Effect of Spinning Rubber Cot Shore Hardness on Yarn Mass Uniformity and Imperfection Levels - Part 1

By: B. Sujai and M. Sivakumar

Abstract:

The effect of nine different spinning front line cots (Synthetic rubber cot) varying only in shore A hardness (56°,63°,65°,66°,68°,75°,83°,85°& 90°) on 100% cotton ring spun yarn has been investigated. The change in cotton yarn properties like mass uniformity, unevenness %, Imperfection levels (in all class) with progressive change in shore A hardness has also been reported. The count and process parameter's from opening and cleaning machines that covers blow room & carding then breaker & finisher drawing, speed frame and up to ring spinning kept identical. As one progress from lesser shore hardness (56°) to higher shore hardness (90°) the yarn unevenness % and imperfection levels gradually increases. Linear regression technique is used to analyze the data.(Linear regression is a form of regression analysis in which the relationship between one or more independent variables and another variable, called dependent variable, is modeled by a least squares function, called linear regression equation. A linear regression equation with one independent variable represents a straight line.)

Keywords:

Ring spinning, Shore A hardness, Spinning front line cot, cotton yarn, yarn unevenness, yarn imperfection , Linear regression

Introduction:

Yarn quality is essential to the economic success of spinning plants. International competition and market requirements dictate the necessity to produce quality yarns at an acceptable price.

In general yarn quality is influenced by:

- Quality of raw material
- Opening & cleaning operations at Blow room & Carding
- Speeds & Settings kept at various stages of yarn production and its functions.
- Process control techniques and parameters kept at spinning
- Humidification, (temperature and humidity)
- labour force training and their skills.
- Maintenance of production equipment and vital components.

Drafting components have a significant influence on yarn quality and production costs in ring spinning. Especially spinning top roller covers i.e., cots and drafting aprons. These are the main components of the drafting mechanism and certainly it has more influence on the quality of the yarn produced.

Cots are used in draw frame, comber, speed frame and ring frame, whereas aprons are used only in speed frame and ring frame. The purpose of cots is to provide uniform pressure on the fibre strand to facilitate efficient drafting and use of aprons help to have better grip & control on fibres particularly floating fibres. A front line cot in ring spinning should also offer sufficient pulling force to overcome drafting resistance. Mathematically, Force of pulling required at front line cot ≥ Frictional resistance between fibres + Force exerted by the aprons on fibres.

Essential Characteristics of a spinning cot

The raw material Compounds on the basis of special rubber in the hardness range of approx. 63 to 90 Shore A hardness are used as coating raw materials.
The composition of the raw material determines the characteristics of the cot such as

- Shore A hardness of the rubber cot
- Resilience properties, low Compression set values and elasticity of the cot.
- Surface Characteristics like grip offered on fibre strands.
- Abrasion resistance.
- tensile strength
- Swelling resistance
- Color

These characteristics should fulfill the following demands made on a top roller cover

- Good fiber guiding
- No lap formation
- Long working life
- Good ageing stability
- Minimal film formation

Normally synthetic top roller cots are available in cylindrical form. The technical specifications of a top roller cot are i) Bare roller diameter BRD ii) Finished outer diameter FOD iii) Width or Length iv) construction like Alufit or PVC core and v) Shore A hardness. Shore hardness is one of the main properties of top roller cot and varies for different types of fibre, application etc,

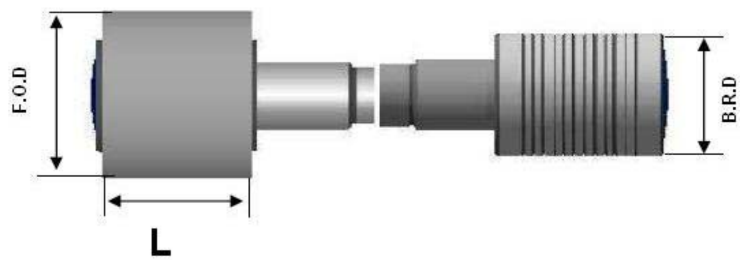


Fig 1. Technical specification of top roller cot

Shore hardness

Generally Shore hardness of a rubber cot is measured by using an instrument called 'Durometer' and the value is expressed in A scale. Cots are available in wide shore hardness ranging from 63° to 90° shore

Definition of shore hardness

Hardness may be defined as the resistance to indention under conditions that do not puncture the rubber. It is called elastic modulus of rubber compound. These tests are based on the measurement of the penetration of the rigid ball into the rubber test piece under specific conditions. The measured penetration is converted into hardness degrees. Shore A Durometer is used for measuring soft solid rubber compounds. Other scales are also used like Shore D which is used to measure the hardness of very hard rubber compounds including ebonite. The main drawback is in reproducibility of results by different operators. So, a practical tolerance of 5° is acceptable. As per the ASTM (D 2240 – Defines apparatus to be used and its sections such as diameter , length of the indentor , force of spring and D 1415 –Defines specimen size) , DIN, BRITISH & ISO Standards following test conditions have been laid for measuring SHORE A HARDNESS of rubber products .

1. The specimen should be at least 6 mm in thickness.
2. The surface on which the measurement made should be flat.
3. The lateral dimension of the specimen should be sufficient to permit measurements at least 12 mm from the edges.

Fig 2. Durometer analog and digital models

Top roller pressure, cots Ø, shore hardness of the cot and nipping length relationship

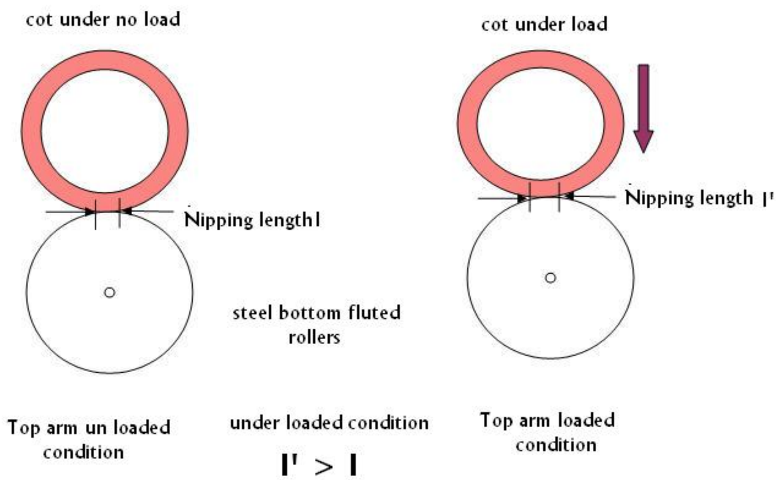


Fig 3. Shore Hardness and bottom roller contact area relationship

Mathematically, Arc of contact or the nipping length made by top roller cot with fluted roller (l) is inversely proportional to the shore hardness of the rubber cot. In general , Lower the shore hardness higher will be the contact area with steel bottom roller better so that there will be positive control on fiber's strand producing the yarn with better mass uniformity , lesser imperfection levels. Under Identical condition a cot measuring 56° Shore Hardness will make larger arc of contact with steel bottom than a cot measuring 90° Shore.

