INTRODUCING WAGNER RUBBER WHEELED CHIP DOZERS

A COMPARATIVE ANALYSIS OF WOOD CHIP DAMAGE UTILISING A WAGNER RUBBER WHEELED CHIP DOZER VERSUS A TRACKED MACHINE

A Dissertation submitted in partial fulfillment

Of the requirements for the degree of

Masters of Professional Studies

At

Lincoln University

By

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2010

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EXECUTIVE SUMMARY

The research undertaken met the expectations of the author by demonstrating that use of tracked machines increased the damage of wood chip quality distribution specification.

It was clearly evident through field trials with both the Wagner CHD 24S and the CAT D8R that the rubber wheeled machine (Wagner) has less impact on wood chip damage than a tracked dozer.

The key findings are as follows:

- The average difference between a wheel dozer and tracked machine was a 1.75% increase in defects using a tracked machine
- There is less than a 1% chance of being no difference between wheeled and tracked machines. The data concluded that it was therefore highly likely to be some machine damage from tracked machines
- The over thick wood chips decreased with the wheeled machine, this is an unexpected outcome, but shows the effect of rubber wheels on large chip that breaks the chip and increasing the "accepts"
- Compaction versus "fluffing" were very notable during the field trials, one would suspect that more compaction would improve not only the storage utilization of a wood chip pile but also easy chip management when pushing and carrying with machine

Formation of a commercial view, per actual cost benefit of rubber wheeled versus tracked machine, has not been achieved. The reason is that the author has not been able to obtain accurate information on the cost or impact of wood chip quality on the pulping process. Pins and fines are either used for fuel or taken off site, or in the Kraft pulp production process, they will increase the amount of chemicals used to compensate.

There is scope to advance this current research to expand it over an entire wood chip pile as the expectation is that the damage by tracked dozers is actually understated. This statement is made based on the visual observations of the field trials conducted within this research paper.

The key point is that there is an increase in wood chip distribution specifications outside minimum and maximum parameters (damage) using tracked machines on wood chip piles.

ACKNOWLEDGMENTS

I would like to acknowledge and pass on my thanks for the support and mentoring of John Ellis, Group Technical Manager of C3 Ltd and a previous employee of Forest Research Institute where he specialized in forest mensuration[∂]. His guidance and assistance with regards to sampling techniques and statistical analysis has assisted me greatly throughout this research.

Thanks to Paul Pedersen and Pedersen Group staff (Vernon and Rob) who operate at the Kawerau site and supplied the CHD 24S Chip Dozer and Cat D8R dozer for the trials undertaken. The staff was extremely helpful and interested in the process and the results of this study.

Thanks to Alister Coulter of Wood Industry Technical Services Ltd for his help in assisting with laboratory testing of wood chip and reference material related to chip size screening.

I would also like to thank my employer C3 Ltd who sponsored me through this project and have been very supportive.

A special thanks and acknowledgement goes to Prof Chris Kissling, who has been my tutor for two course papers and my supervisor for this project. He has been a great advocate for this course and encouraging management to participate in this field of study. I appreciate his understanding of completing study combined with the workload of an employee such as myself in an executive position dealing with the day to day commercial work load, especially through the 2009 "Global financial Crisis". Throughout this project he has given me clear and constructive guidance in fulfilling the objectives of this research. Even in retirement he has committed to seeing me through this last part of the Masters degree, I thank him personally for this commitment and the assistance in my professional career.

[∂] Mensuration. The part of geometry concerned with ascertaining lengths, areas, and volumes.

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1.0 INTRODUCTION

The research project that has been undertaken was to determine the impact on woodchip quality distribution specification by a tracked dozer machine and comparing this to a rubber wheeled dozer. It has been a question raised by customers, suppliers and contractors with no confirmed answer regarding the end result – that is, what is the impact on woodchip quality? This has been a practical field test using correct statistical sampling and analysis to answer that question. The author believes that the rubber wheeled machines would have significantly less impact and not damage the wood chip as much as a tracked machine.

The structure of this report is as follows:

- Section 1 Introduction to research undertaken including aims and objectives, methodology, statistical testing and sampling trial description;
- Section 2 Literature review of previous related research on the subject including wood chip specifications;
- Section 3 Operational review of machines and capabilities;
- Section 4 Analysis of data collected during field trial;
- Section 5 Presentation of research results;
- Section 6 Observations and discussion on the research outcomes;
- Section 7 Conclusions drawn from this research;

1.1 General Introduction

Wood Chips, both hardwood and softwood, are used primarily as a raw material for technical wood processing, predominantly for pulp and paper manufacture. There are a number of other uses for wood chips other than processing such, as fuel, mulch and bio fuels.

Exporters and importers of wood chips tend to accumulate large piles of woodchips before transportation or processing. As wood chips are a commodity product, they are normally transported through break bulk shipping that enables large volumes of wood chip to be moved at a relatively low price. Alternatively, at large processing plants (pulp and paper mills) the wood chip is stored then pushed by machinery into hoppers that “feed” the processing plant.

To accumulate enough woodchip to ship or for daily processing capacity involves stockpiling large piles within the range of 50,000 – 250,000 tonnes, dependent on available site storage and operating facilities. The handling of wood chips is a process outlined as follows:

- Log(s) once harvested are transported to a chipping facility, where bark is removed by putting the log(s) through a debarker unit. Each log then goes through a wood chipper and onto a conveyor to the chip pile.
- Another form of chipping occurs in the forest, using an “in field” mobile chipper. This requires the fallen tree to be processed in the forest with the actual wood chips only being delivered to the chip pile facility. From here the truck bin is emptied into a “hopper” (bin) and then conveyed to the chip pile.
- Sawmill and processing residues are also chipped on site and again delivered to the chip facility and conveyed onto the chip pile.

Chip stockpile management is the process of moving the chip from the conveyor. The conveyor transports from an infeed hopper. The conveyor system is belt driven and will move the chip upwards so as to place the wood chip on top of the wood chip pile, where it can then be pushed by machine over the storage foot print. The same goes for loading out; the stockpile is managed by age and the oldest cargo is moved onto another conveyer via a hopper for vessel or processing plant loading requirements.

Traditional methods of moving this product is by a “tracked” dozer machine that pushes the wood chips into large stockpiles from receival at stockpile and during the loading out process. This is typically a bulldozer that has been equipped with a large chip bucket on the front so as to push the wood chip.

Allied Systems, a USA-based engineering company, have manufactured a purpose-built “Wagner” Chip dozer designed to push wood chip, utilising a rubber-wheeled base to perform this task.

The purpose of this study is to conduct a sampling project of wood chip that has been worked (run over) with a rubber wheeled chip dozer and a tracked bulldozer and then evaluate what the difference the two machines have had on wood chip quality specifications.

The research undertaken is specific to Pinus radiata softwood in New Zealand and is confined to one site, Norkse Skog mill at Kawerau.

1.2 Commercial Consideration

C3 Ltd (Author employed by C3 Ltd) is a materials handling company that operate at 14 Port sites throughout New Zealand. The company specializes in forestry handling which includes wood chip pile management. C3 Ltd is the Australasian agent for Wagner (Allied Systems) products, which includes Wood Chip Dozers.

