International Journal of Reliability and Applications
Vol. 10, No. 2, pp. 89-99, 2009

Using Reliability Tools to Characterize Wood Strand Thickness of Oriented Strand Board Panels

J. S. Chastain
Department of Statistics, Operations, and Management Science
331 Stokely Management Center,
and Tennessee Forest Products Center,
University of Tennessee, Knoxville, TN 37996-0532 USA

T. M. Young*
Tennessee Forest Products Center, 2506 Jacob Drive,
University of Tennessee, Knoxville, TN 37996-4570 USA

F. M. Guess
Department of Statistics, Operations, and Management Science
335 Stokely Management Center,
University of Tennessee, Knoxville, TN 37996-0532 USA

R. V. León
Department of Statistics, Operations, and Management Science
337 Stokely Management Center,
University of Tennessee, Knoxville, TN 37996-0532 USA

Abstract. Oriented Strand Board (OSB) is an important engineered wood product used in housing construction which has a lower environmental impact or “carbon footprint.” In this paper, reliability and statistical tools are applied to gain insights on the strand thickness of OSB panels. An OSB panel consists of several hundred wood strands that are resinated and pressed. The variability of OSB strand thickness for six manufacturers in the Eastern United States is examined as a whole, as well as individually. Little research exists on OSB strand thickness across mills even though strand thickness variability has been documented in laboratory experiments to greatly influence the dimensional stability of OSB panels. Our aims are to quantify and characterize strand thickness, plus apply reliability techniques, such as Kaplan-Meier curves, to characterize the probability of strand thickness. We further explore graphically and statistically the thickness of the strands.

Key Words : *Reliability analyses, explore graphically and statistically, thickness, Oriented Strand Board, Weibull, largest extreme value, logistic, loglogistic, Kaplan-Meier curve.*

1. INTRODUCTION

Oriented Strand Board (OSB) is an important engineered wood-panel product used in residential housing construction which is created from wood strands cut from small round logs which are resinated (phenolic or isocyanates) and formed under pressure and heat. The panels of OSB are layered with strands in non-random (“oriented”) directions to form mats. The horizontal orientation of the strands gives the panels both strength and durability. Generally, the strands are up to six inches (152.4 mm) long and approximately one inch (25.4 mm) in width.

Strand thickness variability may influence mat formation, which impacts final board reliability, and dimensional stability of the final OSB panel (Tackie et al. 2008; Hermawan et al.2006; Paul et al. 2005). OSB manufacturers generally target a strand thickness of 0.030 inches, or 0.762 mm (Boyer et al. 2007). As Brochmann et al. (2004) noted, early studies by Brumbaugh (1960), Post (1961), and Jorgenson and Odell (1961) found that particles and strands which are too thick, produced increased thickness swell (TS). Brochmann et al. (2004) also documented the effect of thinner face strands on reducing 24-hour TS, while the thicker strands produced higher internal bond (IB), but had the lowest surface area for resin bonding, all effecting product reliability.

OSB is a direct substitute for plywood, which is a traditional engineered veneered-layered wood panel used primarily for housing construction (Wang 2007). OSB is most often used in housing construction as roof sheathing, wall sheathing, and flooring. It is used to a lesser extent in furniture, as well as shelving, and has some applications in industrial construction. Many architects and contractors prefer OSB to plywood because it can be tailored for certain specialized uses (e.g., varying thickness and density) and has a price advantage to plywood (Anonymous 2007).

The purpose of this study is to explore the thickness variability of OSB strands. Samples of strands were collected from six mills in the Eastern United States.

2. EXPLORING STATISTICALLY OSB STRAND THICKNESS

Data on thickness of strands are summarized in Table 2.1.

Table 2.1. OSB strand thickness descriptive statistics for each mill’s complete data.