Trial methodology

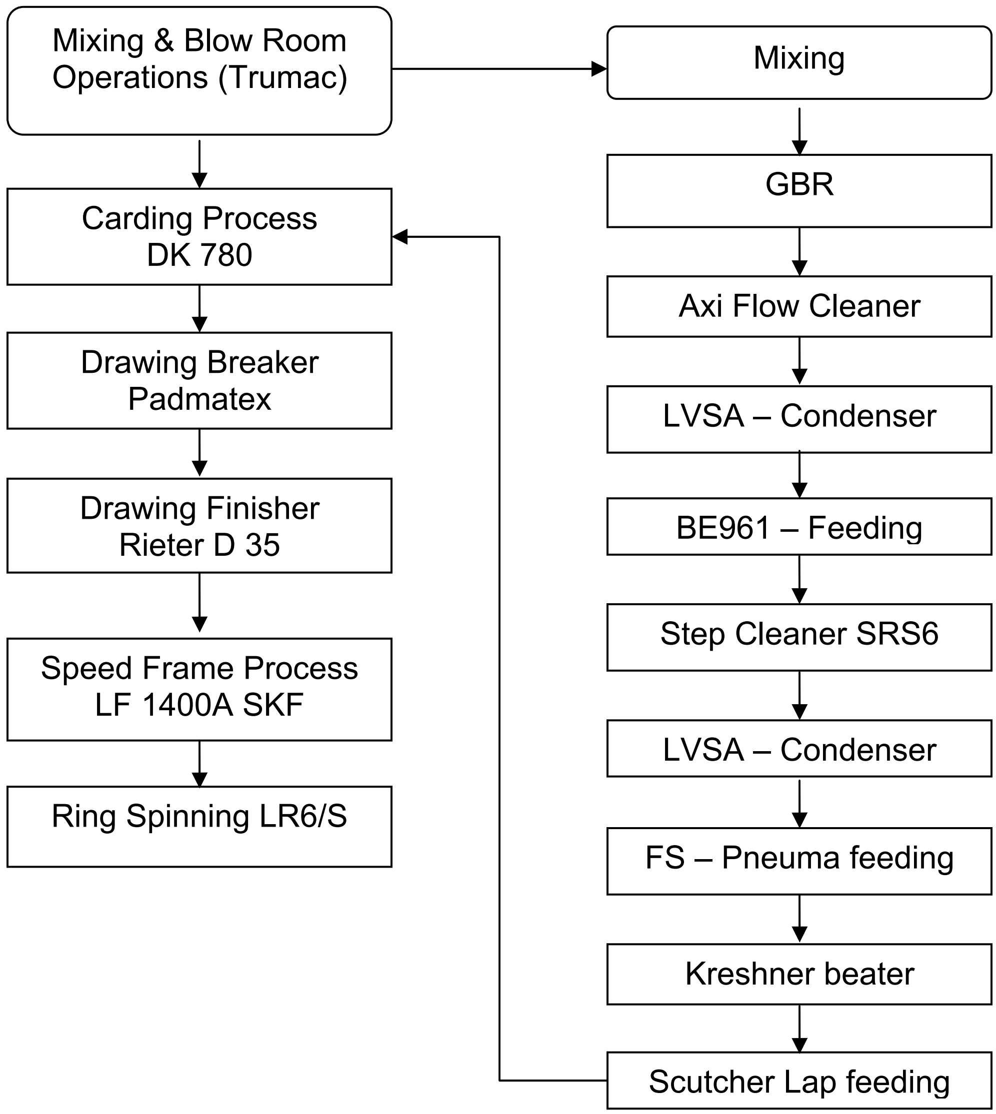
To carry out this investigation 100% MCU -5 cotton was chosen as raw material with the following fibre parameters and 64^s Ne Karded weaving Count was produced at ring spinning.

HVI Test data:

2.5 % Span Length in mm	30.70	Bundle Strength at 3 mm Gauge	23.5 gms / Tex
50 % Span Length in mm	13.70	Fibre Micronaire	3.8 µgs / Inch
Raw Material Trash %	3.3 %	Short Fibre Content by (n)	27.8 %
Short Fibre Content by (w)	10.3 %	Maturity Ratio	0.88
Immature Fibre Content	6.2 %	Neps / Gram	106

Table – 1

Sequence of machinery for raw material processing – Karded Process



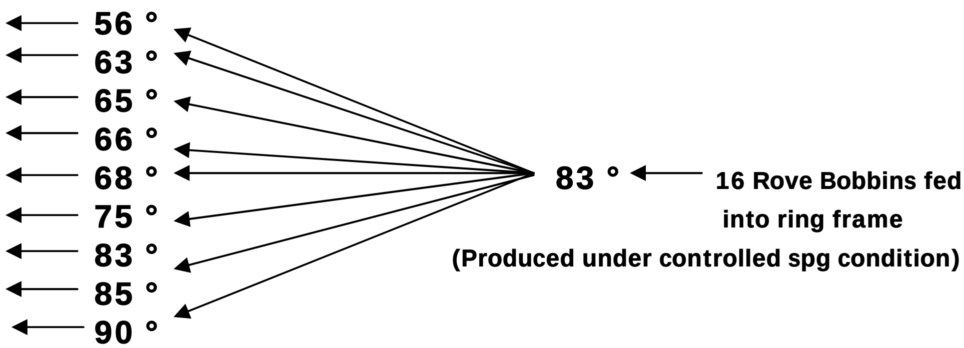
64s Ne Karded warp count was produced in ring spinning by using the above sequence of machinery , Various process parameters like hank / count , speeds & setting , life of the individual elements like card wire , rings etc kept identical throughout the study.

16 finisher draw frame sliver cans was collected and fed to LF1400A speed frame so that 16 Full rove bobbins can be doffed and can be utilized for ring frame trials with different front line cots varying only in shore Hardness.

Cots mounting and buffing:

For this investigation only alufit cot was chosen for both front and back line position. 8 top roller bare shells were carefully selected for every Shore hardness (16 cots per trial study in front line position) and mounting was carried in Vertical Pneumatic mounting m/c. For back line position standard 83° Shore hardness cot was used through out the trial study.