As part of the sales initiative, the question raised by this research topic is seen as a strategic advantage commercially if there is a tangible benefit of using a specialized machine over conventional tracked machinery with regards to impact on wood chip quality. As both machines are within similar purchase price ranges, evidence of differentiation of capabilities is critical.

1.3 Aims and Objectives

The aim of this study has been to determine the impact on wood chip quality utilizing a rubber wheeled chip dozer and comparing this to a tracked bulldozer working on a radiata soft wood chip pile.

The research undertaken will provide important marketing data for the potential sales of Wagner Chip Dozers and benefit to C3 Ltd. It will also provide factual data to "Allied" Wagner factory in Portland, Oregon, USA.

The objectives of this study are as follows:

a. To research any relevant information that has compared rubber-wheeled machines versus tracked machinery in woodchip operation and to demonstrate what advantages can be derived by either type of machinery and identify any existing information that actually shows any benefit of each machine.

b. Critical analysis of research data to identify actual impact of wood chip damage and present the findings.

c. To determine the wood chip dozer suitability for chip pile management above conventional tracked machinery

d. Provide recommendations for the use of rubber wheeled machines for chip pile management

1.4 Methodology

The following methodology was applied to this research project:

1. A literature search on any relevant information related to machinery damage on wood chips. Included in the literature research relevant to the topic is information regarding wood chip quality and wood anatomy.

2. To provide statistical analysis for research undertaken involving a field trial of two machines, a CHD24S Wagner Chip Dozer and a CAT D8R Dozer, both fitted with standard chip dozer blades at Norkse Skog pulp and paper mill located at Kawerau in the Bay Of Plenty, New Zealand.

3. At the conclusion of the research phase, findings are presented and explanations given for how this research can be used in wood chip operations or what scope there is to extend this research to further gain more knowledge of improved handling of wood chip products.

1.5 Analytic Approach

A standard t-test was used to examine the significance of differences between wheel and tracked machines. That is, the Student's t distribution examined the probability of chips lying outside t standard errors.

The definition of a t-test from Wikipedia states "A ***t*-test** is any statistical hypothesis test in which the test statistic follows a Student's *t* distribution if the null hypothesis is true. It is most commonly applied when the test statistic would follow a normal distribution if the value of a scaling term in the test statistic were known. When the scaling term is unknown and is replaced by an estimate based on the data, the test statistic (under certain conditions) follows a Student's *t* distribution".

What this means and why the t-test is appropriate for this research is that the wood chip that was tested follows a "normal distribution" and the statistical analysis shows the difference between the two normal populations before and after a machine has driven over the wood chip. Reference for formulas were taken from Montgomery Douglas C (2005).

1.6 Wood Chip Sampling Methodology

Each truckload of chips delivered to a pulp mill will have a percentage of chips below the minimum size (fines and dust) and greater than the acceptable maximum size. The percentage of chips outside specification (spec) will vary within a truckload. Thus, samples taken within a truckload will show varying percentages of chips "out of spec".

To determine an appropriate sample size to perform field trials, a pilot trial was conducted to establish the variation in chip within a truckload.

From the calculated variance in chip size between samples, it is estimated that 40 samples are required to calculate a mean "out of spec value" with a confidence interval of plus or minus 1%. This figure is based on the premise that rubber-tired machines may cause as little as a 1% increase in fines.

The initial pilot sample undertaken determined the within-load variation in wood chip sizes. This was done by taking ten, 1kg samples of wood chips that were taken from a load of wood chips that was laid out over a 20m length and 3m width. The chips were collected at 2m intervals and then sent to Wood Industry Technical Services Ltd (WITS) based in Whakatane, who then reported the information back in the following categories of:

- Chips within specification
- Chips outside specification (Dust, fines, pins, and oversize)

This data provided the sample variation and allowed an estimate of samples required to detect a change of 1% in the percentage of chips outside specification.

The following graph shows the distribution of chip sizes in the pilot sample.

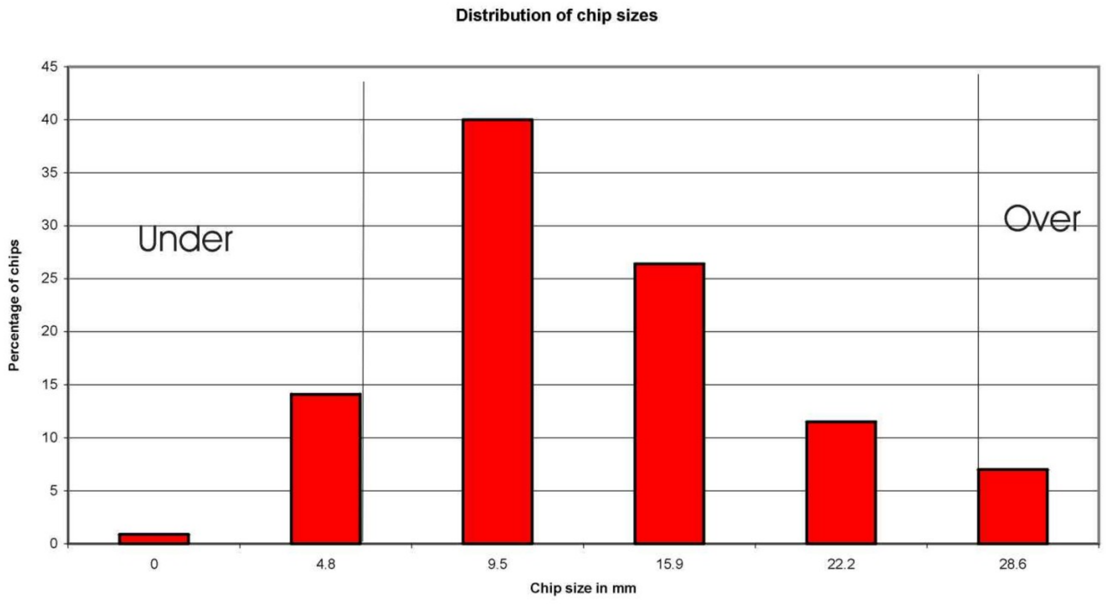

Figure 1 Pilot Sample Distribution of Chip Sizes

The research will be examining differences in wood chips within spec before and after a machine has passed over them. It is assumed that wood chips will follow a normal distribution of sizes.

The statistic we are interested in is a <u>difference of a difference</u>. i.e., (wheel_b4-wheel_after) - (track_b4-track_after). If we have N samples per machine run, the formula for a t-test of the significance of this difference is: (Snedecor and Cochran 1989)

Formula: ((mean_wheel_b4-mean_wheel_after)-(mean_track_b4-mean_track_after))/(sqrt(4*meanVar/N))

Where,

A. mean_wheel_b4 is mean %outsize chips for the run before treatment for the wheeled tractor

B. mean_wheel_after is mean %outsize chips for the run after treatment for the wheeled tractor

C. mean_track_b4 is mean %outsize chips for the run before treatment for the tracked tractor

D. mean_track_b4 is mean %outsize chips for the run after treatment for the tracked tractor

E. N is the number of samples per run

F. meanVar is the mean variance of the four runs - i.e. calculate the variance of each run and average across the 4 runs

G. t is t-statistic with degrees of freedom 4*N-4

1.6.1 Field Trial

The sample collection process was based on laying out two individual loads of wood chip on a flat piece of ground. Two truckloads from Rotorua Sawmill (Claymark) were chosen as the sample loads at Norkse Skog mill. This was because the wood chip was from the same source.

