COMPUTERMATIC TIMBER-GRADING MACHINE — LABORATORY EVALUATION OF PERFORMANCE WITH RESPECT TO FEED SPEED AND THE DYNAMIC/STATIC DEFLECTION RELATIONSHIP

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(Received for publication 1 April 1986; revision 19 December 1986)

ABSTRACT

Timber of various stress-grades was passed a number of times through a Computermatic stress-grading machine running at 60 m/min and 150 m/min in a laboratory. The deflection of all the tested points on each stick was recorded, and deflection at each of the points was also determined statically for comparison. The range of dynamic deflection values for each point (termed repeatability) and the mean deflections were also calculated. Data from tests on verification sticks were used to determine differences between deflection measurements taken statically and those taken in a Computermatic machine.

There were no consistent differences in mean deflection measurements at the two feed speeds. A mean increase in repeatability error of one-half of one machine measuring unit found at the higher feed speed was considered to be of little practical significance in industry. The modulus of elasticity as determined by the Computermatic machine on the verification sticks at the point of least stiffness was on average slightly lower than the same property determined on the static machine. Three percent of the sticks had modulus of elasticity differences greater than the 10% allowed by the current Australian Standard.

Keywords: stress-grading; Computermatic; deflection; stiffness.

INTRODUCTION

The Computermatic timber-grading machine, in its current design form, has been in use throughout the world for over 10 years. During that time it has proved suitable for many grading operations in Australia and currently there are 15 being used in the eastern states. All the machines are used in-line in softwood mills and are processing either seasoned *Pinus radiata* D. Don or seasoned *Pinus elliottii* Engelm.

The fact that it was developed locally and designed specifically for grading locally grown species has no doubt contributed to the success of the Computermatic in Australia. Also, technical support for the machine and for machine-grading in general is being supplied by the Forestry Commission of N.S.W. who originally developed the Computermatic (Booth 1964; Anton & Bryant 1973).

Few data on repeatability and feed speed effects on reading accuracy of stress-grading machines have been published. Recent comments (Fewell 1984) have indicated that problems are being experienced with reading accuracy at the higher feed speeds.

The object of the work described here was to define the likely repeatability performance of the machine on dressed timber under laboratory conditions and to determine if there was any significant loss of accuracy at high machine feed speeds.

METHOD

Nine pieces of dressed pine timber of cross-section 90 × 35 mm were chosen from material from five Australian producers. They represented the full range of grades that are encountered in plantation-grown softwood and were chosen so that as far as possible (for the poorer grades) a major defect was present which had a dramatic effect on local stiffness. The timber therefore represented material ranging from essentially clear grade to material with major defects. The slender cross-section was chosen because it was expected that any adverse dynamic effects would be obvious with this size. Also, 35 mm is generally the smallest thickness scantling that is machine-graded in Australia.

The timber was docked to a length that would ensure the measurement of 15 points on each piece, resulting in a total of 135 measured points for comparison. Maximum values encountered for spring, bow, and twist were 11 mm, 15 mm, and 19 mm respectively.

The Computermatic machine used for the tests is located within the Wood Technology & Forest Research Division of the Forestry Commission of N.S.W. The machine was inspected to ensure that it was in correct operating condition and the zero of each transducer was set using a calibrated straight edge. The loading cylinder pressure gauge was also checked for correct calibration. Load cylinder pressure used was 230 kPa, cylinder stage 1 producing a nominal 890N force during grading.

The infeed consisted of a simple adjustable fence and a set of horizontal rollers. The fence was set at an angle of approximately 0.6° to the datum line of the machine's vertical rollers. The optimum settings for the load cylinder delay and the restrictor were found to be 0, 1 for 60 m/min and 0, 6 for 150 m/min respectively. A print-out unit capable of displaying the readings taken by the machine was used to determine these settings with the aim being to minimise impact loading effects on the readings. The two feed speeds were chosen because they approximate the normal minimum and maximum production operating speeds. A return cylinder pressure of approximately 500 kPa was used.

