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A Novel Application of the Sirolan-Laserscan to Independently Measure Cotton Fibre Fineness and Maturity, A Preliminary Study.

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1. Plain English Summary

The commonly used Micronaire value for cotton is related to both fibre fineness and maturity. There is a need for a new measurement technique to separate these. This is of particular importance to the Australian industry where varieties of fine mature cotton have the potential to be wrongfully discounted commercially by misinterpreting a low Micronaire value as indicating immaturity in a coarser fibre.

Recently CSIRO Division of Wool Technology has developed a new instrument for measuring wool fibre diameter, the Sirolan-Laserscan. It is now in commercial use worldwide.

Recent preliminary studies using wool have demonstrated that the Sirolan-Laserscan can be used in a new mode of operation to give independently both the average fineness of a sample as well as information on the fibre cross sectional shape i.e. fibre maturity.

This preliminary project was designed to extend these studies to see if the Sirolan-Laserscan, in this new mode of operation, can be applied to cotton.

Fourteen cotton samples whose fineness and maturity values had been measured in previous work sponsored by CRDC formed a useful set to evaluate the approach. These samples covered a broad range of both fineness and maturity values.

A good correlation was found between the average fibre fineness measured by the Laserscan and the previously reported values.

These encouraging preliminary results indicate that, in this novel mode of operation, the Sirolan-Laserscan can be used to determine the average fibre linear density or fineness of cotton samples.

Following this successful preliminary study the next stage will be to examine possibilities of simultaneously measuring fibre maturity using the Sirolan-Laserscan and the scope for scaling up the technique from the laboratory to become a useful commercial measurement technique.

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2. Background

2.1 Micronaire Unsatisfactory

Cotton fibre fineness, sometimes referred to as linear density, and maturity are key quality parameters for cotton. They are important to both processing performance and end product characteristics. Unfortunately current commercial methods of assessing these parameters are inaccurate. The Micronaire value, determined from an Airflow technique, is a measure of the average fibre surface area of a sample. As such, micronaire is a mixture of both fibre fineness (mass per unit length) and maturity. It has been estimated that micronaire represents two-thirds fibre fineness and one-third maturity (Steadman, 1997). Recent experience has shown that for many cotton varieties the micronaire value may not be a good indicator of either property (Williams and Yankey, 1996). This leads to ambiguity in commercial trading with sometimes a buyer arguing that a low micronaire reading denotes immaturity whereas the seller interprets it as fineness (Steadman, 1997). This is of particular importance to the Australian industry where varieties of fine mature cotton have the potential to be wrongfully discounted commercially by misinterpreting a low Micronaire value as indicating immaturity in a coarser fibre.

Steadman's recent paper (1997) reviews the various other techniques that have been applied to measuring fibre fineness and maturity. To date, no satisfactory approach has been established for routine commercial testing.

2.2 Wool Measurement and the Sirolan-Laserscan

In commercial trading, the fineness of wool samples has, for many years, been determined using an airflow technique similar to that used for the micronaire measurement. As wool fibres are approximately circular in cross-section, the results of this test are accurately interpreted as a mean fibre diameter. For the Australian wool clip, typical mean fibre diameter values are between 18 and 24 μm with differences of 0.1 μm being significant commercially.

The Sirolan-Laserscan was developed at CSIRO Wool Technology as a commercial instrument for the rapid measurement of the full fibre diameter distribution of wool samples (IWTO, 1993). The technique, illustrated schematically in Figure 1, suspends fibre snippets in an isopropanol-water mixture that transports them such that they cross the path of a laser beam. The fibre diameter of each fibre snippet is determined from its interaction with the laser light. The Sirolan-Laserscan technique is now an approved test method for commercial testing of wool samples and is being used by the trade worldwide.