Statistic	**Mill A**	**Mill B**	**Mill C**	**Mill D**	**Mill E**	**Mill F**
Mean	0.0357	0.0311	0.0288	0.0318	0.0364	0.0291
Median	0.0335	0.0310	0.0275	0.0308	0.0365	0.0268
Standard Deviation	0.0124	0.0058	0.0127	0.0137	0.0151	0.0134
CV	34.73%	18.65%	44.10%	43.08%	41.48%	46.05%
IQR	0.0135	0.0040	0.0140	0.0159	0.0222	0.0162

---

* Corresponding Author.
E-mail address: tmyoung1@utk.edu

Minimum	0.0130	0.0210	0.0045	0.0070	0.0085	0.0067
Maximum	0.0955	0.1030	0.0715	0.1155	0.0890	0.0876
Skewness	1.0293	9.3936	0.9477	1.7258	0.2927	1.3612
Kurtosis	2.2333	116.4694	1.6523	8.3946	0.0281	2.9531
Sample Size	300	200	140	150	150	304

*The units of measure for the mean, median, standard deviation, IQR, minimum, maximum are in inches.

The mean and median for each data set fall close to 0.03 inches (0.762 mm). Most of the standard deviations fall around 0.01 inches (0.254 mm) with the coefficient of variation ranging from 18.7 percent to 46.1 percent. Mill B has a sample standard deviation less than 50 percent of that of the other five mills. Also, Mill B has a much lower interquartile range of 0.004 inches (0.1016 mm) when compared to the other five mills. Mill B is skewed the most as assessed by the skewness coefficient, and this can be explained partially by an extreme outlier in the complete data. Mill B also has the highest kurtosis, meaning it is the most peaked distribution.

Nine distributions are examined to determine the best-fitting distribution (Exponential, Frechet, Largest Extreme Value, Logistic, Loglogistic, Lognormal, Normal, Smallest Extreme Value, and Weibull). Akaike's Information Criterion (AIC) is used to score the distributions where the lowest score is judged as the best (Akaike 1973, Bozdogan (2000), see Table 2.2.

Table 2.2. AIC score of nine distributions for each mill's complete data.

Distribution	Mill A	Mill B	Mill C	Mill D	Mill E	Mill F
Exponential	-1395.8	-983.8	-708.8	-730.4	-689.8	-1538.8
Frechet	-1748.6	-1662.4	-768.0	-824.6	-762.0	-1775.6
LEV	-1819.8	-1673.4	**-837.8**	**-884.6**	-823.6	-1831.6
Logistic	-1798.2	-1705.8	-832.0	-878.2	-824.6	-1781.2
Loglogistic	**-1820.8**	**-1725.4**	-834.8	-883.8	-813.8	-1829.6
Lognormal	-1819.0	-1699.8	-826.8	-878.0	-813.6	**-1833.6**
Normal	-1781.8	-1714.0	-823.2	-857.8	-829.0	-1755.4
SEV	-1620.2	-1713.0	-760.0	-794.2	-789.6	-1579.6
Weibull	-1783.2	-1717.6	-833.0	-868.8	**-835.0**	-1793.0

The Largest Extreme Value and Loglogistic distributions are the most popular for the wood strands for the complete data. Mill E has the thickest wood strands and has the Weibull distribution for the complete data. Box plots of each mill indicate that outliers exist (Figure 2.1). After removing the most extreme outlier from each mill, AIC scores suggest that the most common distribution is the Weibull, followed by the Largest Extreme Value (Table 2.3).

Table 2.3. AIC score of nine distributions for each mill (excluding most extreme outlier).

Distribution	**Mill A**	**Mill B**	**Mill C**	**Mill D**	**Mill E**	**Mill F**
Exponential	-1394.6	-983.4	-706.8	-731.0	-688.2	-1537.8
Frechet	-1748.6	-1675.6	-766.4	-825.4	-760.8	-1775.4
LEV	**-1823.8**	-1708.2	**-838.2**	-892.4	-824.0	-1835.4
Logistic	-1806.4	-1766.2	-835.0	-892.8	-827.4	-1788.4
Loglogistic	-1823.6	-1759.0	-834.6	-888.0	-813.6	-1831.4
Lognormal	-1823.4	-1756.4	-826.4	-884.2	-813.6	**-1836.2**
Normal	-1799.4	-1768.2	-828.2	-894.2	-835.2	-1768.4
SEV	-1677.6	-1767.0	-768.8	-851.6	-814.4	-1602.8
Weibull	-1800.0	**-1774.0**	-836.0	**-898.2**	**-840.0**	-1801.4