RING FRAME COTS POSITIONING



Front Line Positions cot **back Line position cot**

No. of spls utilized for trial study - 16 Spls / Shore Hardness range.

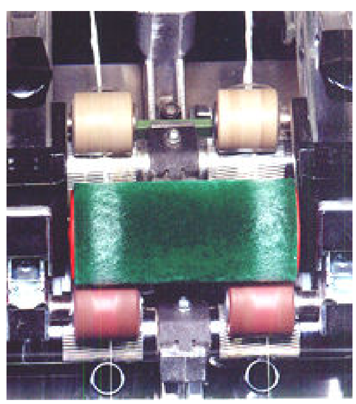


Fig 4

After mounting of cots grinding was carried in semi – automatic double width grinding machine. Grinding stone was dynamically balanced one and stone dressing was also carried by single point diamond dresser. Other important parameters to be noted are stone grid which is 80s grid with porosity 14. “Depth of cut” and “total contact time in sec” with grinding stone was carefully adjusted to get “Optimum Surface finish or Ra Value “on all the front line cots that varies in shore hardness. Since a softer cot requires “extra care” in terms of “feed rate” and “total contact time” during buffing to get optimum Ra Value than a harder cot which is generally good in grindablity .

Normally for ring spinning application an “Average Roughness Value “(Ra Value) of 0.8 ± 0.2 µm is generally recommended for front and back line cots . This range of roughness value is considered optimum. Too smooth or too rough surface will invite undrafted ends or lapping. Ra Value should be adjusted according to the cots working performance and quality of drafted strand.

After buffing Finished outer diameter F.O.D was maintained 30.00 mm in all the cots.

Results and discussions

At ring frame with the below mentioned parameters 64s Ne Karded warp was produced by using different shore hardness cots that ranged from 56° to 90° in front line .At back standard 83° was kept and Cops were collected in full stage with proper identification.

Machine parameters:

Make of RF	LR 6	**Material Processed**	100% cotton
Drafting type	P 3-1	**Fibre Length (2.5% Span)**	30.70 mm
Space size	2.75 mm	**Total draft**	33.31
Dyed / grey	N/A	**Break Draft**	1.13
Yarn Count In Ne	64s Karded Warp	**Spindle speed**	19,500 (Avg)
Roving hank	1.7	**FRS**	15.00 mts / min
Roving TM	1.04	**RF - TM**	4.14
Bottom Roller gauge	42.5 / 60 mm	**T.P.I**	33.12

Table – 2

Uster results:

S.NO	FRONT LINE	SHORE A	BACK LINE	SHORE A	COUNT	Um %	CVm %	CVm (1m)%
1	RD 56/A	56	GS 483	83°	64s Ne	13.81	17.83	4.54
2	E 463	63	GS 483	83°	64s Ne	14.12	18.21	4.53
3	GL 265	65	GS 483	83°	64s Ne	14.10	18.20	4.21
4	GR 266	66	GS 483	83°	64s Ne	14.30	18.45	4.27
5	RD 68	68	GS 483	83°	64s Ne	14.43	18.69	4.72
6	GO 375	75	GS 483	83°	64s Ne	14.50	18.80	4.30
7	GS 483	83	GS 483	83°	64s Ne	15.20	19.62	4.29
8	GB 585	85	GS 483	83°	64s Ne	15.54	20.06	4.68
9	GG 590	90	GS 483	83°	64s Ne	15.81	20.40	4.44

Table – 3 Shore Hardness Vs Yarn Mass uniformity

S.NO	FRONT LINE	SHORE A	BACK LINE	SHORE A	COUNT	Thin -30%	Thin -40%	Thin -50%
1	RD 56/A	56	GS 483	83°	64s Ne	4633	960.5	97.75
2	E 463	63	GS 483	83°	64s Ne	5015.50	1116.25	121.75
3	GL 265	65	GS 483	83°	64s Ne	4956.25	1103.50	126.00
4	GR 266	66	GS 483	83°	64s Ne	5291.00	1233.75	150.25
5	RD 68	68	GS 483	83°	64s Ne	5290.00	1255.50	149.00
6	GO 375	75	GS 483	83°	64s Ne	5521.0	1335.8	160.0
7	GS 483	83	GS 483	83°	64s Ne	6265.50	1652.50	226.25
8	GB 585	85	GS 483	83°	64s Ne	6563.50	1830.50	266.25
9	GG 590	90	GS 483	83°	64s Ne	6954.25	2066.25	325.25

Table – 4 Shore Hardness Vs thin faults per Km

S.NO	FRONT LINE	SHORE A	BACK LINE	SHORE A	COUNT	Thick +35%	Thick +50%
1	RD 56/A	56	GS 483	83°	64s Ne	1960	601.25
2	E 463	63	GS 483	83°	64s Ne	2140.00	661.00
3	GL 265	65	GS 483	83°	64s Ne	2202.25	699.00
4	GR 266	66	GS 483	83°	64s Ne	2278.50	726.00
5	RD 68	68	GS 483	83°	64s Ne	2363.75	772.00
6	GO 375	75	GS 483	83°	64s Ne	2474.5	827.5
7	GS 483	83	GS 483	83°	64s Ne	2901.75	1045.25
8	GB 585	85	GS 483	83°	64s Ne	3006.50	1114.00
9	GG 590	90	GS 483	83°	64s Ne	3178.25	1221.00

Table – 5 Shore Hardness Vs thick faults per Km

S.NO	FRONT LINE	SHORE A	BACK LINE	SHORE A	COUNT	Neps +140%	Neps +200%	Neps +280%
1	RD 56/A	56	GS 483	83°	64s Ne	4543	1444.25	424.5
2	E 463	63	GS 483	83°	64s Ne	4841.75	1548.75	444.75
3	GL 265	65	GS 483	83°	64s Ne	4754.25	1543.25	461.00
4	GR 266	66	GS 483	83°	64s Ne	5168.00	1706.50	492.25
5	RD 68	68	GS 483	83°	64s Ne	5353.75	1775.00	525.25
6	GO 375	75	GS 483	83°	64s Ne	5585.8	1874.3	539.5
7	GS 483	83	GS 483	83°	64s Ne	5695.75	1901.50	556.00
8	GB 585	85	GS 483	83°	64s Ne	5807.25	1975.75	582.25
9	GG 590	90	GS 483	83°	64s Ne	6042.75	2065.00	615.00