The timber was held against the fence as it was being fed in so that a consistent angle was achieved for each pass. Care was taken to ensure that there was no restriction on the timber as it was being graded. The Australian timber industry recognises the need for an automatic infeed system capable of directing the timber into the machine at a consistent angle and designed to ensure there are no restrictions on or forces applied to the timber during grading if accurate repeatable grading is to be achieved with high throughput production (RPRI 1985). The procedure used here was meant to simulate this and it is expected that a correctly maintained machine with a correctly set up automatic infeed system processing similar quality timber will achieve similar results.

Each piece was passed through the machine five times so that an estimate of the repeatability of the measurements could be obtained. Deflection values were recorded with the aid of a computer connected to the output of the machine control unit.

Each piece was tested in bending on a universal testing machine, i.e., under static conditions. The span was identical to that of the testing machine (914 mm) and deflection was measured using a dial gauge located at the mid-point of the span. The load was applied vertically at every point that had been measured by the Computermatic. Errors caused by the unequal overhanging ends that occurred during the testing were minimised by applying a predetermined counterweight to the shorter end during each test. A 50N initial force was also used to overcome additional small unequal overhanging forces.

The static tests were carried out to provide a standard for comparing the results from the dynamic tests. The static measurements were not expected to be identical to the dynamic measurements for all pieces of timber because of the mechanical differences between the measurement conditions, and other factors. For example, during the static test the timber is simply supported but for the Computermatic there are two spans to be considered, neither of which can be considered to be entirely simply supported. Other factors include tolerance errors in machine components, vibration, timber finish, temperature.

Tests at the Forestry Commission Laboratory of many hundreds of full-sized pieces of timber both in the Computermatic at around 100 m/min and statically in a universal testing machine have shown that at the weakest point on each piece the Computermatic reading is generally slightly higher than the static measurement. These measurements are undertaken in the preparation of verification sticks used in production as part of a quality assurance (QA) scheme for machine-graded timber (SAA 1978). A summary of results from some of this testing is included. For the verification stick results, static deflections were converted to units by dividing by 0.1905 and the Computermatic readings were calculated as the mean of the minimum and maximum of three consecutive runs. Neither result was rounded to the nearest machine unit before analysis. The static measurement was performed in a manner similar to the method specified in AS-1749 (SAA 1978) for the testing of specimens from mechanical grading operations as part of the QA system.

The verification sticks are selected from material without excessive distortion and therefore the results are probably not applicable to highly distorted material.

RESULTS

Effect of Feed Speed on Deflection Measurement and Repeatability

Means of the five readings taken at the two machine speeds and the static readings are given in Fig. 1 and 2. Machine units are equivalent to a deflection of 0.1905 mm, and the machine is capable of detecting sudden changes in local stiffness (*see* Fig. 1–2). Absolute differences in deflection readings at the two feed speeds appear to be small with the only stick showing any observable indication of "tracking" performance differences being FC25 which had the highest deflections (Fig. 2).