The reason why the load is laid out on the pad is so that there is no other intervention with any items of plant. This allows the rubber wheeled machine and tracked dozer to be compared against the same sample and therefore to calculate accurately the difference of impact on the wood chip by the two handling techniques. The process undertaken is as follows;

1. Wood chip load laid out over 20m pad x 4m width
2. The minimum amount of chip that could be tested was in 5 kg samples
3. To collect 40 samples at different locations over the sample load, batch sampling of 5 x 1kg samples were taken.
4. The samples were collected by placing eight string lines across the sample load, each string line had five markers where to collect the 1kg sample. (See Figure 2 – Grid sample collection).

   A random number generator was used and applied to the sample collected (refer Appendix 1 – Random sample numbers used for each sample).

   The following sample codes were used as follows:

- CW (Untouched before wheel loader)
- CT (Untouched before Tracked machine)
- W (After Wheel loader had been over chip)
- T (After Tracked machine had been over chip)

1	6	11	16	21	26	31	36
2	7	12	17	22	27	32	37
3	8	13	18	23	28	33	38
4	9	14	19	24	29	34	39
5	10	15	20	25	30	35	40

Figure 2 Grid Sample Selection for collecting wood chip

Grid line with “knot” as marker to collect sample.

Figure 3 – Photo showing Grid line for sampling

5. For each of the four sample classes undertaken there were 8 x 5kg bags (each bag contained 5 x 1kg random samples). At each sample point, chips were extracted from a cylindrical hole of 150mm in diameter and about 120mm in depth. The samples were sent to Wood Industry Technical Services Ltd (WITS) to confirm chip size distribution for each sample including dust and bark.

6. The two loads were sampled prior to the wheeled loader or dozer running over each separate pile.

7. The wheel loader then made six return passes over the laid out load before redoing the grid layout again to take samples.

8. The same process was performed for the tracked D8 Dozer on the "track" sample pile

9. Statistical analysis of data will form the main content of this research project and the findings presented.

2.0 LITERATURE REVIEW

An extensive review of literature associated with all woodchip handling was conducted to gain knowledge of previous research undertaken that is relevant to this topic.

2.1 Related Research to Topic

A thorough web search found no published information about woodchip damage related to machinery impact.

Allied Systems Ltd in the USA were approached for any material to which they had access over the many years that the chip dozer manufacture has taken place in the USA. A paper (unpublished) on Chip Pile Storage Deterioration – Particle size reduction, by Bill Fuller (1990), Forest to Product Consultant, was presented to Matt Richarz, Weyerhaeuser, tabling information and proposing research along the lines of research undertaken in this project.

The question Fuller raised was “what is the difference in chip size deterioration between rubber tyre (Wagner) and tracked (Caterpillar – type) chip movers?”

Observations in this paper were:

- Tracked plant running over wood chip, that the sheer force caused damage.

Fuller also makes references to rubber wheeled chip dozer’s capabilities as follows:

- Less contamination from one pile to another
- Less damage to asphalt bases (where chip is stored)
- Potential for less chip damage

These comments on the machine’s application and versatility, being rubber wheeled, relates to the maneuverability of this product on and around a chip pile.

The paper also presents data published in Pulp and Paper Technology Series – No 5. The table clearly indicates increase in wood chip degradation (damage) but there is no supporting documentation on the methodology used or how the sample was taken.

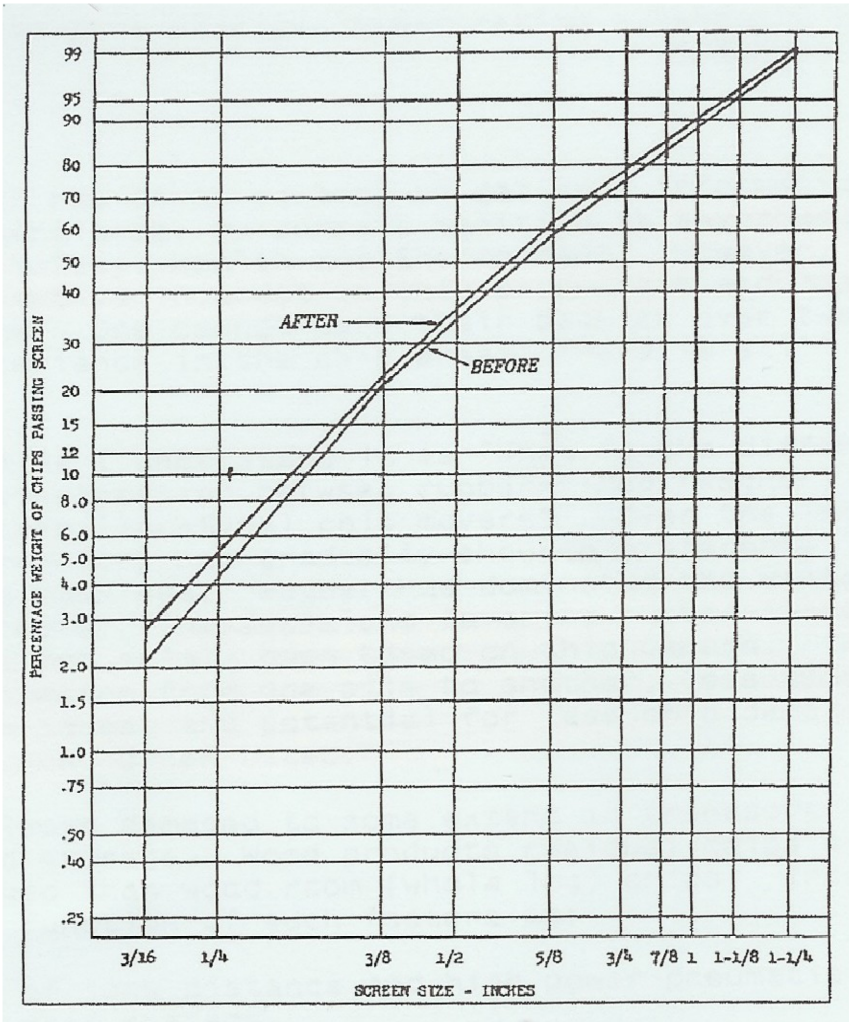

Figure 4 Chip degradation caused by running bulldozer over chip pile

Pulp and Paper Technology Series – No 5 (1979) Published by the joint textbook committee of the Pulp and Paper Industry

This table demonstrates clearly the impact of machines working on wood chip pile. The information tabled in this paper was to generate interest for funding of research to "develop direct data on fines generation from tracked vs. rubber tired vehicles".

No further research was conducted on Fuller's project.

However it is important to note that Fuller was an advocate by observation of rubber wheeled machines. He claimed that they did less damage than conventional tracked dozers.

2.2 Outside storage of Wood Chips

Haas and Kalish (1975) published a paper on Transport and Handling in the Pulp and Paper Industry. They identified problems with conventional chip handling systems. They noted that most existing systems for managing wood chip,   require bulldozers to reclaim wood chip while operating on woodchip piles. They state that ‘a considerable amount of chip damage normally occurs”. However, they made some interesting points.