Table – 6 Shore Hardness Vs Neps faults per Km

	FRONT	BACK	Normal Sensitivity Levels			
S.NO	SHORE A	SHORE A	Thin - 50%	Thick +50%	Neps +200%	Total
1	56	83°	97.75	601.25	1444.25	2143.25
2	63	83°	121.75	661.00	1548.75	2331.50
3	65	83°	126.00	699.00	1543.25	2368.25
4	66	83°	150.25	726.00	1706.50	2582.75
5	68	83°	149.00	772.00	1775.00	2696.00
6	75	83°	160.00	827.50	1874.30	2861.75
7	83	83°	226.25	1045.25	1901.50	3173.00
8	85	83°	266.25	1114.00	1975.75	3356.00
9	90	83°	325.25	1221.00	2065.00	3611.25

Table – 7 Shore Hardness Vs Normal sensitivity level imperfection per Km

	FRONT	BACK	Increased Sensitivity Levels			
S.NO	SHORE A	SHORE A	Thin - 40%	Thick +35%	Neps +140%	Total
1	56	83°	960.5	1960	4543	7463.5
2	63	83°	1116.25	2140.00	4841.75	8098
3	65	83°	1103.50	2202.25	4754.25	8060
4	66	83°	1233.75	2278.50	5168.00	8680.25

5	68	83°	1255.50	2363.75	5353.75	8973
6	75	83°	1335.8	2474.5	5585.8	9396
7	83	83°	1652.50	2901.75	5695.75	10250
8	85	83°	1830.50	3006.50	5807.25	10644.25
9	90	83°	2066.25	3178.25	6042.75	11287.25

Table – 8 Shore Hardness Vs Increased sensitivity level imperfection per Km

Linear regression technique is used to analyze the data **Linear regression** is a form of regression analysis in which the relationship between one or more independent variables and another variable, called dependent variable, is modeled by a least squares function, called "linear regression equation". This function is a linear combination of one or more model parameters, called regression coefficients. A linear regression equation with one independent variable represents a straight line. The results are subject to statistical analysis.

For example consider the sample data X and Y as shown in the table

x	y
1.0	2.6
2.3	2.8
3.1	3.1
4.8	4.7
5.6	5.1
6.3	5.3

if we have a set of data, (x_i, y_i) , shown at the left. If we have reason to believe that there exists a **linear relationship** between the variables **x** and **y**, we can plot the data and draw a "best-fit" *straight line* through the data. Of course, this relationship is governed by the familiar equation $y = mx + b$. We can then find the **slope, *m*,** and **y-intercept, *b*,** for the data, which are shown in the figure below.

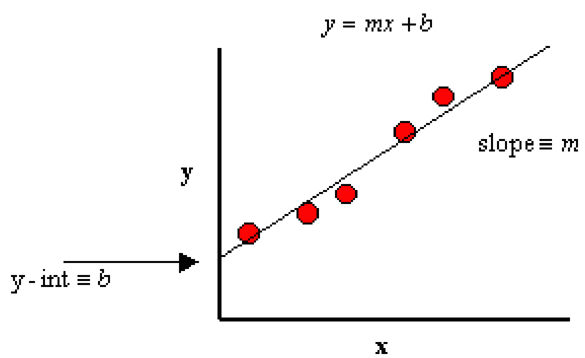
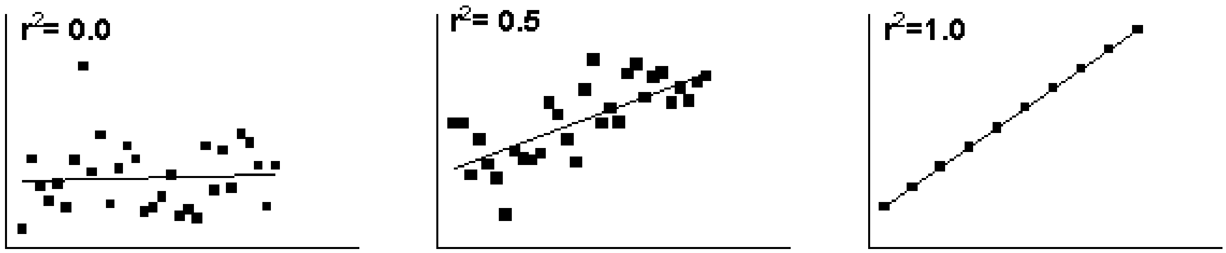


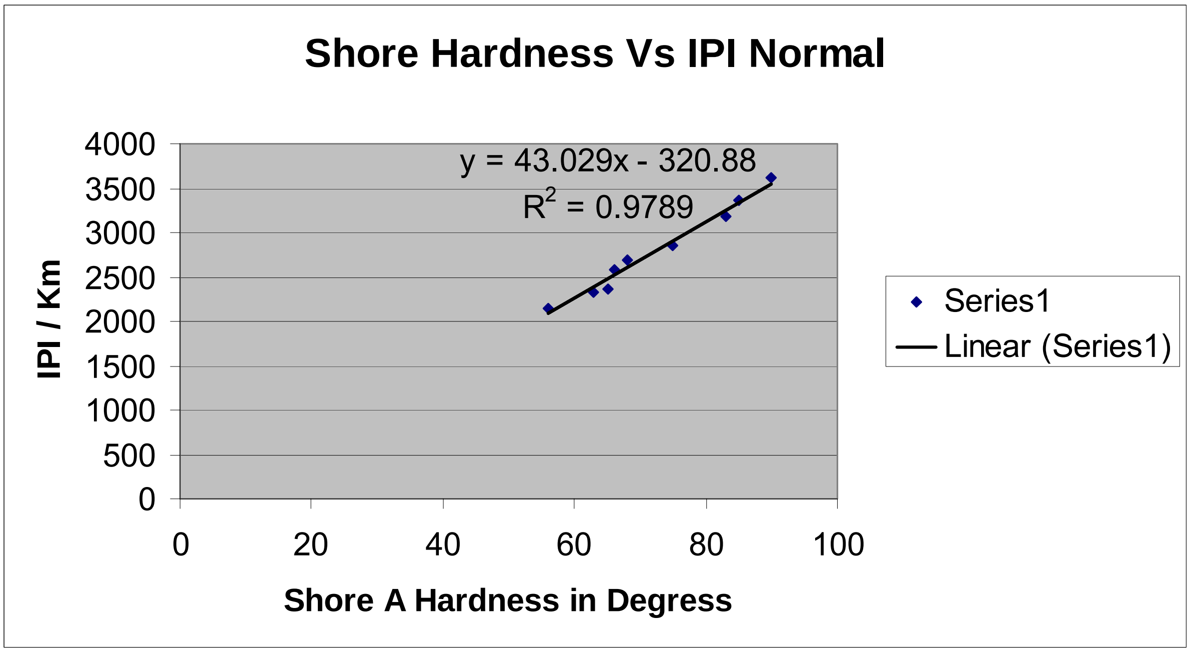
Fig 5

In the same manner we can plot a graph based on the data provided in table 3, 4, 5, 6, 7 & 8 between shore hardness of the cot and mass uniformity or U(m) % or Imperfection level etc. Where X is nothing but the shore A hardness and Y is yarn quality parameter like IPI / Km etc,