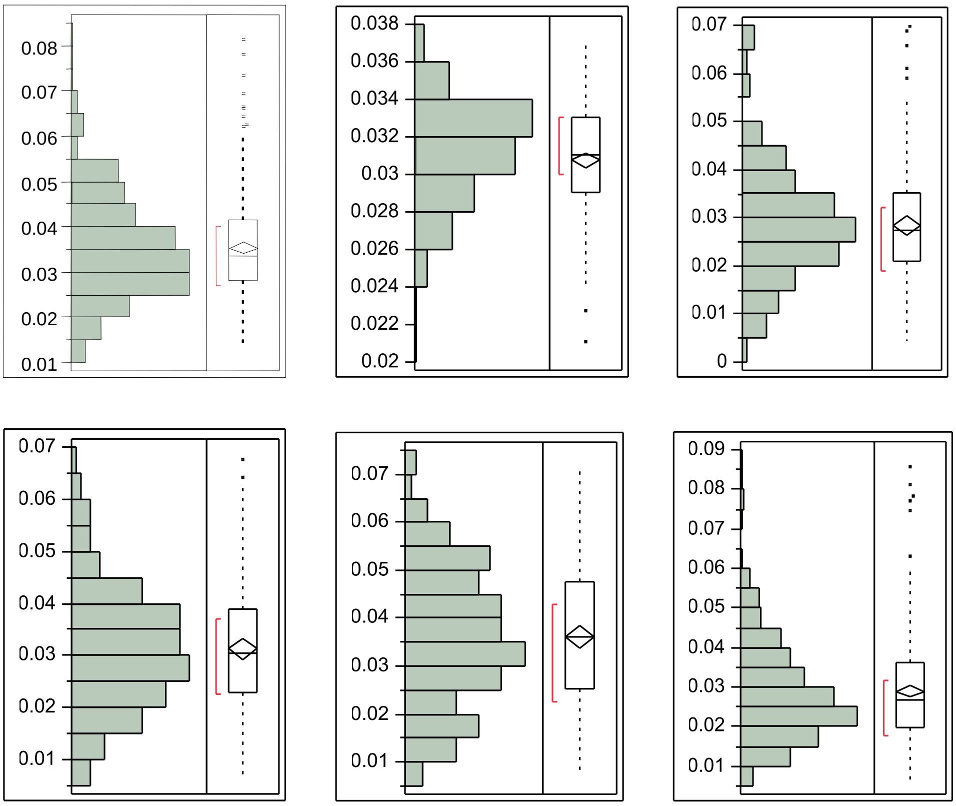

Figure 2.1. Strand thickness histograms and box plots for each mill excluding most extreme outlier (Mill A upper left, Mill B upper middle, Mill C upper right, Mill D lower left, Mill E lower middle, Mill F lower right).

*The units of measure are in inches.