1. That wood chips are reclaimed on a last-in first-out basis
2. That due to time frames in storage this led to “excessive biological deterioration” that, with the impact of the tracked dozer, caused more damage to the wood chip.

Their paper was highlighting the impact in conventional wood chip handling and that they were advocating more automation to stop increase handling of wood chip.

Both points are correct in context; however, the countermeasure to this is effective stock pile management, with correct stock turnover for shipping or processing plant and knowing the limitation of wood chip “life” in the condition that the chip pile is being managed. This refers to seasonal conditions, hot and cold, also and more importantly the amount of rain or wind that can affect the pile.

George J. Hajny’s (1966) study of “Outside Storage of Pulpwood Chips” focused on the quality and deterioration of wood chips through the process to final pulping. He compared “the quality of stored woodchips in comparison to pulpwood storage”. This means keeping logs in round wood form versus chips and residues (woodchips from mills).

In reviewing deterioration of pulpwood during storage some key points were identified as follows:

- Species
- Age of wood (from when cut)
- Removal of Bark
- Length of storage
- Method of piling

•

The method of piling is important as this is where the chip dozers / tracked dozers manage the wood chip pile. Hajny (1966 p.100) made the following statement "Compaction of chips is an important factor in pile building, since chips in the uncompacted portions of the pile deteriorate at a much faster rate than in the compacted areas of the pile

This is important as what Hajny is making reference to is that poorly constructed or managed chip piles result in wood chips deteriorating faster. The reason this happens is due to exposure to moisture, oxygen, decay organisms, fluctuating heat (cold and hot) and length of time the woodchips have been sitting in the pile. Hajny refers to references throughout his paper that concurs with this statement.

The utilisation of correct machinery with when operating on wood chip piles not only reduces damage but also assists in compaction and maintaining the quality of the wood chip. The wood chip is not as exposed to same level of moisture, oxygen and heat within the pile remains fairly constant. As noted by Hajny (1966 p99) "temperature studies on piles of southern pine chips show a remarkable degree of uniformity".

Comparing wood chip damage rubber wheeled versus tracked dozers is also part of the wood chip quality process during the handling phase of chip pile management.

Butcher and Howard's (1962) study of "Outside Storage of Pinus radiata Wood Chips in New Zealand" again focused on "pulp quality through biological deterioration of wood chips". The research was to determine if it was feasible to store radiata woodchips for six months in New Zealand. This was carried out at the Kawerau pulp mill (Tasman Pulp and Paper).

The main areas of research focused on the decay and amount of stain / fungi as chips became older. The important information relevant to research undertaken in this paper is that radiata wood chips do deteriorate rapidly and that they should, ideally, be used within three months. It is therefore imperative to use the best type of machinery in wood chip pile management to minimise this process of deterioration.

In a presentation by John "Rusty" Dramm (2000) on "Is it time to Revisit the Log Sort Yard" he makes reference to "Material handling Concepts".

Dramm noted research carried out by Sinclair and Wellburn (1984) show the following principles of material handling as follows:

- Reduce or eliminate unnecessary movements and combined movements

- Increase the size and weight of quantity of material moved where possible
- Select equipment to match all aspects of material and flow in the system
- Maximize the load and minimize the distance on high intensity moves

Although they were discussing moving logs within yards, it is the same concept for managing a chip pile. Any unnecessary movement, particularly by tracked dozers, causes more potential damage of wood chips. If a dozer can work at maximum capacity when pushing wood chip then there is not the requirement for additional handling of product. This really depends on the amount of traction available to both the rubber wheeled dozers and tracked dozers. The objective of this research paper was to identify which machine type has less impact on the wood chip and again with reference to the materials handling concepts "select equipment to match all aspects of material".

2.3 Wood Chip Quality

This section is to explain about specifications and quality.

The Canadian Standards Authority publication "Scaling Round wood / Measurement of Woodchips, Tree Residues, and By Products (2000) makes reference to "Classification as to Size and Form" of wood chips.

What they state is "Woodchips may be classified according to their dimensions and according to forms such as slivers, oversize, accepts, shorts, pins, fragments and fines"

This is done by using sieves that can then determine what actual size the wood chips are and from the sample taken apply this to the overall stockpile.

Export specifications do vary between countries and the method applied for this research project, SCAN-CM 40:94 is described in section 2.4.

2.3.1 Impact of alternative Chipping operations

Wood Chip quality can be affected by the different type of "chipper" used to produce chip. I am comparing an in field operation to an onsite chipper.

In field chippers are mobile and operate within the harvesting area. Chipping fresh logs saves transport and associated unloading costs when chips can be taken from the harvesting site directly to mill or Pport. Quality issues can arise through the knives not cutting efficiently., This is mitigated by truck load sampling of loads to ensure they are meeting the required specification of export or mill size wood chip. The benefits of an infield chipper are:

- Lowers cost of transporting product
- Lower capital cost of plant for chipping

An onsite chipper is normally based at a processing plant or export facility. This type of facility is large and capable of high tonnage throughput. Being on site allows:

- Better quality control
- Consistent chipping of large volume

2.3.2 Measurement and Conversion of Wood Chips

Jones (2005) discusses wood properties of commercial tree species. An important element of commercial plantations is wood density and is described by Jones as follows:

1. Basic Density – oven Dry weight of wood divided by under-bark volume when green
2. Air-Dry density – weight of wood divided by under-bark volume at 12% moisture content
3. Green Density – weight of wood divided by under-bark volume, both being measured on freshly felled timber.

The wood Density of Pinus radiata is as follows:

Species	Density (kg/m3)		
	Basic	Air-Dry	Green
Pine, radiata (Softwood)	420	500	960
Tawa (NZ Native Hardwood)	580	720	1080
Rimu (NZ Native Softwood)	490	600	960

Table 1 Wood Density of New Zealand Timber

The following table comes from the publication of Ellis and Lloyd (2005) which shows the conversion of wood chips to unit of product.

Wood Chips	Unit of Product	Roundwood equivalent (m3)
Radiata pine sawmill chip*	BDU	2.7
Radiata pine sawmill chip	BDMT	2.5
Radiata pine mature whole log chip	BDU	2.9
Radiata pine mature whole log chip	BDMT	2.7

Table 2 Wood Chip Measurement

*Bone dry unit (BDU) equates to 2400 Pounds (1089 kg) of oven-dry matter, and is the unit commonly used for export chips. The Bone dry metric tonne (BDMT) is 1000kg of oven-dry chips. Both BDU and BDMT are derived from the (sampled) ratio of oven-dry chip to green chip.

The point from this is that wood density determines strength and the ability of the "strength" to manage impact of machines. Lower density wood chip is more prone to damage.

2.4 Wood Chip Specifications

A key part of the research was to test the wood chip before and after tracked and wheeled machine use. The standard used to measure wood chip size distribution is the SCAN-test Standard *SCAN-CM 40:94*. (1994) Wood Chips for Pulp Production – Size Distribution.

This is a European measure developed by the Scandinavian Pulp, Paper and Board testing committee, with the current standard revised in 1994. It is standard practice to sample and analyse wood chip quality to ensure an appropriate pulp grade chip is being delivered to the site.