The availability of fibre diameter distribution information for wool samples has led to important advances at CSIRO Wool Technology on the role of diameter distribution in wool spinning (Lamb et al, 1992) and in fabric skin comfort (Naylor and Phillips, 1996). Some commercial mills are now specifying fibre diameter distribution characteristics and not just mean fibre diameter in order to control and improve their product quality.

2.3 Previous Application of the Sirolan-Laserscan to Cotton

Following on from his PhD. studies, Gordon (1995) undertook a small study to examine the application of the Sirolan Laserscan to the measurement of cotton fibre fineness and maturity. Using a set of cottons covering a broad range of fibre fineness and maturity, Gordon compared the measurements taken using conventional techniques (e.g. airflow and cross section data) with the various outputs from the Laserscan in its standard mode of operation. Although a number of interesting effects were observed, none were sufficiently statistically reliable to form the basis of a test method. (In hindsight, this is not surprising as recent calculations by Naylor (1997a and b) have shown that the normal outputs from the Laserscan are influenced by both fineness and fibre cross-sectional shape.)

Recent studies at CSIRO (Naylor 1997a) have demonstrated that in the case of wool fibres and under a new controlled operational procedure (which is different from the normal procedure), the Sirolan-Laserscan can be used as a reliable counter of the number of input fibre snippets. Thus, if the snippets are weighed before the measurement, the average weight per snippet i.e. the average linear density is readily determined. Further, calculations have shown that combining this linear density with the mean fibre diameter as measured by the Sirolan-Laserscan it is possible to infer the average ellipticity of the fibres i.e. how much the cross-section of the fibres is non-circular (Naylor 1997b). (These calculations to determine a shape characteristic, i.e. the fibre maturity, assumed that the fibre has a uniform density. This will need refining to account for the possible effect of the lumen in cotton.) Thus the difference between the observed average shadow size and that calculated from the measured linear density, should relate to the average shape of the fibre (Naylor 1997b) i.e. the fibre maturity.

These preliminary studies thus raise the possibility that this new approach using the Sirolan Laserscan might form the basis for a new test for measuring independently both the fineness and maturity of cotton fibres.

The current limited preliminary investigation was designed to focus on the measurement of cotton fineness or linear density.

3. Methodology

In the Sirolan-Laserscan fibre snippets are individualised and suspended in a carrier fluid. Single snippets are then counted and measured as they interact with a laser beam. Thus in principle the Laserscan gives two independent pieces of information namely (a) the number of snippets observed and (b) fibre thickness. These two pieces of information form the key to the new approach as described above in the Background section, namely a gravimetric determination of fibre fineness expressed as weight per unit length (mtex). The current feasibility study followed in two stages as follows:

Firstly, preliminary experiments were undertaken measuring cotton with the Sirolan-Laserscan in this new mode of operation. This assessed the inherent compatibility between the instrument and cotton and evaluated the counting statistics for cotton using the Sirolan-

Laserscan. Simple tests of the sample preparation and measurement technique like the repeatability of the raw data from the same cotton were investigated.

For the next set of experiments, cotton samples with known fibre linear densities and fibre maturity covering a broad range were used to test the proposed approach. Fortunately most of the Gordon's well characterised samples (1994,1995) were available and formed the sample set.

All cottons samples were conditioned at 20 C and 65% relative humidity for at least 24 hours before taking measurements. A controlled relative humidity value is important as the technique relies on an accurate value of the weight of fibre snippets. After weighing, fibres were fed into the Sirolan-Laserscan at a controlled rate such that the instrument did not reach its software controlled maximum counting rate of 100 counts per sec. The Sirolan-Laserscan was set such that it continued to count until all the sample was exhausted. This yielded the total number of fibres N 'seen' by the instrument. A predetermined instrument correction factor, α , was then applied to yield the total fibre snippets in the sample. The average fineness (linear density) F was then calculated by the formula:

$$F = \alpha W / (NL)$$

where W is the total weight of the snippets and L is the snippet length.