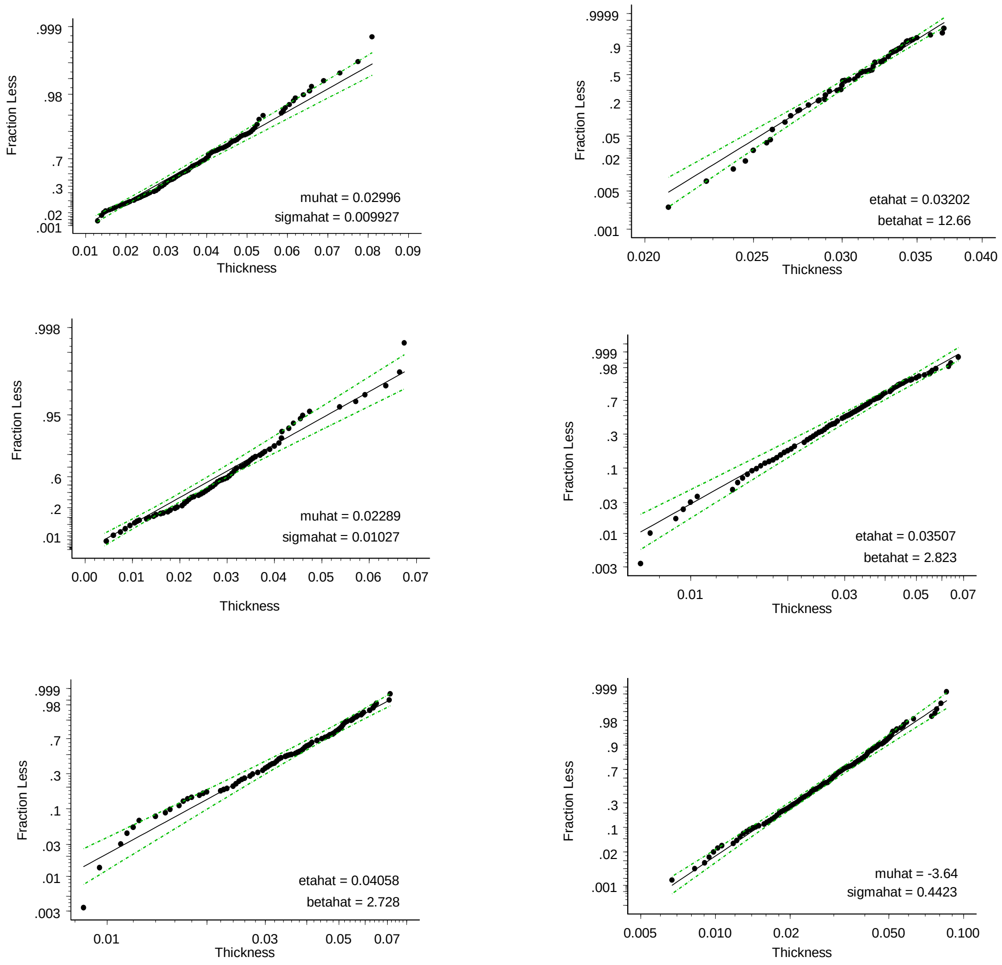

Figure 2.2. Probability plots for best-fit distributions (greatest outlier excluded), Mill A (upper left – LEV), Mill B (upper right - Weibull), Mill C (middle left – LEV), Mill D (middle right – Weibull), Mill E (lower left – Weibull), Mill F (lower right - lognormal)

There was one extreme outlier for Mill A, which was removed after discussions with mill management (i.e., large strand thickness is typically removed from process during screening of strands). The best fit for the distribution was the Largest Extreme Value (LEV) without this outlier (Figure 2.2). Mill B has one low outlier. The mean and median are very close, and the middle 50 percent of the data fall within a fairly tight range as compared to the tails of the distribution. The best-fit distribution for Mill B was the Weibull (Figure 2.2). Mill C has numerous thick outliers which skew the distribution to the right. The mean and median are almost identical, and the skewness coefficient of 0.9477 indicates a positive skewness. The best distribution for the data was the LEV (Figure 2.2). Mill D has two mild outliers, plus one extreme outlier which are removed from the box plot in Figure 2.1. The distribution is skewed right according to both the box plot and the histogram. The box plot shows that the mean and median values are very close to one another. The best fit for the distribution was the Weibull (Figure 2.2). Mill E has a fairly symmetric distribution and the histogram shows very small tails that rise steeply to the middle of the data. The best fit distribution was the Weibull.

Mill F is skewed right due to numerous high outliers. Even without these outliers, the distribution appears to be skewed right as judged by both the box plot and the histogram. The highest outlier is removed in order to score the AIC. The best-fitting distribution for Mill F is the lognormal, regardless of the treatment of the highest data point (Figure 2.2).