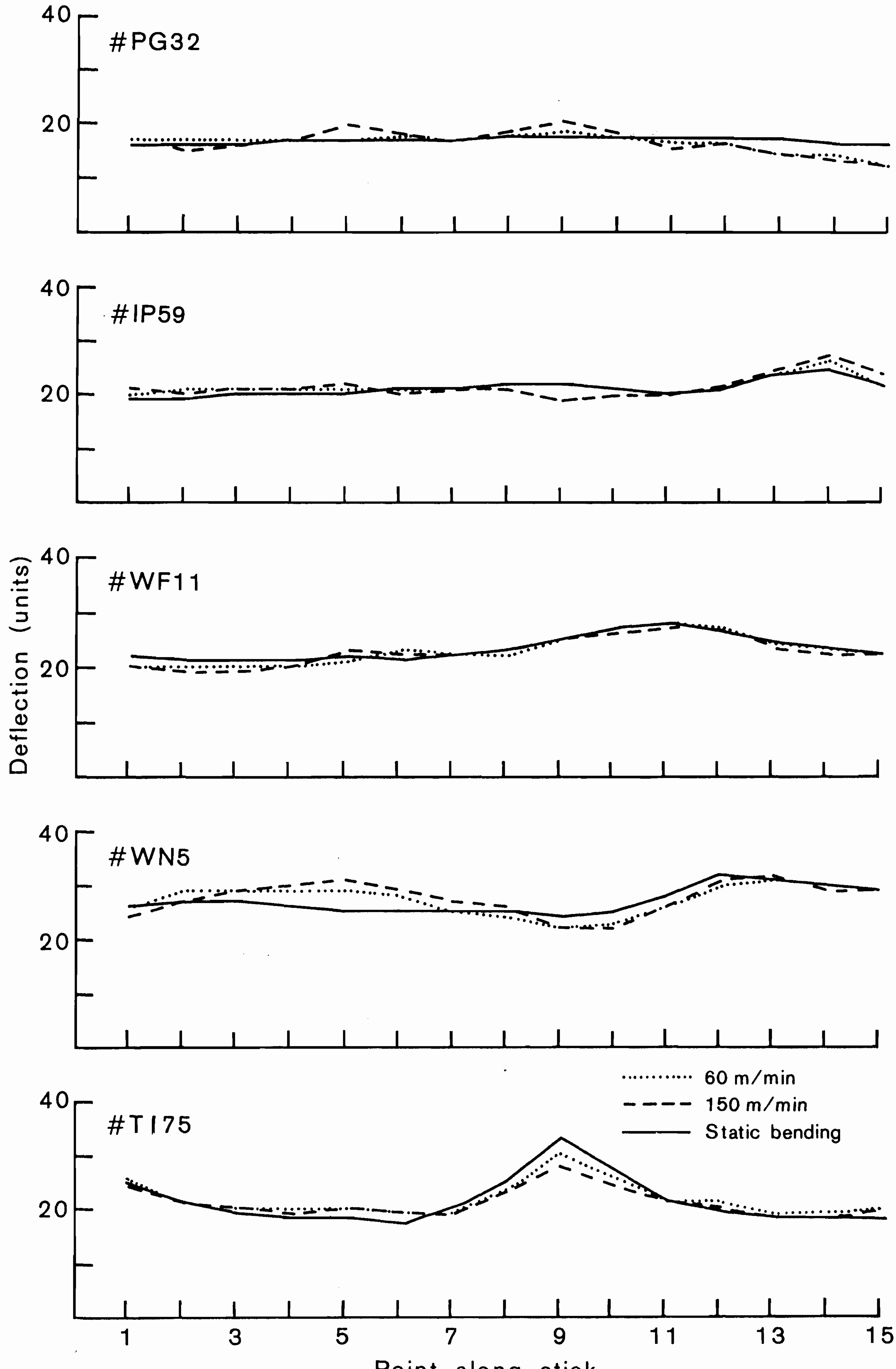

FIG. 1—Deflection measurements taken by a Computermatic machine at two feed speeds and by a static machine, at points 152 mm apart along sticks PG32, IP59, WF11, WN5, and TI75.