4. Results

4.1 Preliminary Experiments

Preliminary experiments demonstrated that the mini-core technique for preparation of fibre snippets, which is commonly used for raw wool samples, was not satisfactory for the current purpose. Samples prepared in this manner tended to form 'clumps' in the Sirolan-Laserscan and leading to significant errors in the counted number of snippets.

As an alternative, a protocol was developed using aligned 'beards' of fibres from the SpinLab Fibroliner (normally used to prepare cotton samples for fibre length measurements). Fibre snippets were then cut using a standard Sirolan-Laserscan guillotine.

Table 1 shows some preliminary results indicating the reproducibility of the system. It was observed that the variability was improved by weighing all replicates at the same time thus removing errors due to small changes in the relative humidity of the atmosphere.

The first section in Table 1 lists the results for a wool top that was used for calibration purposes. Following previous work (Naylor 1997a) it is reasonable to assume that the wool is circular in cross-section and hence the measured diameter can be used to calculate the average fibre linear density as the density of wool is known. Using this value, Equation 1 can be used to determine α , as shown. Thus it is estimated that the Laserscan registers only 40.1% of the available snippets.

The value of alpha will be determined by the alignment of the laser beam relative to the optical cell, the relative size of the measurement area and the total cell size, and the flow

pattern within the cell. Fortunately it has been shown previously (Naylor, 1997a) that for a given instrument α is approximately constant over a broad range of fibre fineness values.

Whether or not a particular snippet is 'seen' or not by the Sirolan-Laserscan can be thought of statistically as a random event and Poisson counting statistics should apply. Accordingly the standard deviation of repeated measurements of N is $N^{0.5}$. In the present case N is approximately 20,000 giving an expected standard deviation of 0.7%. This is in good agreement with the observed experimental variability for both the wool and cotton samples in Table 1.

Table 1 also lists the results of repeated measurements on two cotton samples. This illustrates the precision of measurement with the standard deviation of the mean of five measurements being approximately 1%.

4.2 Main Results

Following the success of these preliminary experiments, all the samples available from Stuart Gordon's work were measured and the results are summarised in Table 2 and Figure 2. Gordon's maturity and linear density values were determined by a double compression airflow technique. It can be seen in Figure 2 that there is a good correlation between the two different approaches. It should be noted the double compression airflow technique is believed to be more accurate at ranking samples according to linear density rather than in its determination of absolute values. Thus it is not surprising that the line of best fit is not $y=x$. Note the good relationship and the fact that, in contrast to Gordon's earlier results (1995) the very immature sample is not an outlier.

It is interesting that in Figure 2 there is one obvious outlier, sample USDA 18. Removing this data point from Figure 2 improves the R^2 value of the fitted line to 0.984.

To explore the validity of the current approach further, the linear density of some of the samples was measured using the Vibroscope, a third independent technique. This single fibre technique using a commercial instrument is based on observing the point of resonance of a vibrating single fibre. For each sample, approximately twenty fibres were measured and the mean results are also listed in Table 2. Samples not measured were too short for measurement using this technique. Figure 3 plots the Laserscan values against the values obtained from the Vibroscope. There is good agreement as shown with the best fit line being close to the $y=x$ line i.e the absolute values agree well. Sample USDA 18, the outlier in Figure 2 is not an outlier in this relationship.

Figure 4 plots the relationship between Gordon's results and the Vibroscope data. Note that the best fit line deviates from the line $y=x$ and that sample USDA 18 is an outlier. The reported double compression airflow result for sample USDA 18 is the 'odd one out' from the three different measurement techniques.

In summary the new Sirolan-Laserscan approach appears to accurately measure the linear density of the cotton samples tested.

Some simple estimations of fibre maturity using the existing Laserscan data lead to very poor correlations with Gordon's data. As explained earlier, ignoring the effect of the lumen, is an over simplification for an effective measurement of fibre maturity.