3. COMPARATIVE ANALYSES OF STRAND THICKNESS

Nonparametric Wilcoxon/Kruskal–Wallis One-Way Analysis of Variance (ANOVA)

A comparison of box plots among the mills illustrates differences in the median strand thickness (Figure 3.1). The box plots also reveal differences of the variances of strand thickness among the mills. Given the non-normal distributions of the six mills, the nonparametric Wilcoxon/Kruskal–Wallis one-way ANOVA was used to compare median strand thickness among the mills.

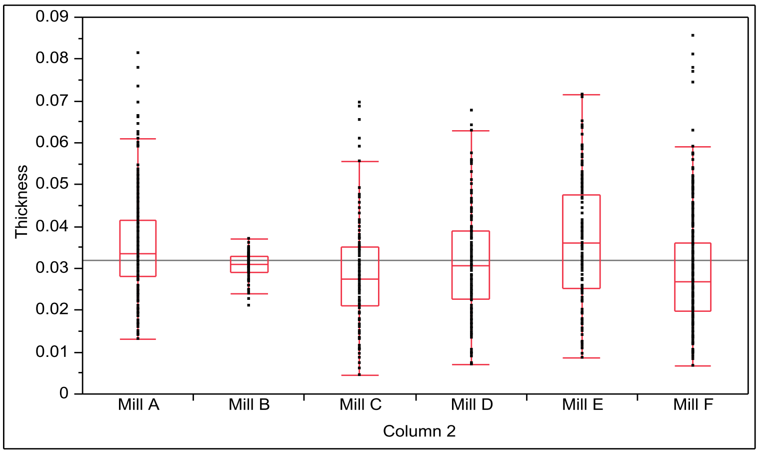

Figure 3.1. Box plots of strand thickness for all mills.
*The units of measure are in inches.

There was strong statistical evidence (p-value < .0001) from the Wilcoxon/Kruskal–Wallis one-way ANOVA that medians of strand thickness were different (Table 3.1). The median strand thicknesses of Mills E and A were statistically larger than the median strand thicknesses of Mills B, C, D and F (p-value < 0.0001). The median strand thicknesses of Mills E and A were not statistically different. The median strand thicknesses of Mills F and C were statistically smaller than the median strand thicknesses of Mills A, B, D and E (p-value < 0.0001). The median strand thicknesses of Mills E and A were not statistically different, and the median strand thicknesses of Mills D and B were not statistically different.

Table 3.1 – Wilcoxon/Kruskal-Wallis tests (rank sums) for strand thickness by mill.

Level	**Count**	**Rank Sum**	**Rank Mean**	**(Mean-Mean0)/Std0**
Mill A	299	218380	730.368	6.157
Mill B	199	123965	622.940	0.148
Mill C	139	71049	511.140	-3.793
Mill D	149	90554	607.742	-0.428
Mill E	149	109555	735.268	4.214
Mill F	303	153439	506.399	-6.337
one-way ANOVA Test, ChiSquare Approximation				
ChiSquare	DF	Prob>ChiSq		
87.6575	5	<.0001		

There was statistical evidence that the variances of strand thickness were unequal among the mills, p-value < 0.0001 (Table 3.2).

Table 3.2. Homogeneity of variances test for strand thickness for each mill.

Level	**Count**	**Std Dev**	**MeanAbsDif to Mean**	**MeanAbsDif to Median**
Mill A	299	0.0118795	0.0091709	0.0090786
Mill B	199	0.0028253	0.0022616	0.0022332
Mill C	139	0.0121688	0.0091442	0.0090683
Mill D	149	0.0119218	0.0094409	0.0094295
Mill E	149	0.0145250	0.0120004	0.0120034
Mill F	303	0.0130119	0.0098879	0.0097295

Test	**F Ratio**	**DFNum**	**DFDen**	**Prob > F**
Brown-Forsythe	36.6342	5	1232	<.0001
Levene	39.4781	5	1232	<.0001
Bartlett	79.8940	5	.	<.0001
Welch one-way ANOVA testing Means Equal, allowing Std Devs Not Equal				