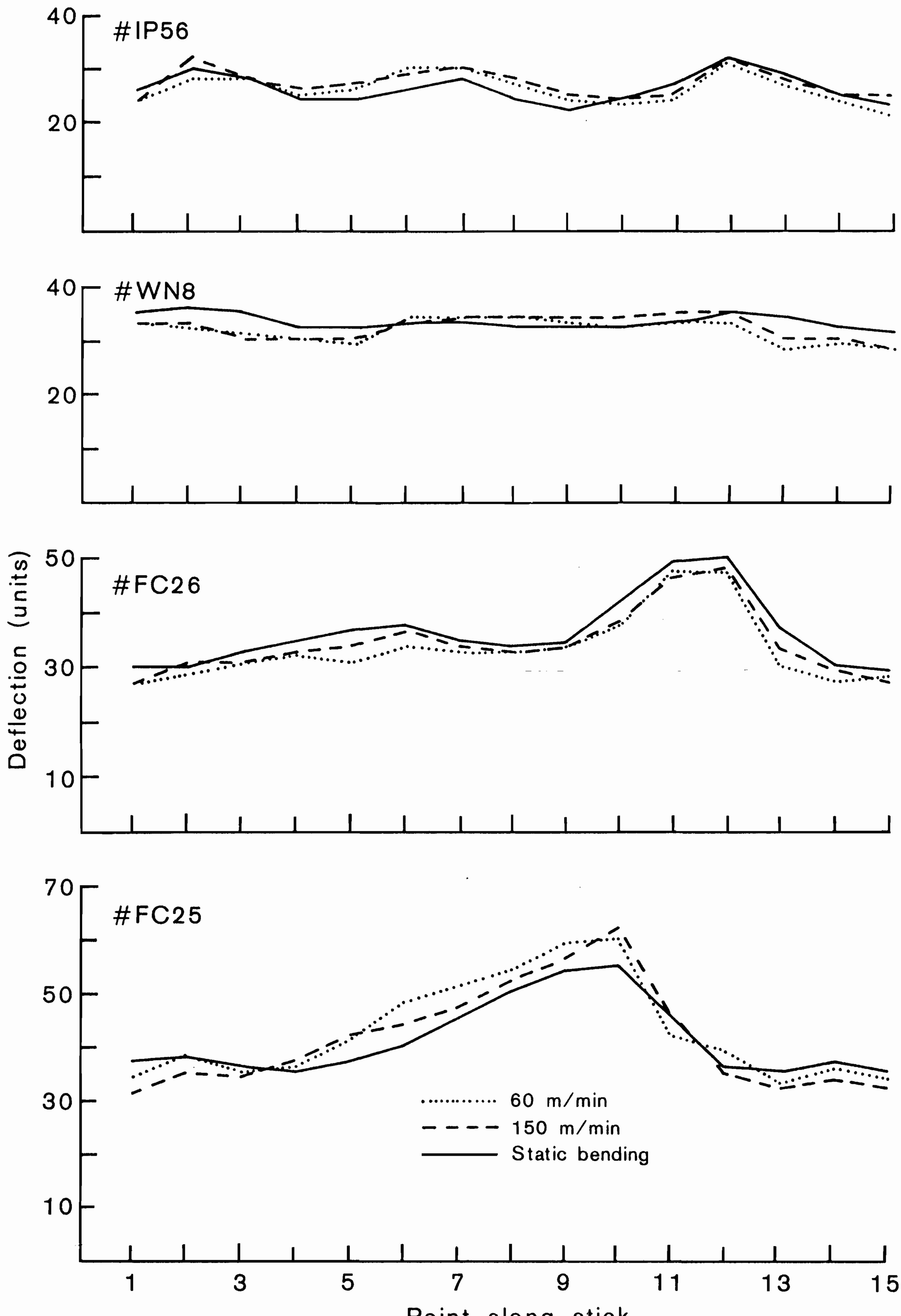

FIG. 2—Deflection measurements taken by a Computermatic machine at two feed speeds and by a static machine, at points 152 mm apart along sticks IP56, WN8, FC26, and FC25.

There are indications (Fig. 2) that the inertia of the machine loading mechanism could be just starting to affect the readings – note the overshoot at Points 10 and 11 and the undershoot at Point 12 for the faster speed. Also observable is an apparent "lagging" in the readings at the faster speed as the modulus of elasticity (MOE) decreases dramatically from the sixth reading. More tests would, however, need to be undertaken to prove this is indeed what was happening and that the phenomenon was not just limited to the particular stick. It should be noted that with stick FC26 (Fig. 2), which also has a sharp stiffness change, there does not appear to be any "tracking" problem at the highest speed.

Actual maximum deflections for the common stress grades in 35 × 90-mm *P. radiata* are as follows: F11 – 20 units, F8 – 27 units, F5 – 42 units, F4 – 48 units. Stick FC25 is therefore well into the reject category at its least stiff section.