Anders Bjurulf (2006), explained, that since 1985 there have been eleven standards published (concerning chips, author's addition):

1. SCAN-CM 39:94: Dry matter content
2. SCAN-CM 40:94: Size distribution (later replaced by 40:01, author's addition)
3. SCAN-CM 41:94: Sampling
4. SCAN-CM 42:95: Bark content
5. SCAN-CM 43:95: Basic density

6. SCAN-CM 46:92: Bulk density
7. SCAN-CM 47:92: Thickness and thickness distribution
8. SCAN-CM 48:92: Length and length distribution (also applicable to width)
9. SCAN-CM 50:94: Determination of acetone-soluble matter (later replaced by 49:03, author's addition)
10. SCAN-CM 53:94: Wood content in the bark fraction
11. SCAN-CM 59:96: Brightness

The Scandinavian standard is applied to mills in New Zealand.

The SCAN - CM 40:94 describes the following:

- Size Distribution - "the content of chips in different classes, grouped according to size and shape"

- Size Classification -"A procedure for separating, by means of screens, a sample of wood chips into fractions according to size and shape"

- Chip Classifier - " Apparatus for chip size classification"

The standard then describes the size definitions as follows:

- Oversize chips - " Chips that do not pass the first screen of the classifier when chip size classification is performed as specified in this standard

- Over thick chips - "Chips that do not pass the first screen of the classifier , but are retained on the second screen, when chip size classification is performed as specified in this standard."

- Accept Chips - "Chips that pass the two top screens of the classifier, but are retained on the third screen, when chip size classification is carried out as specified in this standard"

- Pin Chips - "Chips that pass the three top screens of the classifier, but are retained on the fourth screen, when chip size classification is carried out as specified in this standard"

- Fines - "Chips that pass all four screens of the classifier when chip size classification is carried out as specified in this standard"

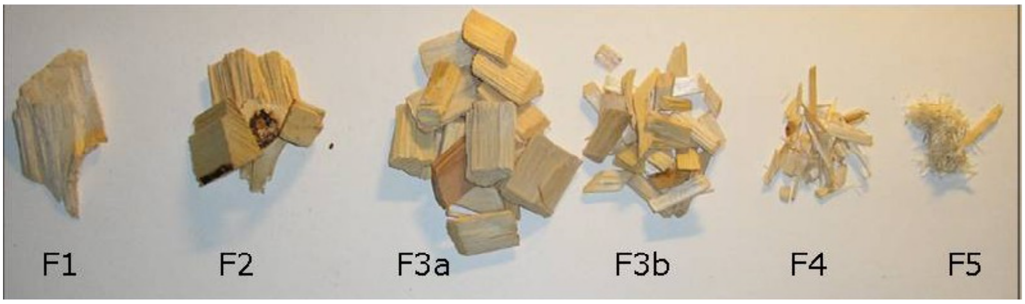

Figure 5 - The resulting classes of SCAN-CM 40 classifying.

The photo above taken from Bjurulf's thesis paper shows clearly the chip grades, his grading is summarised as follows;

- F1 - Oversize Chips
- F2 - Over thick Chips
- F3a - Accept Chips
- F3b - Accept Chips
- F4 - Pin Chips
- F5 - Fines

The wood chips used in this research were independently tested by Alister Coulter, from Wood Technical Services Ltd based in Whakatane, New Zealand. This facility applied the correct application of testing chip size distribution to SCAN- CM 40:94.

The test principle as explained under the SCAN-CM 40:94 is as follows: " A test sample of chips is placed on the top screen of a stack of four screen trays. The screens have holes or slots of specified dimensions and the stack is kept in a reciprocating motion. After a specified time the screening is stopped and the five fractions obtained are weighed separately. The size of each fraction is its mass, expressed as a percentage of the total mass of all five fractions".

Wood Technical Services describe the size distributions as follows:

- Over Thick
- Over Longs

- Accepts
- Pins
- Fines
- Bark

It is noted that bark has been added.

The correct size distribution testing has been an important part of this research as it gives a recognized testing methodology that could then compare both samples of the research undertaken.

2.5 Conclusion

The literature review highlighted that although commentary has been made about machine damage on wood chip, apparently there is no research undertaken on the particular subject of this dissertation.

3.0 OPERATIONAL OVERVIEW OF MACHINES AND CAPABILITIES

The two machines used for this research were:

- A CAT D8R Tracked Dozer and;
- A Wagner CHD 24S Chip Dozer

Figure 6 - Cat D8R and Wagner CHD 24S

Both items are configured to operate on a wood chip pile.

3.1 CAT D8R

The D8R Dozer

Advantages:

- The pushing ability – that is how much wood chip it can move per run, the bucket has a large capacity
- Its ability to work on very steep terrain – which is important as most mills and Port operations are constrained by space
- Operating efficiency – Proven manufacturer with worldwide back up service for parts and support and track record of a very reliable operating machine
- Stockpile management

Disadvantages:

- Noise – from track “clanging” especially when going backwards down the pile. This is an issue at Port operations that work under stringent noise operating constraints
- Speed – Slower compared with a Chip Dozer

3.2 Wagner CHD 24S Chip Dozer

The Wagner Chip dozer is a specialized machine that has been custom built to operate on wood chip piles.

Advantages:

- The “carry and Doze” concept effectively doubles production over a straight blade machine
- Its speed and versatility – “Double oscillating chassis with center hinge bearing”
- Operating efficiency – cost and productivity
- Chip “bucket dumps 4m ahead of axle for maximum safety”
- Stockpile management

Disadvantages:

- The requirement for skilled specialised operators
- Maximum perceived operating slope of 40 degrees
- Built to order (Do not buy off the shelf)

3.3 Machine Specifications

The following table shows a comparison of specifications between each machine.

	CAT D8R	WAGNER CHD 24S
Weight*	37.5 Tonnes	36.1 Tonnes
Horse Power	305	450
Cost (NZD)	$ 800,000.00	$ 800,000.00
This is without Bucket		

Table 3 Machine Specification Comparison

This shows that the machines have nearly the same weight and are similar in cost to purchase. The author notes that he could not get accurate operating costs per hour for both these machines and therefore has left the operating cost comparison out of this paper.

3.4 Overview of Machines

When reviewing the specifications there is no reference from both companies regarding impact on wood chip.

The author of this research sees it to be very important to highlight a competitive advantage which can be used in a successful marketing strategy in the wood chip handling field of operation.

3.5 New Zealand Environment

Wood Chip handling, either at manufacturing sites or at Ports has to comply with environmental considerations that are becoming more relevant within the business operations.

The Resource Management Act 1991 www.legislation.govt.nz – is powerful legislation that allows for consultation over any land use, or change to land use type. Not only can it take a long time and cost a lot of money to establish the “rules” for land use, but there is much environmentally related compliance associated with this legislation.

Due to many processing plants and port facilities close to residential establishment noise is the major issue and is now highly monitored in New Zealand operations.

At the new port facility at Marsden Point (New Zealand North Island), the export chip pile had to use a rubber-wheeled machine as part of the license to operate to mitigate the noise generated by a track dozer working during the night.

This was not the actual noise of the engine but the “clanking noise” of tracks moving up and particularly moving down a chip pile.

It is on that note that it is important to recognize any benefit of the rubber wheeled machine with regards to noise reduction but also the value of less damage to the product (Wood chips) means that the machine maybe better suited to the New Zealand operational environment.

