	86,6	69,8	1,1716		X	X	X	X		X	X
6	86,6	86,5	79,9	1,1739		X	X		X	X	X	X
7	87,0	86,9	9,5	1,1575		X	X	X	X	X	X	X
7	86,6	86,6	69,0	1,1712	X	X	X	X	X		X	X
8	87,0	86,9	9,0	1,1571	X	X	X	X	X	X	X	X

Results and Discussion

- Stepwise regression selects a model by automatically adding or removing individual predictors, based on their statistical significance.
- By this method, we can control the details of the process, including the significance level.
- Regression coefficients and significance level of the independent variables of different models are given in Table 3.
- Regression coefficient is the constant, that represents the rate of change of a dependent variable, as a function of changes in the independent variable.
- P value is used for determining statistically significance.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	12.86**	14.41**	-31.08**	-36.06**	-37.99**	-39.86**	-9.732**
Strand spacing (mm)	0.023	0.038	-0.023**	-0.023**	-0.018*	-0.015	-0.020**
Yarn count (Ne)	-0.029**	-0.048**	-0.11**	-0.109**	-0.109**	-0.109**	-0.105**
Twist coeff. (α_e)	1.884**	1.813**	1.166**	1.162**	1.156**	1.164**	1.198**
Nep count		-0.044**	-0.003**	-0.012**	0.0005	-0.026**	0.046**
L(w)			1.813**	1.958**	2.016**	2.091**	1.602**
SFC(w)				0.283**	0.485**	0.508**	-10.84**
Total count					-0.047**	-0.058**	-0.007
Trash count						0.458**	0.234**
$SFC(w)^2$							2.192**
$SFC(w)^3$							-0.138**
Adj. R^2	0.0796	0.1774	0.8433	0.8443	0.8582	0.8692	0.8887
Akaike	12671.2	12392	8238.6	8243.5	8012.6	7811.4	7411.9
Schwarz	12694.4	12421.1	8293.5	8284.3	8059.2	7863.8	7475.9
lnL	-6332	-6191	-4123	-4115	-3998	-3897	-3695

** is significant for α=0.05

Table 3. Stepwise regression models.

- White's test was applied for seeking if there is a heteroskedasticity in the regression model.
- A new model was established to solve this problem and regression coefficients of variables, t-val-ues and significance level of each varia-ble of the new model are given in Table 4.

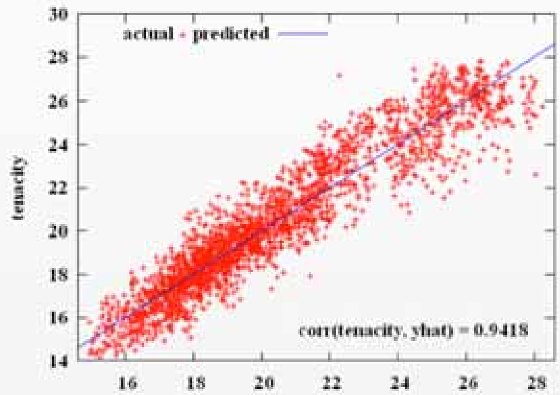
Results and Discussion

Table 4. Regression coefficients and significance level of the model.

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
Constant	-18.233	1.627	-11.2027	<0.00001	***
Strand spacing (mm)	-0.031	0.008	-3.7412	0.00019	***
Yarn count (Ne)	-0.107	0.002	-46.5413	<0.00001	***
Twist coeff. (αe)	1.306	0.045	29.0271	<0.00001	***
Nep count	0.012	0.005	2.2049	0.02755	**
L(w)	1.773	0.035	50.3232	<0.00001	***
SFC(w)	-8.535	0.549	-15.5264	<0.00001	***
Total count	-0.022	0.004	-5.9009	<0.00001	***
Trash count	0.302	0.029	10.2810	<0.00001	***
$SFC(w)^2$	1.754	0.109	16.0521	<0.00001	***
$SFC(w)^3$	-0.107	0.007	-14.8322	<0.00001	***
Mean dependent variable	20.3154	S.D. dependent variable		3.1997	
Sum squared residual	8754.034	S.E. of regression		1.8780	
R^2	0.8849	Adj. R^2		0.8844	

Results and Discussion

- From the following graph, it is clearly seen that there is very high correllation between predicted and actual yarn strength values.



23

Conclusion

- In this study we have tried to predict yarn strength, with AFIS fibre properties and yarn parameters by linear multiple regression analysis.

Yarn strength (cN/tex) = -18,233- 0,031 F.A.M. - 0,107 Yarn count (Ne) + 1,306 (α_e)+ 0,012 NepCnt + 1,773 Lw – 8,535 SFCw + 1,754 $SFCw^2$ – 0,107 $SFCw^3$– 0,022 TotalCnt + 0,302 TrashCnt

- According to regression analysis, yarn production parameters significantly effect yarn strength.
- Yarn strength increases with decreasing strand spacing and yarn count (Ne) but increasing the twist coefficient.
- The most important fibre properties influencing yarn strength are fibre length and short fibre content.

24

Conclusion

- Spinners are recommended to select raw materials having higher fibre length but lower short fibre and foreign material content for increasing yarn strength.
- Although, they have to take into consider that, producing coarser yarns, with higher twist coefficients and smaller strand spacing, will provide higher yarn strength.
- Consequently statistical evaluation showed that our equations had a large R^2 and adjusted R^2 (0.88) values.

25

Thank You…

26