The differences between the means of the five readings for the two feed speeds are given in Table 1. Whilst it may not be strictly correct to take means in the manner indicated in the Table, there appears to be no trend toward an indication of speed effects in the individual results or in the means. Total mean difference for all points on all sticks was found to be +0.1 units. This reinforces the conclusion that running the machine at 150 m/min has little over-all effect on measurement accuracy. Further work on timber with dramatic changes in MOE would be needed to determine whether or not the machine had difficulty in tracking that type of timber at the higher speeds. The relatively high value at the fifth point is due to effects generated by the machine loading system and to the machine design.

TABLE 1—Difference between mean deflection readings in machine units at the two feed speeds. Negative values indicate that the reading at 150 m/min was less than the reading at 60 m/min.
Machine unit = 0.19 mm

Stick No.	Point along stick														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PG32	0	-2	-1	0	3	0	0	1	2	1	-1	0	0	-1	0
IP59	1	-1	0	0	1	-1	0	0	0	0	0	0	1	1	2
WF11	0	-1	-1	0	2	-1	0	1	0	-1	-1	0	-1	-1	0
WN5	-2	-2	0	1	2	1	2	2	0	-1	0	1	1	-1	0
TI75	-2	0	0	-1	0	0	0	0	-2	-2	0	-1	-1	-1	0
IP56	0	4	0	1	1	-1	0	1	1	1	1	1	1	1	4
WN8	0	1	-1	0	1	-1	0	0	1	2	2	2	2	1	0
FC26	0	2	0	1	3	3	1	0	0	1	-1	1	3	2	-1
FC25	-3	-3	-1	1	1	-4	-4	-2	-3	2	4	-4	-1	-2	-2
Mean	-0.7	-0.2	-0.4	0.3	1.6	-0.4	-0.1	0.3	-0.1	0.3	0.4	0	0.6	-0.1	0.3

The range of deflection readings for each point for the five runs and two feed speeds (the repeatability) is given in Table 2. Absolute repeatability varied from 0 to 4 units for both feed speeds. Mean repeatability for the individual points along each stick varied from 0.4 to 1.7 units for the lower speed and from 1.1 to 2.0 at the higher speed (Table 2). Over-all mean repeatability was 1.2 at 60 m/min and 1.7 at 150 m/min, a difference of only half a unit which is considered to be of little significance in practical terms.

TABLE 2—Range of the deflection readings taken from five runs of each stick at each point measured by the grading machine at the two feed speeds used. Machine unit = 0.19 mm

Stick No	Point along stick														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							60 m/min								
PG32	1	1	0	1	1	2	1	0	2	1	0	2	0	1	1
IP59	2	2	0	2	2	1	1	2	1	1	0	0	1	2	2
WF11	1	2	1	1	3	1	2	1	2	0	0	1	1	1	0
WN5	3	2	0	1	1	4	3	1	1	0	0	1	1	1	1
TI75	1	1	1	1	1	1	2	2	1	2	1	1	1	1	1
IP56	1	2	2	2	2	1	2	1	2	1	0	2	1	1	2
WN8	1	0	1	0	1	1	1	2	1	1	1	2	1	0	1
FC26	1	2	1	0	1	1	2	0	1	1	1	2	2	1	1
FC25	1	2	2	1	2	1	1	1	2	2	1	1	1	1	1
Mean	1.3	1.6	0.9	1.0	1.6	1.4	1.7	1.1	1.4	1.0	0.4	1.3	1.0	1.0	1.1
							150 m/min								
PG32	2	1	2	1	1	1	2	1	2	1	1	1	1	2	1
IP59	2	3	1	1	2	1	2	2	1	2	2	2	2	2	1
WF11	2	2	2	1	2	2	1	2	1	1	3	1	1	2	2
WN5	2	3	1	2	4	3	2	2	2	1	3	2	1	2	1
TI75	1	0	2	1	2	2	1	2	2	2	2	1	2	1	1
IP56	1	3	4	1	2	1	2	2	1	2	2	2	1	1	1
WN8	2	2	1	2	2	2	2	2	2	1	1	2	2	1	1
FC26	1	2	2	3	1	2	2	2	1	2	1	2	2	2	1
FC25	2	1	1	3	2	2	2	3	2	3	2	1	3	2	1
Mean	1.7	1.9	1.8	1.7	2.0	1.8	1.8	2.0	1.6	1.7	1.9	1.6	1.7	1.7	1.1