F Ratio	**DFNum**	**DFDen**	**Prob > F**
15.0271	5	454.29	<.0001

4. KAPLAN-MEIER CURVES OF STRAND THICKNESS

Given the non-normal distributions of this data, the nonparametric Kaplan-Meier survival curves may offer unique insights in strand thickness within a mill, and between mills. Kaplan-Meier curves are typically used to analyze the time to failure or pressure to failure of a product; compare Meeker and Escobar (1998), Guess et al. (2006), and Wang et al. (2007). However, given the non-normal strand thickness data of this study, non-parametric Kaplan-Meier plots may offer the practitioner more defendable insight for assessing strand quality (Figure 4.1).

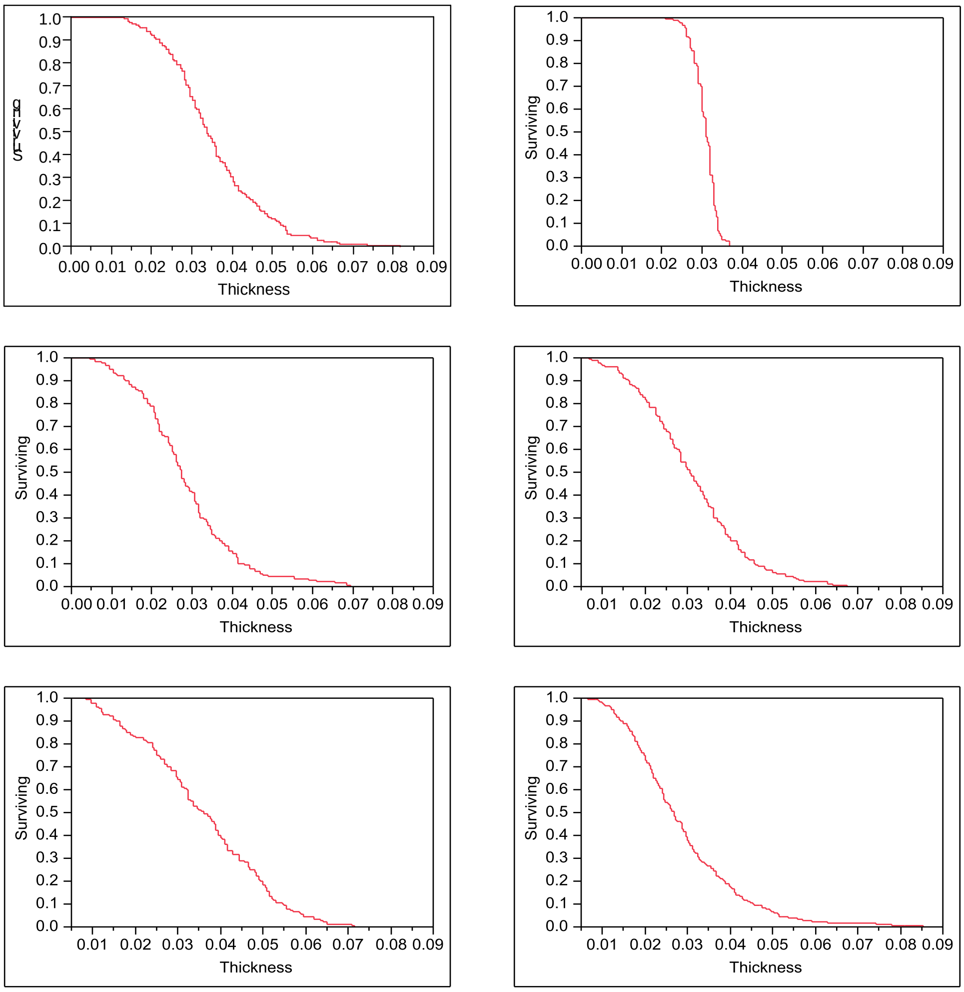

Figure 4.1. Kaplan-Meier curves of strand thickness for each mill, Mill A upper left, Mill B upper middle, Mill C upper right, Mill D lower left, Mill E lower middle, Mill F lower right.