5. Research Conclusions

Based on the results to date, the new approach of using the Sirolan-Laserscan in this new mode of operation looks promising as the basis of a new technique for measuring cotton fibre fineness.

6. Intellectual Property

Whilst the current application of the Sirolan-Laserscan is novel, it is based on a well established principle, namely the gravimetric determination of fibre fineness. The Sirolan-Laserscan instrument is protected by various patents owned jointly by CSIRO and AWRAP.

7. Impact on Cotton Industry

A commercially viable technique for accurately measuring both fibre fineness and maturity would undoubtedly be of significant value to the Australian cotton industry. It would enable growers to confidently identify and market fine mature cottons without the current ambiguity caused by the micronaire measurement.

To date, this small preliminary research project has indicated that this new approach is scientifically viable of measuring cotton fineness. At this stage it will not have any direct impact on the industry ie further development work is required to fully assess the technical and commercial viability of the process.

8. Recommendations for Future Work

The current preliminary work has indicated that there is potential for the approach to technically measure fibre fineness. To maximise the usefulness of this information, it is desirable to be also able to measure fibre maturity. There are several ideas, utilising the optical measurement side of the Sirolan-Laserscan (rather than just the counting approach) which need to be investigated.

Further, in reality any new commercial fibre measurement approach must be compatible with the current HVI system. This will need to be assessed and evaluated as the current ideas are progressed.

9. Acknowledgments

Support for this project was provided by the Cotton Research and Development Corporation, their assistance is gratefully acknowledged.

10. Publications from Project

Naylor, G.R.S. and Sambell J. Measuring Cotton Fineness using the Sirolan-Laserscan. Proceedings 9th Australian Cotton Conference, 731-734, 1998.

Naylor, G.R.S. and Sambell J. Measuring Cotton Fineness Independently of Maturity using the Sirolan-Laserscan. Beltwide Cotton Quality Measurement Conference, Jan 1999. (in preparation).

11. References

S.G. Gordon, Cotton Fibre Maturity: Its Measurement and Effects on Processing. PhD Thesis, LaTrobe University, Bundoora, Victoria, Australia, 1994.

S.G. Gordon, Evaluation of The Sirolan-Laserscan Instrument for Measuring Cotton Fibre Fineness and Maturity. CSIRO Wool Technology Internal Report, 1995.

IWTO Test method 12-93: Measurement of the Mean and Distribution of Fibre Diameter using the Sirolan-Laserscan Fibre Diameter Analyser, 1993.

P. Lamb, G. de Groot and G.R.S. Naylor, Does Fibre Diameter Distribution Affect Worsted Yarn Quality?. Proc. Aachen Textile Conference, 3,599-605,1992.

G.R.S. Naylor (1997a). A Novel Application of the Laserscan to measure Fibre Linear Density. CSIRO Division of Wool Technology Confidential Laboratory Report No WTL 97.02.

G.R.S. Naylor (1997b). The Effect of Fibre Ellipticity on the Sirolan Laserscan Measurement of Fibre Diameter. CSIRO Division of Wool Technology Confidential Laboratory Report No WTL 97.01.

G.R.S. Naylor and D.G. Phillips, Skin Comfort of Wool Fabrics. In 'Proc. Top-Tech 96 Symposium' CSIRO Division of Wool Technology, pp356-361, 1996.

R.G. Steadman, Cotton Testing, Textile Progress, 27(1), 1997.

G.F. Williams and J.M. Yankey, New Developments in Single Fiber Fineness and Maturity Measurements. Cotton Quality Measurements Conference, Beltwide Cotton Conferences, 2, 1284-1289, 1996.

11. Tables

Table 1.