r², a measure of goodness-of-fit of linear regression

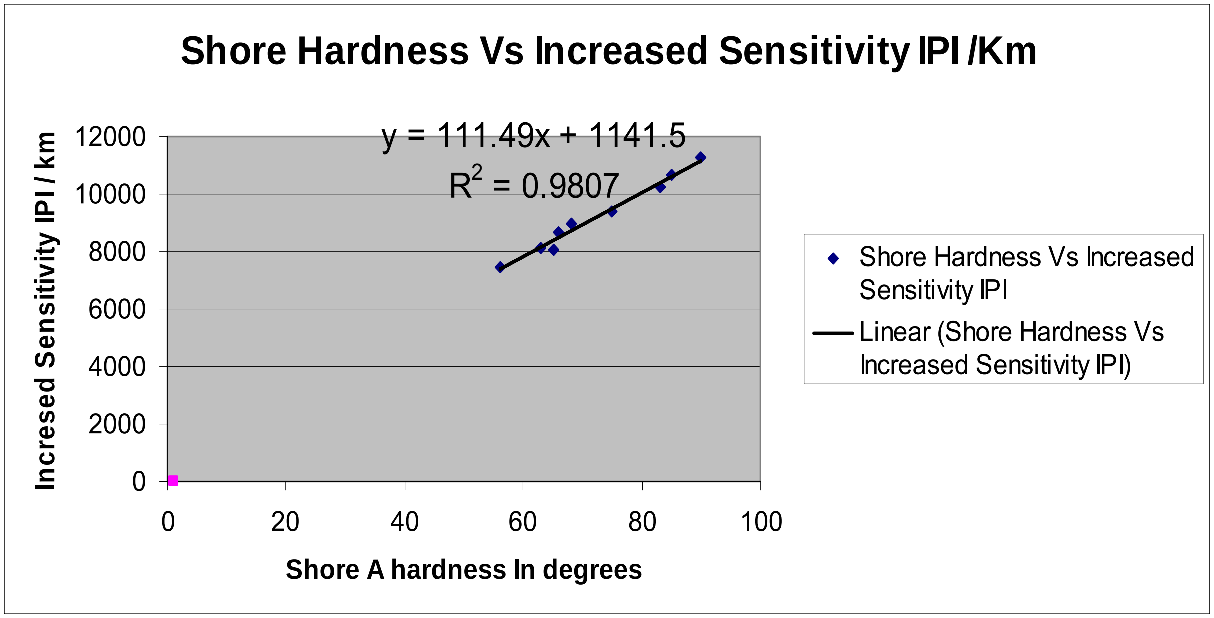
The value r^2 is a fraction between 0.0 and 1.0, and has no units. An r^2 value of 0.0 means that knowing X does not help you predict Y. There is no linear relationship between X and Y, and the best-fit line is a horizontal line going through the mean of all Y values. When r2 equals 1.0, all points lie exactly on a straight line with no scatter. Knowing X lets you predict Y perfectly.





Graph – 1

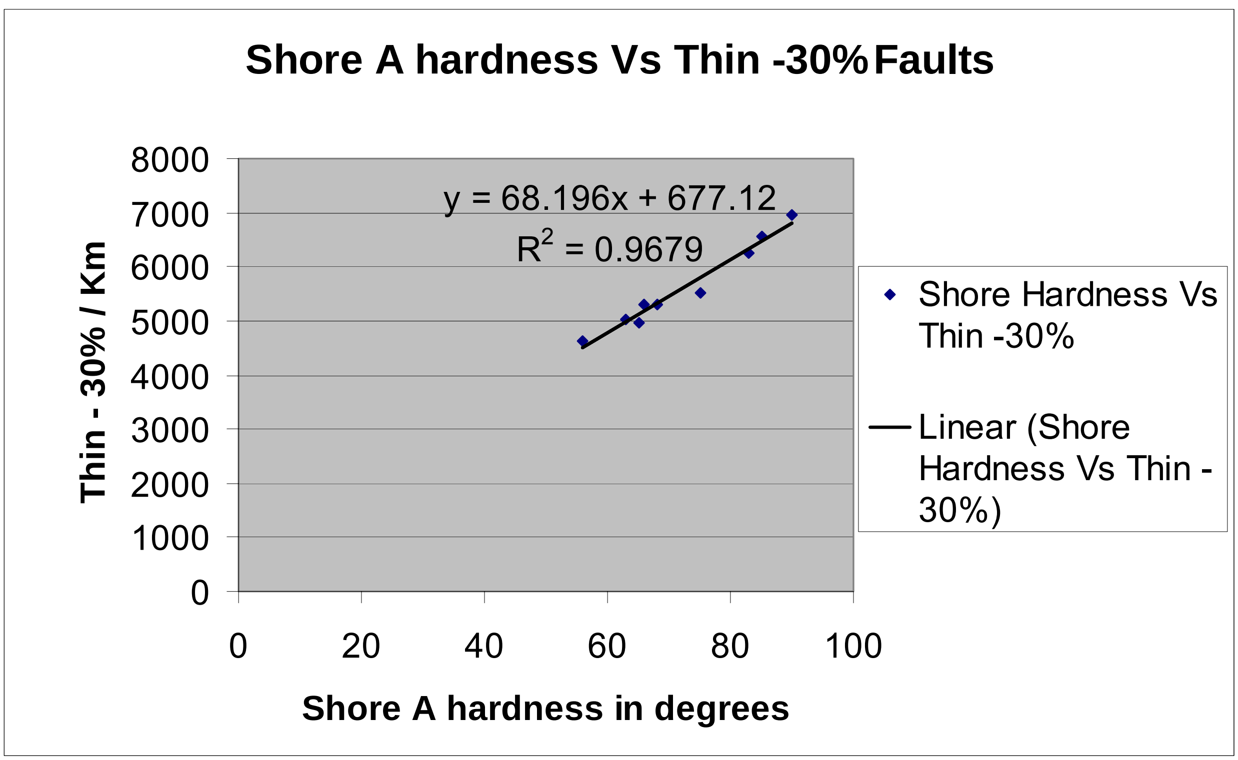
The above graph clearly illustrates that there is a strong Colerration between Shore hardness of front line cot and normal imperfection level (Sum of Thin – 50 %, Thick +50% & Neps +200% per Km of the produced yarn). The value of r^2 = 0.9789 which is almost 0.98. This signifies that one can have definite prediction about the IPI level with different shore hardness. In our investigation we haven't used 72° Cots in front line. If we had used in our trials then the IPI level would be around 2781 / Km. (Y = 43.029X – 320.88) Where X is Shore Hardness 72° and Y is IPI/Km. this shows the practical significance of linear regression technique.