*The units of measure on the horizontal axis's are in inches.

In Figure 4.1, the Kaplan-Meier curves graphically illustrate the probability of strand thickness equal to a target of 0.03 inches (0.762 mm). For example, in Mill A the probability that strand thickness will be 0.03 inches (0.762 mm) is approximately 0.70, where in Mill B for this same thickness the probability is approximately 0.9, and for Mill C for this same thickness the probability is approximately 0.5, i.e., mill B is more likely to attain the target thickness relative to other mills. Another useful interpretation of the

Kaplan-Meier curves for Mill A is that five percent of strands have a thickness less than 0.0185 inches (0.4699 mm) and 95 percent of strands have a thickness less than 0.0590 inches (1.4986 mm). The plot also indicates that the probability decreases at an increasing rate between strand thicknesses of 0.03 and 0.04 inches (0.762 and 1.016 mm).

An overlay of the Kaplan-Meier curves for all mills reveals unique perspectives (Figure 4.2). See Dinse et al. (1993) for survival plots for comparison among groups (Kaplan and Meier, 1958, Meeker 2008). For example, Mill B's Kaplan-Meier curve decreases the quickest illustrating that strand thickness is more consistent which may also imply better product quality control. The other five mills are somewhat similar in strand thickness but the Kaplan-Meier plots reveal that Mill E has the thickest strands relative to the other mills. The Kaplan-Meier curve is like a signature (or curve) for the whole process, which helps the mills manager better their unique signature for the whole process. The mills may want to look at the whole distribution of the thickness in managing better its randomness.

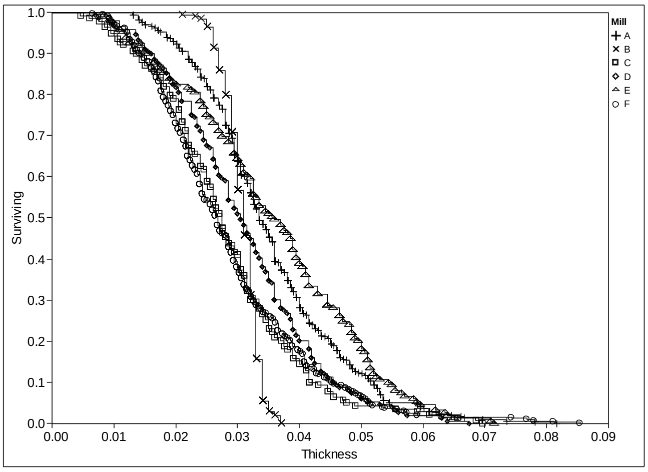

Figure 4.2. Reliability Kaplan-Meier plot of strand thickness for all mills. *The unit of measure on the horizontal axis is in inches.

5. CONCLUSIONS

Exploring the strand thickness of oriented strand board (OSB) from six Eastern U.S. mills has provided useful insight on the variability and distributions of the strand thickness data. Because OSB is commonly used in housing construction, understanding the variability of OSB strand thickness is important to manufacturers so they can reduce variation and improve the dimensional stability in the manufacturing of OSB panels. This will improve engineering capability of OSB and customer satisfaction.

The Largest Extreme Value Distribution and the Weibull Distribution were common fits to the data sets both with and without extreme outliers. Mill B clearly had the least variability in strand thickness measurements. Other manufacturers may be able to learn from Mill B and seek to reduce variability in their strand thickness.

The various extreme values in the data sets may indicate a need for more uniform strand thickness during the flaking operation which will improve log yield. As mentioned above, Mill B has the most consistent wood strand thickness. However, improvements can still be made in all mills to reduce variability. The mills generally had extreme outliers with wood strands unusually thick. Producing strands too thick may be problematic if undetected during screening, e.g., damaging expensive presses. Hence, a more reliable thickness overall will be better for both the customer and the manufacturer. It is hoped that this exploratory statistical study will provide valuable insight to the technical, operations, and management staffs of OSB mills.