Wool Calibration				
Sample	Weight (mg)	Mean Diameter (μm)	N	ALPHA
1	50.0	21.9	19738	0.398
2	50.0	22.0	19938	0.406
3	50.0	22.1	19432	0.399
4	50.0	22.0	19701	0.401
5	50.0	22.0	19674	0.400
			MEAN	0.401
			SD	0.003
			CV (%)	0.74
Cotton 7				
Sample	Weight (mg)		N	Linear Density (mtex)
1	16.0		21563	160
2	16.0		21219	163
3	16.0		20828	166
4	16.0		21096	164
5	16.0		21072	164
			MEAN	163
			SD	2
Cotton 13				
Sample	Weight (mg)		N	Linear Density (mtex)
2	18.0		22590	172
3	18.0		21753	179
4	17.5		21435	176
5	18.0		21741	179
			MEAN	177
			SD	3

Table 2.

Stuart Gordon's Results			Laserscan Results	Vibroscope
Sample No.	Maturity Ratio	Linear Density (mtex)	Linear Density (mtex)	Linear Density (mtex)
7	0.88	141	163	177
8	1.02	183	206	199
10	1.00	175	187	197
USDA13	0.61	140	177	
USDA14	0.79	134	160	186
USDA16	0.94	158	163	172
USDA18	0.90	232	196	187
USDA19	0.95	249	257	247
USDA21	0.92	368	410	
USDA22	1.00	359	404	
24	0.95	163	190	177
32	0.99	178	200	184
36	0.81	163	178	190
42	0.98	169	202	188

12. Figures

Figure 1. Schematic Diagram of Sirolan-Laserscan

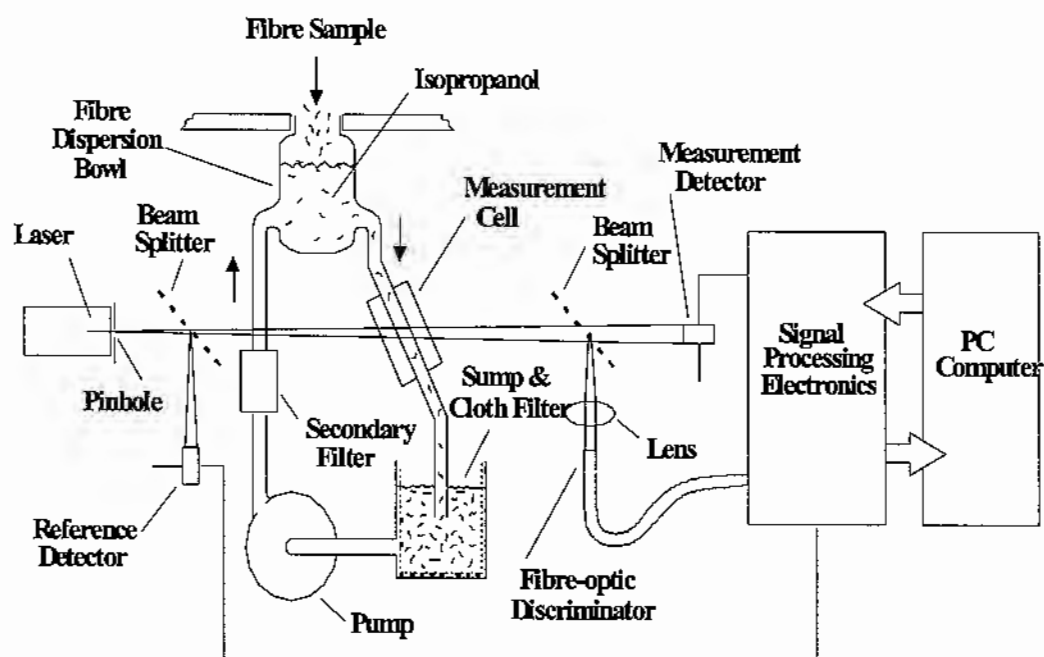


Figure 2. The relationship between the Linear density measured by the Sirolan-Laserscan and that measured previously by Gordon using a double compression Airflow technique.