Differences between Computermatic Deflection Measurements and Static Deflection Measurements for Verification Sticks

In order to determine the difference between Computermatic deflection measurements and standard static measurements, an evaluation of the differences in deflection measurements taken by the Computermatic and a static machine at the point of least stiffness on 162 verification sticks of various cross-section sizes was carried out (Table 3). The results show a mean difference of +0.13 units, indicating that the Computermatic machine reads slightly more in terms of unit deflection than the static method. Standard deviation was 1.98, skewness 0.20, and kurtosis 3.59. Assuming a normal distribution of data, approximately 95% of results fell within ±4 units from the mean.

Looking at the results from the viewpoint of industrial quality assurance, 24% of the Computermatic readings were >1 unit below the static measurements and in 14% of readings this difference was >2 units. AS-1749 (SAA 1978) requires that specimens tested in a static machine do not show deviations greater than 10% below the lower limit of MOE for the stress-grade indicated by the grading machine. The 10% limit on MOE is equivalent to an 11% difference in deflection measurement.

TABLE 3—Comparison of deflections measured by Computermatic and by static test (deflection units)

Computermatic-Static (units)	Frequency (No.)	Frequency (%)	Cumulative (%)
-5 to <-4	5	3.1	3.1
-4 to <-3	5	3.1	6.2
-3 to <-2	12	7.5	13.7
-2 to <-1	16	9.9	23.6
-1 to < 0	44	27.3	50.9
0 to < 1	32	19.9	70.8
1 to < 2	22	13.7	84.5
2 to < 3	11	6.8	91.3
3 to < 4	10	6.2	97.5
4 to < 5	1	0.6	98.1
5 to < 6	2	1.2	99.4
6 to < 7	1	0.6	100.0

Generally, the sticks that showed the greatest negative deviations were ones with high over-all deflections. The maximum percentage relative deviation encountered here was generally less than the 11% maximum allowed by AS-1749 for most of the sticks. Only 3% of the sticks fell outside this limit (Table 4). However, the standard needs to specify the maximum number of specimens that can lie below the 11% limit because this situation will eventually occur in practice. From these results it is concluded that 5% is a realistic figure and one that can probably be met by a machine under proper control. The 5% would be expected to cover repeatability error as well. This factor was not considered in the above analysis.

Lower exclusion limit values of modulus of rupture will probably not be greatly affected by this apparently incorrect grading because the distribution of errors lies fairly equally in both conservative and non-conservative regions, resulting in roughly equal numbers of pieces being upgraded and downgraded by the Computermatic compared to the theoretical grade determined using the static method. In-grade tests are considered to be the most effective way of monitoring the strength of graded timber and it is by the use of this technique that effects of this type can be evaluated.

TABLE 4—Comparison of deflections measured by Computermatic and by static test (percentage of static test)

Computermatic-Static / Static	Frequency (No.)	Frequency (%)	Cumulative (%)
-15 to <-11	5	3.1	3.1
-11 to <-10	5	3.1	6.2
-10 to < 5	23	14.3	20.5
- 5 to < 0	49	30.4	50.9
0 to < 5	37	23.0	73.9
5 to < 10	24	14.9	88.8
10 to < 15	11	6.8	95.7
15 to < 20	4	2.5	98.1
20 to < 25	2	1.2	99.4
25 to < 30	0	0.0	99.4
30 to < 35	1	0.6	100.0

CONCLUSION

No consistent differences were found in mean deflection measurements at the two feed speeds.

There was a mean increase in repeatability error of one-half of one machine measuring unit at the higher feed speed but this was considered to be of little practical significance when the machine is used in industry.

The tests on the least stiff section of verification sticks showed that the modulus of elasticity as determined by the Computermatic machine was on average slightly lower than the same property determined on the static machine. Three percent of the sticks had modulus of elasticity differences greater than the 10% allowed by the current standard. It is suggested that the standard should make some allowance for this by permitting 5% of static modulus of elasticity results to lie outside the 10% limit for each machine grade.

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