ACKNOWLDEGMENTS

This research was supported by The University of Tennessee Agricultural Experiment Station McIntire-Stennis TEN00MS-89, USDA Special Wood Utilization Grants R112216-100.

REFERENCES

Argent, S.J., Bendell, A. and Manning, P.T. (1986). Proportional Hazard Modeling in the Analysis of Transmission Failure Statistics, *Euredata Conference*, 624-633.

Cox, D.R. (1972). Regression Models and Life Tables (with discussion), *Journal of Royal Statistical Society B*, **34**, 187-220.

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In B.N. Petrov and F. Csaki (eds.), *Second International Symposium on Information Theory*, Acaderniai Kiado, Budapest, 267-281.

Anonymous. (2007). Structural Board Association website at http://www.osbguide.com/. Accessed April 11, 2008.

Boyer, J.L., Shmulsky, R. and Haygreen, J.G. (2007). *Forest Products and Wood Science: An Introduction.* Fifth Ed. Blackwell Publishing, Wiley. New York.

Bozdogan, H. (2000). Akaike's information criterion and recent developments in information complexity. *J. Math. Psychol.*, **44**(1), 62-91.

Brochmann, J., Edwardson, C. and Smulsky, R. (2004). Influence of resin type and flake thickness on properties of OSB. *Forest Products Journal*, 54(3), 51-55.

Brumbaugh, J. (1960). Effect of flake dimensions on properties of particleboards. *Forest Products Journal*, **10**(5), 243-246.

Dinse, G.E., Piegorsch, W.W. and Boos, D.D. (1993). Confidence statements about the time range over which survival curves differ. *Applied Statistics*, **42**(1), 21-30.

Guess, F.M., Steele, J.C., Young, T.M. and León, R.V. (2006). Applying novel mean residual life confidence intervals. *International Journal of Reliability and Application*, **7**(2), 177-186.

Hermawan, A., Ohuchi, T., Tashima, R. and Murase, Y. (2006). Manufacture of strand board made from construction scrap wood. *Resources, Conservation and Recycling*, **50**, 415-426.

Jorgenson, R.N. and Odell, R.L. (1961). Dimensional stability of oak flakeboard as affected by particle geometry and resin spread. *Forest Products Journal*, 11(10), 463-466.

Kaplan, E. and Meier, P. (1958). Nonparametric estimation from incomplete observations. *Journal of the American Statistical Association*, **53**, 457-481.

Meeker, W.Q. (2008). Reliability course website at http://www.public.iastate.edu/~splida/. Accessed April 11, 2008.

Meeker, W.Q. and Escobar, L.A. (1998). *Statistical Methods for Reliability Data*. John Wiley & Sons, New York, NY.

Paul, W., Ohlmeyer, M., Leithoff, H., Boonstra, M.J. and Pizzi, A. (2005). Optimising the properties of OSB by a one-step heat pre-treatment process. *Holz als Roh- und Werstoff*, **64**(3), 227-234.

Post, P.W. (1961). Relationship of flake size and resin content to mechanical and dimensional properties of flakeboard. *Forest Products Journal*, **23**(8), 52-60.

Tackie, A.D., Wang, S., Bennett, R.M. and Shi, S.Q. (2008). Investigation of OSB thickness-swell based on a 3F density distribution. Part I. The finite element model. *Wood and Fiber Science*, **40**, 91-102.

Wang, Y. (2007). Reliability analysis of oriented strand board's strength with a simulation study of the median censored method for estimating of lower percentile strength. M.S. Thesis. The University of Tennessee. Knoxville. 85p.

Wang, Y., Young, T.M., Guess, F.M. and León, R.V. (2007). Exploring reliability of oriented strand board's tensile and stiffness strengths. *International Journal of Reliability and Application*, **8**(1), 113-126.