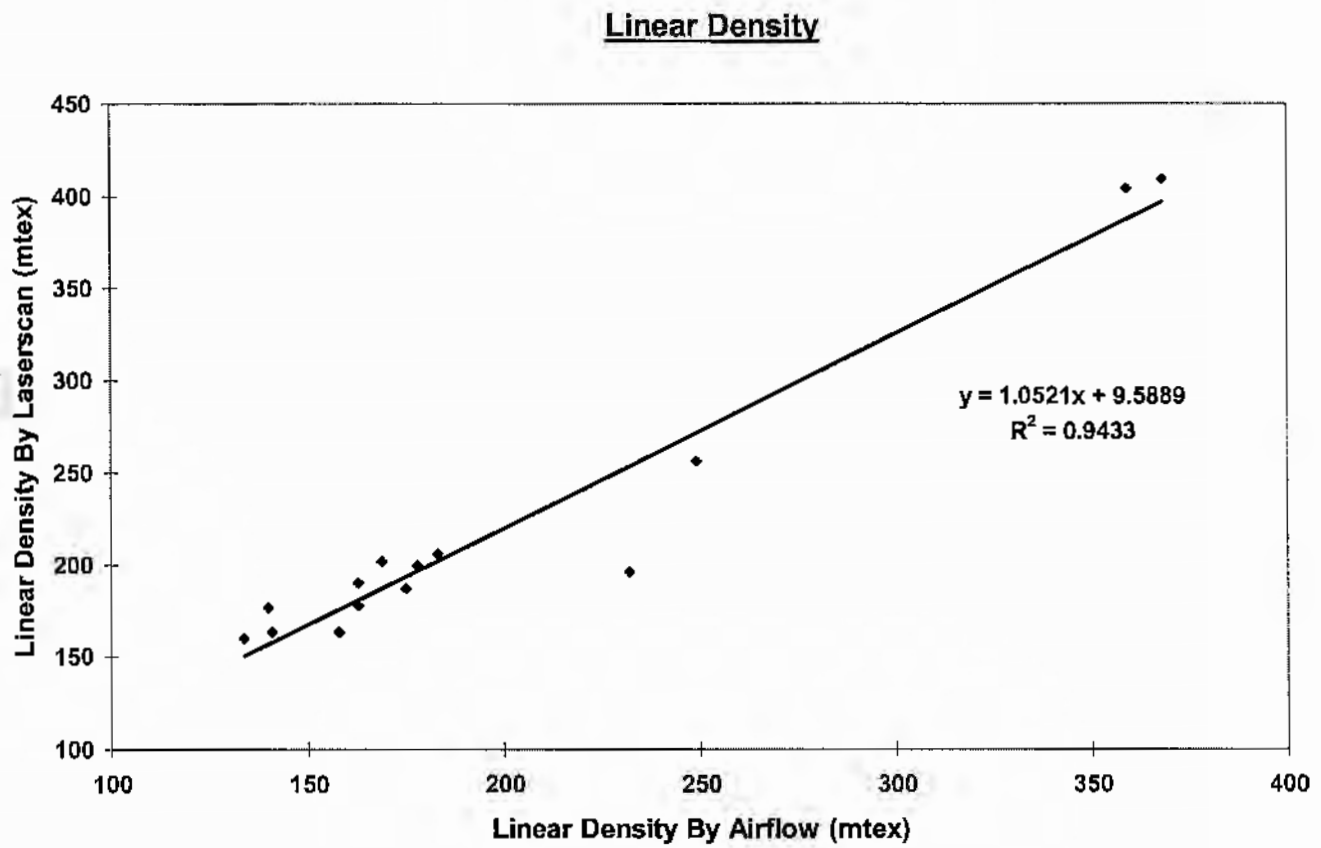


Figure 3. The relationship between the linear density measured by the Sirolan-Laserscan and that measured using the Vibroscope. The best fit straight line is indicated as the solid line and the dotted line represents the line $y=x$. The point 'Outlier' is from the sample (UDSA18) that is the outlier in Figure 2.