4.0 DATA ANALYSIS

This section of the report analyzes the data that has been collected from the chip samples during field trials as described in the methodology (Section 1.6.1). It shows the impact on wood chip from each machine and then leads to the next section , that is presentation of the data and what it means in concluding the research findings.

Data from samples collected were sent to Wood Industry Technical Services (Whakatane) for analysis and results are given in Appendix 2.

4.1 Summary of Results

The following table summarizes the change in out-of-specification wood chip after both wheel and tracked machine had run over the sample loads.

Percentage of Out Of Specification of Wood Chip					
Sample	**Wheel Machine Before Running Over Chip as %**	**Wheel Machine After Chip had been run over as %**	**Tracked Machine Before Running Over Chip as %**	**Wheel Machine After Chip had been run over as %**	**Pooled Variance**
1	9.3	9.7	8.7	9.5	
2	11.3	8.1	8.4	10.1	
3	9.7	6.9	8.9	9.7	
4	10.0	9.9	10.5	9.5	
5	9.6	10.10	9.0	9.8	
6	9.5	9.5	8.2	10	
7	9.8	9	8.2	9.9	
8	9.8	9.8	8.3	9.7	
Variance (%)	0.38	1.21	0.58	0.05	0.555
Mean (%)	9.88	9.13	8.77	9.77	
diff of diff (%)	1.75				
t-test (%)	3.32		(n-1)*4df	28	
		sig at .00249 (1%) level			

Table 4 Data Analysis – Percentage of Out Of Specification Wood Chip

Figure 7 shows the percentage of defect wood chip difference between wheel vs. track machine by each sample

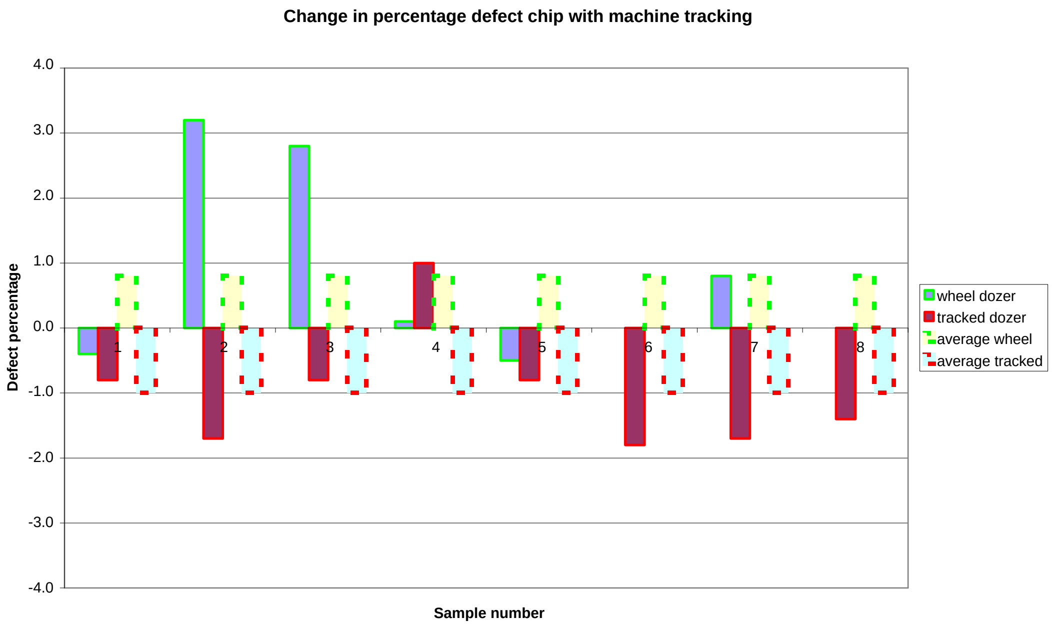

Figure 7 Change in percentage defect chip for both wheel and track machines

Figure 8 shows the change in out of specification wood chip by machine by classification definition across all trials.

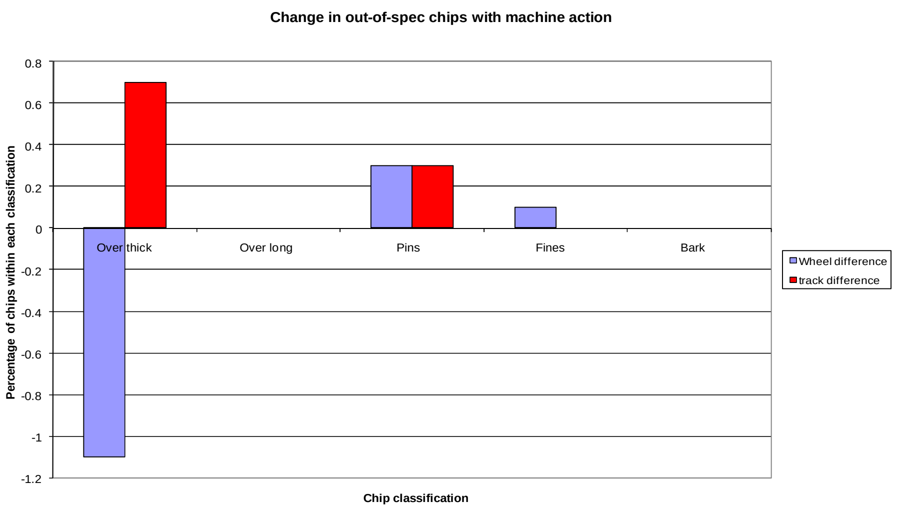

Figure 8 Change in Out Of Specification Wood chips by classification

4.2 Statistical Analysis

The following discussion explains the significance of the data in section 4.1. Key points are:

The average difference between wheel dozer and tracked machine was a **1.75% increase in defects using a tracked machine**.

Using the t-test statistic the difference is **significant at the 99% probability level**; therefore, the null hypothesis is rejected.

Table 4 data showed that the impact of the wheeled dozer on wood chip, decreased the "over thick" percentage section whereas the tracked increased the "over thick' percentage.

Table 5, below, shows the overall scores, with regards to SCAN-CM 40:94 testing showing that the wheeled machine has no impact on the overall score rating of this classification sampling. (Refer Appendix 2 – Data analysis)

Wood Chip Score % In Specification From All samples Taken	
	Sample Score
CW (Before run over)	100 %
W (After run over)	100 %
TW (Before run over)	99 %
T (After run over)	96 %

Table 5 Wood Chip Score percentage in specification from all samples collected

5.0 PRESENTATION OF RESEARCH RESULTS

From the data analysis, this section explains in detail the findings of research undertaken.

5.1 Wood Chip

It is important to note that both samples of wood chip were from the same source, Rotorua Sawmills, as stated in the methodology section. However the wood chip sample for wheeled dozer had a higher percentage of defect chips at 90.1% accepts" (As per table - Appendix 2) than the tracked sample which was at 91.2% "accepts". (As per table -Appendix 2)

The proportion in "Pins" for both samples increased by 0.3% with both machines running over each spread out chip load. What this means is for the impact on "Pins" there was no difference.

The major difference occurred with the "over thick" percentage sample. The sample for wheeled dozer showed prior to running over by machine there were 7.2% of the total sample. However after the chip was run over by the wheeled dozer this reduced to 6.1%. In comparison the tracked machine sample started at 5.5% 'over thick" and this increased to 6.2 % (Refer Appendix 2).