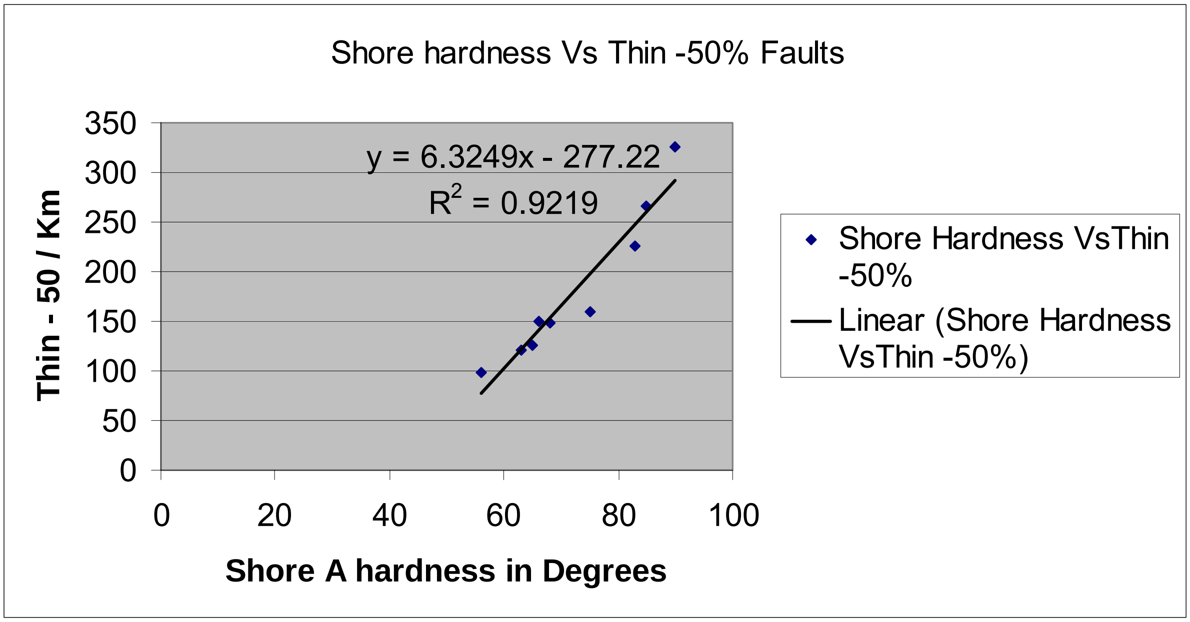
Graph – 2

Graph – 2 also clearly illustrates that there is a strong Colerration between Shore hardness of front line cot and sensitive imperfection level (Sum of Thin – 40 %, Thick +35% & Neps +140% per Km of the produced yarn). The value of r^2 = 0.98.

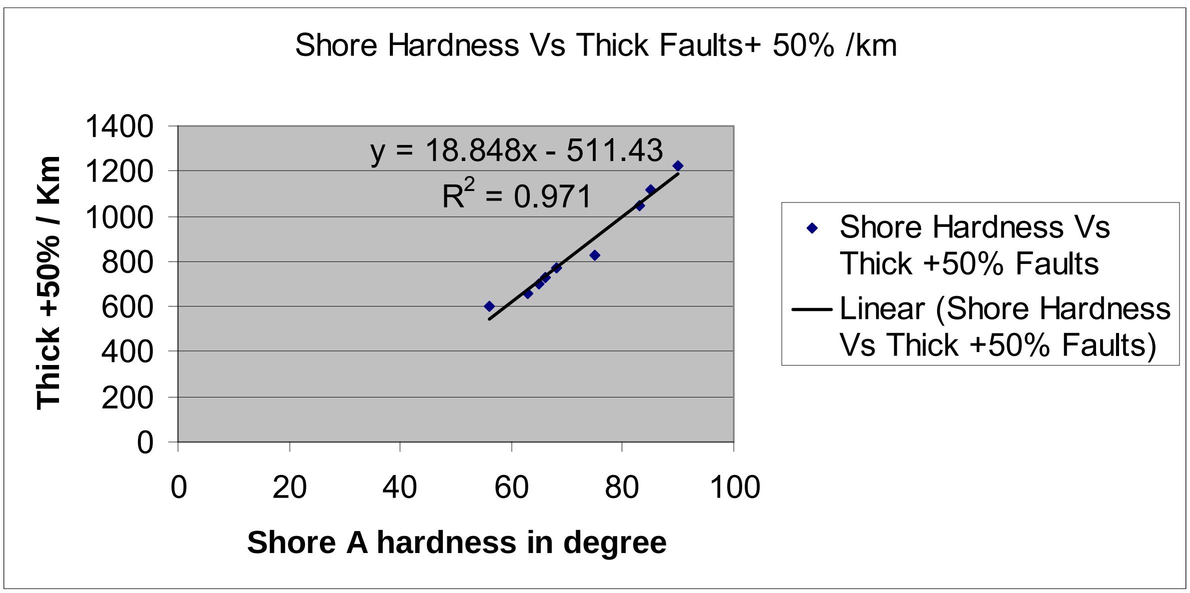
In the similar manner graph is plotted between shore hardness and individual faults.