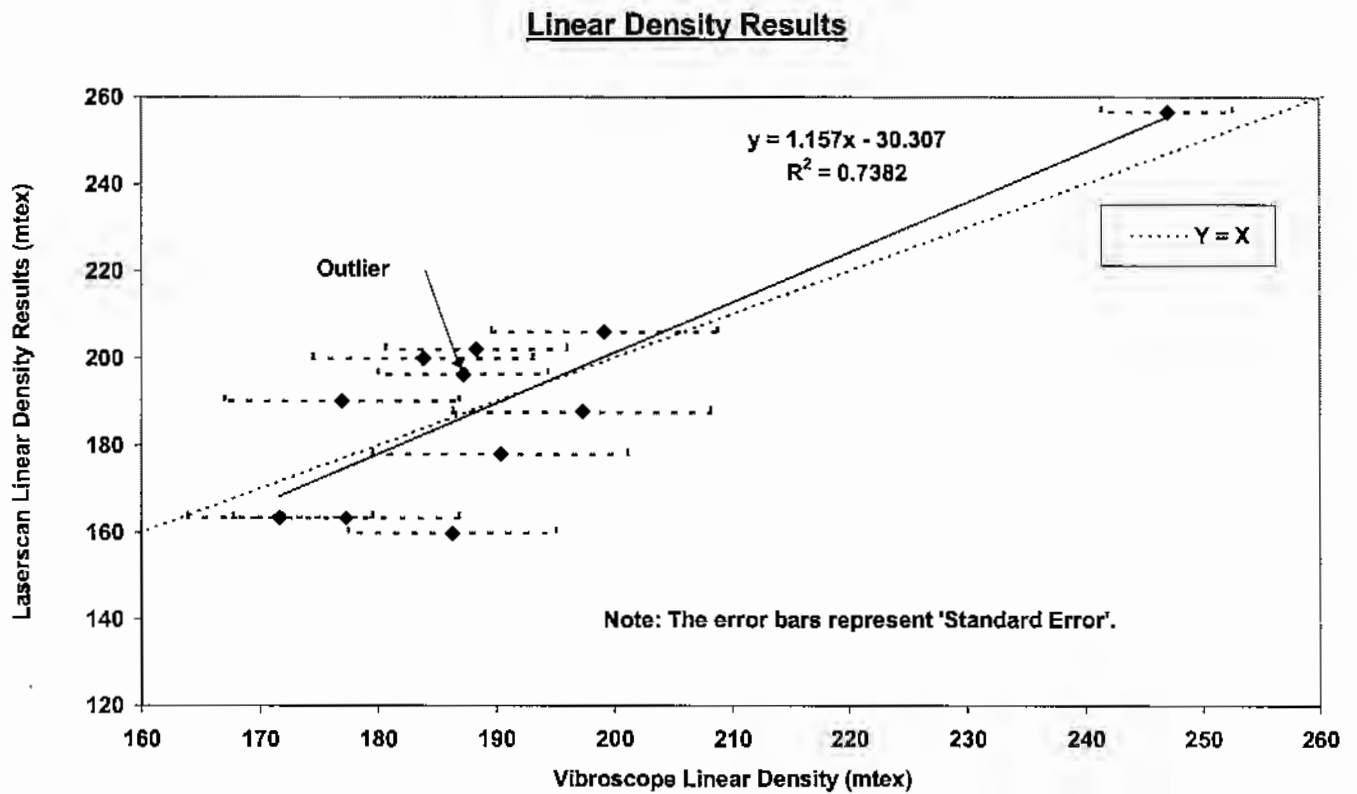


Figure 4. The relationship between the linear density measured by Gordon using a double compression Airflow technique and that measured using the Vibroscope. The best fit straight line is indicated as the solid line and the dotted line represents the line $y=x$. The point 'Outlier' is from the sample (UDSA18) that is the outlier in Figure 2.