Why this occurred is a challenging question. It is apparent that the wheeled dozer when rolling over the oversize wood chip applied pressure that "broke" down the over thick wood chip into another field definition that improved the overall specification. Contrastingly the track dozer "fluffs' the chip (Refer figure 9) which "stretches the fiber and thus prevents it falling through the sorting sieves and therefore increased the percentage of "over thick" specification.

Figure 9 Track Dozer "fluffed" chip after machine had run over wood chip

The wheeled dozer was the opposite to the track dozer in the fact that this machine compacted the wood chip (Refer Figure 5) and the data highlighted a reduction in over thick specification.

Figure 10 - Compaction of wood chip after wheeled dozer had run over wood chip

5.2 Statistical Explanation

The data of the initial sample loads showed that the original distribution of chip was different for both loads, even though it came from same source.

This confirmed that the “difference of a difference” test was the correct methodology to apply to the research undertaken.

The test statistic for a normal t-test is the difference between two means divided by the variation / variability. For the trials undertaken the test statistic was a comparison between the two differences before machine impact and after machine impact divided by the pooled variance. (Pool variance is the average variability over all samples)

What the difference of a difference test demonstrated was that it compared both samples after machinery impact on wood chips. The key points of this test are as follows:

- The wheeled dozer showed a 1.75% increase in wood chip "within specification when compared with the tracked bulldozer
- The difference in chip rejects using tracked machines increased

As stated there is a 99% probability that when using tracked machinery there will be impact (rejects) on wood chip quality. At this significance level, it is not a chance finding, it clearly demonstrates that tracked machines have a greater probability of damaging wood chip.

6.0 OBSERVATIONS AND DISCUSSION

Throughout the field trial and analysis of the data, the question that is raised is how this research applies to the entire wood chip pile. The reasoning behind this question is that the trials were controlled and statistically correct, but applied on flat ground, on a hard surface beneath the chip and on one species of wood chip (Pinus radiata).

6.1 Observations

Observations during field trials are as follows:

The tests applied to one species only, Pinus radiata, which has a low density compared to hard wood chip. Throughout the world, hard wood chip species are still used extensively. The research has not differentiated between species.

The Pinus radiata wood chip sampled was “fresh”. It had a moisture content of 57% so effectively this was ‘wet” chip and the question raised is what would be the impact of damage on wood chip with lower moisture content and or old wood chip. The literature review clearly identified ‘biological deterioration” that manifests in the chip becoming brittle. The observation made during trials would suggest that more damage with older chip would occur with either vehicle type.

Operating a chip pile involves moving the wood chip numerous times to maximize use of the storage space. This can often mean the taller the pile the better. What this means is that the machines are often pushing / carrying wood chip on steep inclines and, obviously, there is a higher degree of traction required under torque power to move wood chip. Whereas the trial that was undertaken was on flat ground with no requirement to “push or carry”, the author suspects that under more power and the increased traction required it would lead to an increase in wood chip damage. The question is how would one compare the wheeled versus track machines during this part of the wood pile management. Observations made during trials showed that the wheeled dozer actually compacted the wood chip and it appeared that fact would make it easier to run over and push / carry wood chip. The tracked dozer with its “light” foot print (that is, a lower pressure per square meter of operating) “fluffs” the chip which under load and increased traction would lead one to believe more damage would occur to the wood chip.

While operating a wood chip pile, there are normally tracks created to push and carry the wood chip so as to maximize storage use and have the ability to productively feed the "hopper" during load out. Additional to these tracks are the "Side slope" requirements of operating the machines. Again one would suspect that the side working on a pile would cause the machine to have weight on one side and actually create a sliding impact on wood chip.

Another observation that was apparent during research was the benefit of a wheeled loader to wood chip quality and compaction.

Wheeled dozers have a distinct operating advantage working on hard stand sites in that they are able to run over hard seal (asphalt / concrete) without damage. In contrast bulldozer tracks have "cleats" and this can damage the hard seal. Wheeled dozers can run off a chip pile and operate on the edge of hard stand ensuring all wood chips are processed. Bulldozers normally operate on a "bed" of old wood chips so as to ensure no damage to hard seal. If the chip pile is not on hard stand, both machines can operate without any issues.

6.2 Discussion

The research that has been undertaken has met the initial hypothesis that tracked machines do have a greater impact on wood chip quality comparing to wheeled dozers.

The following points fall outside the scope of this research project, but are key areas that would require significant investment and time to conduct appropriately full research on wood chip damage.

The main challenge is how to extrapolate the data over an entire working chip pile to quantify accurately damage on wood chip over the entire population. Normal sampling of wood chip is conducted either before entering the mill or during loading of a vessel. This involves taking random samples. The question raised for discussion is whether this sampling is appropriate compared with the sample technique used in to this research.

In Sections 2.2 and 6.1, it has been discussed how the impact of age of wood chip, moisture content, chip pile compaction as variables that will effect wood chip quality. I believe that the research undertaken actually has underestimated the damage on wood chip over the entire process of arrival to end use of the wood chip product. The reason for this statement is that the wood chip used in the testing trials was "fresh" from the sawmill. It is feasible that as wood chip deteriorates that the wood chips are more prone to machine damage as the cell structure (density) reduces due to the elements discussed.

A question that has not been answered is the actual impact on wood chip quality. It is outside the scope of this research but two questions are raised: What is the financial impact for each percentage drop in wood chip quality and what is the overriding effect of wood chip quality to a mill? The author has not been able to find any relevant information that can be used to show the financial impact related to a reduction in wood chip quality. However, the author does believe there are benefits, but would need to gain a greater understanding of the entire pulp process to come to be able to reinforce this conclusion.

It was explained, through personal communications with an ex-employee, that the pulp process is like cooking “potatoes”: if they are all small (wood chip specification) and the same size it is efficient, if you add large “potatoes” (wood chip) and mix with the small wood chip it takes longer to process which equates to more cost. This example explains in a simple manner the pulp process and the effect different size wood chip has on the pulping process.

It has become apparent when discussing with machine operators of wheeled dozers that they believe there is improved storage, due to compaction of wood chip by machine and that there is less detrimental impact on wood chip quality. This research project certainly supports those claims.

7.0 CONCLUSION

The research undertaken was to determine if there was a difference in wood quality specification (distribution) after being handled by a wheeled dozer machine and comparing this to a tracked dozer machine. The author expected that there would be a difference based on observations of seeing both machines in operation and the difference in rubber wheeled impact with regards to compaction versus the tracked nature of fluffing chip.

The literature review mentioned the impact of machines on wood chip and the way chip piles are managed as having a possible impact on wood chip quality. However there was no actual documented research available to this author.

The research that was undertaken was based on a sound statistical methodology and a correct data sampling technique conducted during field trials.

Using the SCAN 40:94 size distribution sample method, the results from data collected, before and after machine impact were then analyzed.