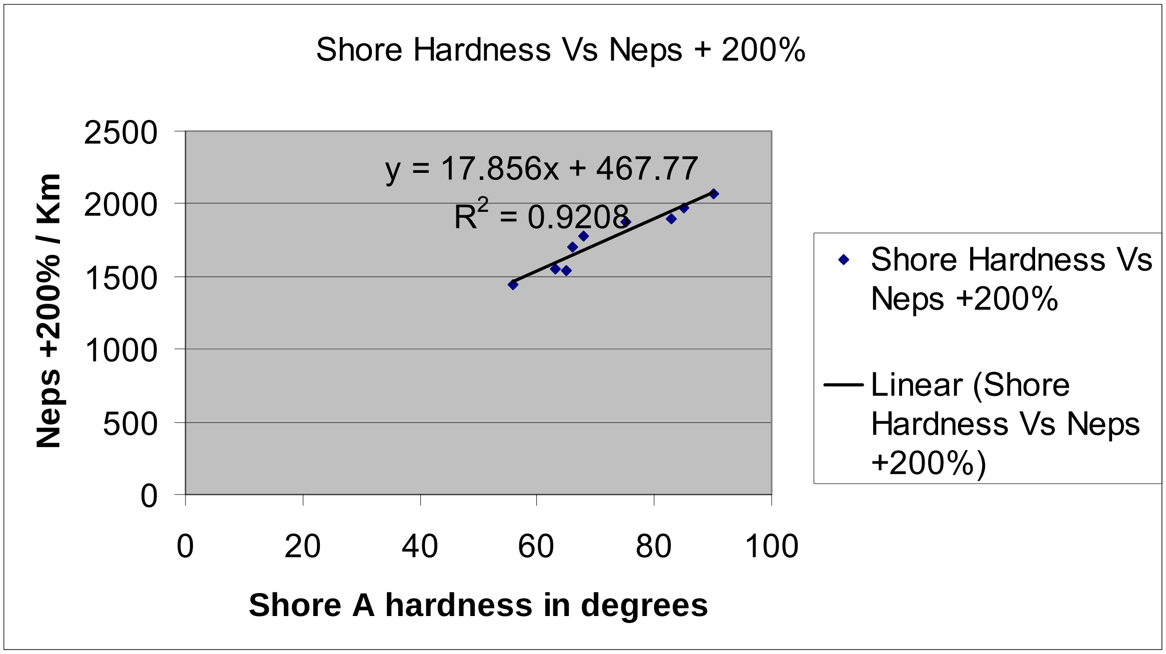
Graph – 3



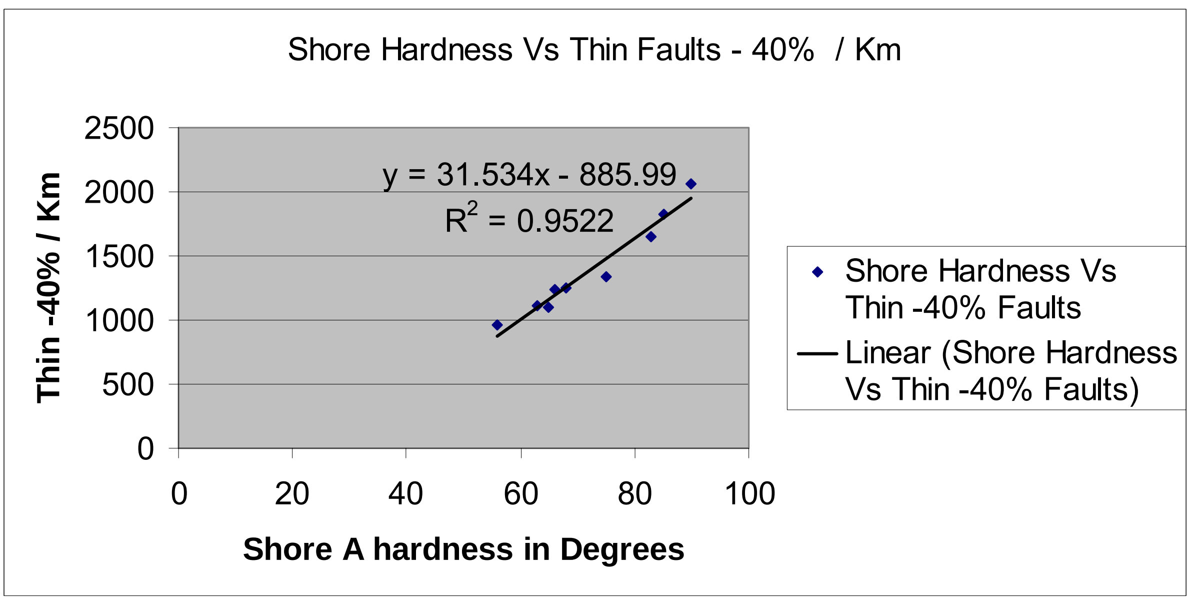
Graph – 4



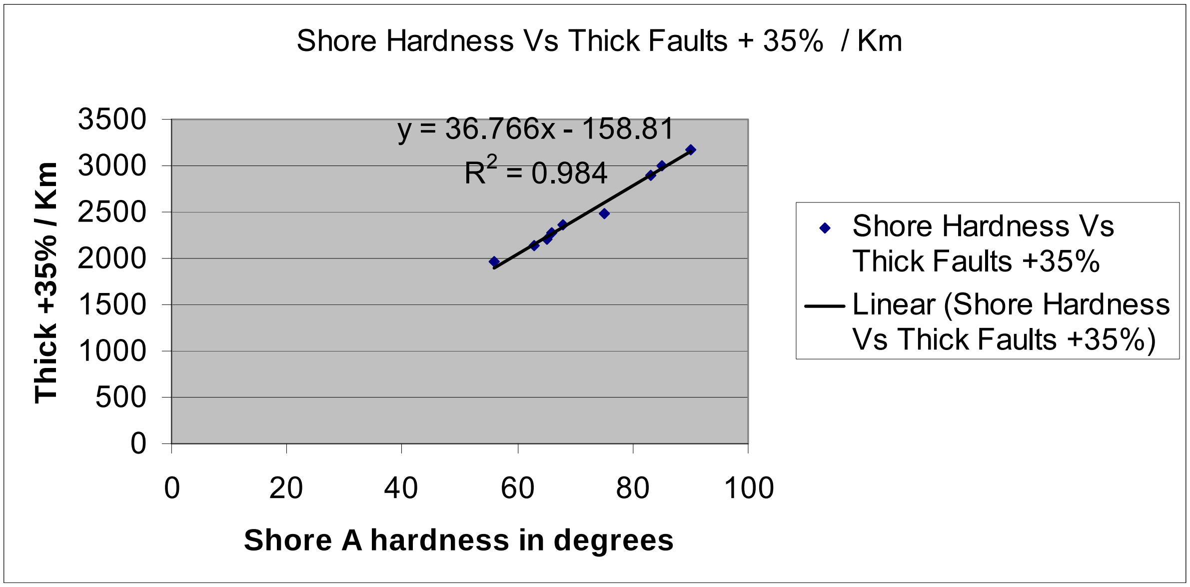
Graph – 5



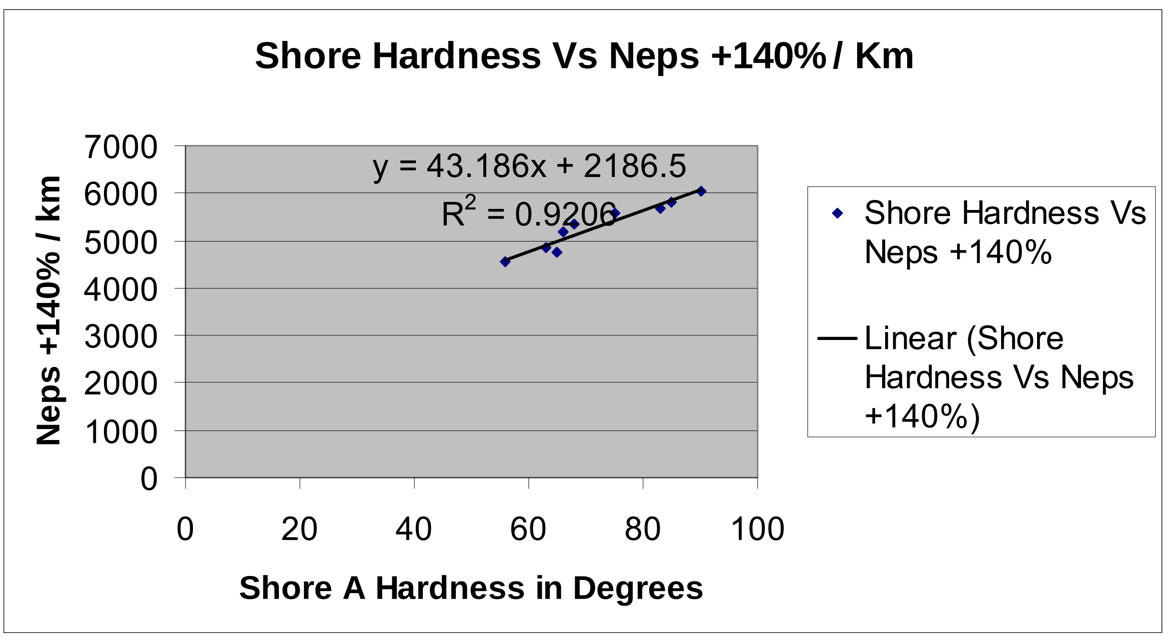
Graph – 6



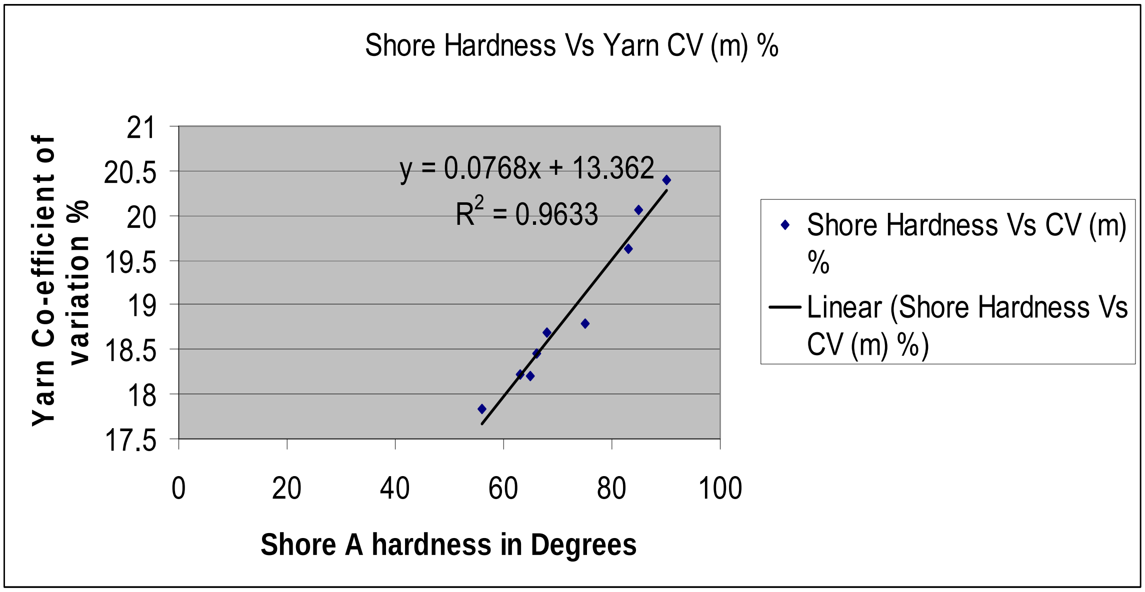
Graph – 7



Graph – 8



Graph – 9



Graph – 10

Conclusion

The effect of nine different spinning front line cots (Synthetic rubber cot) varying only in shore A hardness (56°,63°,65°,66°,68°,75°,83°,85°& 90°) on 100% cotton ring spun yarn has been investigated. The change in cotton yarn properties like mass uniformity, unevenness %, Imperfection levels (in all class) with progressive change in shore A hardness has also been reported.

From the above studies the following conclusion can be drawn:

1. In cotton yarns, with increase in shore hardness form 56° to 90°, the co-efficient of variation of yarn mass CV (m) % and Yarn Unevenness % U (m) % increase by about 2.57 CV(m) % and 2.0 U% respectively.
2. Increase of 1° of shore hardness corresponds to an increase of 2% in imperfection levels in normal sensitivity and 1.5% in increased sensitivity levels.
3. Strong correlation of r^2 values is observed between shore hardness and IPI value both normal and increased sensitivity levels particularly thin – 30%, thick +35% & thick +50% faults.
4. Almost in all the cases the value of r^2 is above 0.92 that signifies one can have definite prediction about the IPI level with different shore hardness.
5. Imperfection level and yarn unevenness % usually increases with increase in shore hardness. This is due to the fact that lower shore hardness cot helps for increase in area of contact with the fluted bottom roller , which significantly shortens the uncontrolled area between apron to cot nipping point.
6. Lower the degree of shore hardness, higher the softness of rubber compound and vice – versa. Even though softer cots under normal spinning conditions produces better yarns with better mass uniformity and IPI levels the major disadvantage is shorter grinding intervals and consequently shorter life span.
7. Hence from quality and working point of view 65° to 68° shore hardness is better for cotton. However, while using blended yarns, use of softer cots will lead to frequent roller lapping and faster wear & tear.
8. It is better to use 65° to 68° for cotton, 72° to 75° for cotton blends and 83° to 85° for 100% for polyester & polyester / viscose. In case of 100% acrylic yarn spinning, 90°

shore hardness need to be used. This is due to the fact that acrylic is a bulky fibre and therefore exerts maximum abrasion over the cots.

9. This article purely deals with the mathematical relationship between shore hardness, yarn mass uniformity and imperfection levels only. It doesn't incorporate other yarn quality parameters like long term irregularities, tensile properties, Hairiness, surface profile characteristics that include appearance, integrity.
10. This investigation is done with respect to one particular yarn count (64s Karded warp), further studies can be conducted with different count range , raw material and other yarn quality parameters can be tested and the relationship can be further extended with respect to cots shore hardness.

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