The key findings confirmed the intent of this research and are as follows:

- The average difference between a wheel dozer and tracked machine was a 1.75% increase in defects using a tracked machine
- There is less than a 1% chance of there being no difference between wheeled and tracked machines. The data concluded that it was therefore highly likely to be some machine damage from tracked machines
- The over-thick wood chips decreased with the wheeled machine, this is an unexpected outcome, but shows the effect of rubber wheels on large chip that breaks the chip thereby increasing the "accepts"
- Compaction versus "fluffing" were very notable during the field trials, one would suspect that more compaction would improve not only the storage utilization of a wood chip pile but also easier chip management when pushing and carrying with machine

The logical next step from this research would be to extrapolate the findings of this research over the entire chip pile. It does raise legitimate questions on how this would be done with regards to slope, how many times chip would be run over, age of wood chip and other variables related to wood chip storage and management. Also the financial impact to a mill / processing operation for wood chip quality distribution has not been analyzed as that stands outside the scope of this research paper. But once a wood chip damage percentage can be extrapolated with confidence over the entire pile then the financial model could be added.

The author believes that the field trials demonstrate that over an entire wood chip pile it would under estimate actual wood chip damage of a tracked machine due to the following variables.

- Wood chip deterioration
- Running machinery on the slopes of the wood chip piles that require more engine power to maintain traction. This additional traction would increase the likelihood of more wood chip damage
- When loading wood chip out there are multiple passes with machines while pushing and carrying wood chip that would increase the amount of damage to wood chip

The research undertaken has met the author's expectations and proved statistically through field trials and laboratory analysis that tracked machines increase damage to wood chip quality size specification.

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9.0 APPENDICES

Appendix 1

Random Number generator for the following samples:

1) CW (Untouched before wheel loader)

5,12,14,29,20 23,21,24,2,30 27,26,17,33,10 9,11,25,38,13 4,34,37,3,19 18,40,6,36,32 31,39,16,1,8 35,7,22,15,28

2) CT (Untouched before Tracked machine)

40,27,34,8,29 20,2,30,35,23 13,7,33,37,17 14,4,39,22,11 10,28,19,3,38 18,36,31,12,15 9,25,26,24,6 21,16,5,32,1

3) W (After Wheel loader had been over chip)

5,36,15,34,4 23,33,8,21,30 17,37,31,26,35 9,14,32,2,39 38,12,18,6,10 22,20, 27,16,11 1,28,24,7,25 3,40,13,19,29

4) T (After Tracked machine had been over chip)

36,4,38,40,16 32,24,5,17,2 15,6,29,10,21 11,16,37,33,9 35,20,19,7,30 3,1,14,22,13 12,25,18,8,23 27,28,34,31,39

1. CW (Untouched before wheel loader)
2. CT (Untouched before Tracked machine)
3. W (After Wheel loader had been over chip)
4. T (After Tracked machine had been over chip)

Appendix 2

The following data shows the results from Wood Technical Services after SCAN 40:94 size distribution.

CHIP SAMPLING ANALYSIS

								Classification						Chip Score			
Date	Time	Shift	Knives	Collector	Grade	OverThicks	OverLongs	Pins	Fines	Bark	Accepts	OverThicks	OverLongs	Pins	Fines	Bark	Total
						Max 12%	*Max 0.5%*	*Max 3.0%*	*Max 0.4%*	*Max 0.4%*	*Min 84.1%*	*20*	*15*	*25*	*20*	*20*	*100*
21-04-2010					CW1	6.3	0.3	2.6	0.1	0.1	90.7	20	15	25	20	20	100
21-04-2010					CW2	8.6	0.0	2.5	0.1	0.2	88.7	20	15	25	20	20	100
21-04-2010					CW3	7.1	0.0	2.5	0.1	0.2	90.3	20	15	25	20	20	100
21-04-2010					CW4	7.6	0.0	2.3	0.1	0.2	90.0	20	15	25	20	20	100
21-04-2010					CW5	6.8	0.3	2.5	0.1	0.2	90.4	20	15	25	20	20	100
21-04-2010					CW6	6.7	0.0	2.7	0.1	0.2	90.5	20	15	25	20	20	100
21-04-2010					CW7	7.2	0.0	2.5	0.1	0.1	90.2	20	15	25	20	20	100
21-04-2010					CW8	7.0	0.3	2.4	0.1	0.1	90.2	20	15	25	20	20	100
						7.2	**0.1**	**2.5**	**0.1**	**0.2**	**90.1**	**20**	**15**	**25**	**20**	**20**	**100**
21-04-2010					W1	6.7	0.0	2.8	0.2	0.2	90.3	20	15	25	20	20	100
21-04-2010					W2	5.0	0.0	2.9	0.2	0.2	91.9	20	15	25	20	20	100
21-04-2010					W3	3.8	0.0	3.0	0.2	0.2	93.1	20	15	25	20	20	100
21-04-2010					W4	6.7	0.2	2.9	0.2	0.1	90.1	20	15	25	20	20	100
21-04-2010					W5	7.1	0.2	2.6	0.2	0.1	89.9	20	15	25	20	20	100
21-04-2010					W6	6.6	0.0	2.8	0.1	0.1	90.5	20	15	25	20	20	100
21-04-2010					W7	6.0	0.0	2.8	0.1	0.2	91.0	20	15	25	20	20	100
21-04-2010					W8	6.8	0.2	2.6	0.2	0.1	90.2	20	15	25	20	20	100
						6.1	**0.1**	**2.8**	**0.2**	**0.2**	**90.9**	**20**	**15**	**25**	**20**	**20**	**100**
21-04-2010					CT1	5.6	0.0	2.9	0.2	0.2	91.3	20	15	25	20	20	100
21-04-2010					CT2	5.1	0.3	2.9	0.2	0.2	91.6	20	15	25	20	20	100
21-04-2010					CT3	5.5	0.0	3.2	0.2	0.1	91.1	20	15	20	20	20	95
21-04-2010					CT4	6.9	0.5	2.9	0.2	0.2	89.5	20	15	25	20	20	100
21-04-2010					CT5	6.3	0.0	2.6	0.1	0.2	91.0	20	15	25	20	20	100
21-04-2010					CT6	5.2	0.1	2.8	0.1	0.3	91.8	20	15	25	20	20	100
21-04-2010					CT7	4.8	0.3	2.9	0.2	0.3	91.8	20	15	25	20	20	100
21-04-2010					CT8	4.9	0.2	3.0	0.2	0.2	91.7	20	15	25	20	20	100
						5.5	**0.2**	**2.9**	**0.2**	**0.2**	**91.2**	**20**	**15**	**24**	**20**	**20**	**99**
21-04-2010					T8	5.3	0.2	3.7	0.2	0.2	90.5	20	15	20	20	20	95
21-04-2010					T7	7.0	0.1	2.8	0.2	0.4	89.9	20	15	25	20	20	100
21-04-2010					T6	5.7	0.4	3.4	0.2	0.2	90.3	20	15	20	20	20	95
21-04-2010					T5	6.3	0.0	3.1	0.2	0.2	90.5	20	15	20	20	20	95
21-04-2010					T4	6.1	0.3	3.1	0.2	0.2	90.2	20	15	20	20	20	95
21-04-2010					T3	6.5	0.2	3.2	0.2	0.2	90.0	20	15	20	20	20	95
21-04-2010					T2	6.0	0.4	3.3	0.2	0.1	90.1	20	15	20	20	20	95
21-04-2010					T1	6.4	0.0	3.1	0.2	0.2	90.3	20	15	20	20	20	95
						6.2	**0.2**	**3.2**	**0.2**	**0.2**	**90.2**	**20**	**15**	**21**	**20**	**20**	**96**