TECHNICAL NOTE: POSITIVE EFFECTS OF DOUBLE-SIDED PROFILING ON THE CUPPING AND CHECKING OF ACQ-TREATED DOUGLAS FIR, WESTERN HEMLOCK, AND WHITE SPRUCE DECKBOARDS EXPOSED TO NATURAL WEATHERING

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Abstract. Machining grooves into the upper surface of wooden deckboards reduces undesirable checking that develops when deckboards are exposed to the weather. But profiled boards cup more than unprofiled boards. We sought a solution to this problem and hypothesized that profiling both sides of boards would reduce the cupping of profiled boards. We tested the effects of profile type (flat, single-, and double-sided profiles) and growth ring orientation (concave vs convex) on the cupping and checking of alkaline copper quaternary–treated deckboards made from Douglas fir, western hemlock, and white spruce. There were significant differences in the cupping of deckboards made from the three different wood species (Douglas fir$<$white spruce$<$western hemlock), and boards with concave growth ring orientations cupped significantly less than boards with convex growth ring orientations. Most importantly, our results show that double-sided profiling reduces the cupping of deckboards, irrespective of wood species, and growth ring orientations of deckboards. Double-sided profiling also significantly reduced checking of deckboards exposed to the weather. We conclude that profiling the underside of profiled deckboards to create a “balanced” double-sided board is a simple solution to the problem of increased cupping that develops when profiled (single-sided) softwood deckboards are exposed to the weather.

Keywords: Douglas fir, western hemlock, white spruce, ACQ-treated decking, profiling, checking, cupping, growth ring orientations, weathering.

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INTRODUCTION

Wooden boards used for residential decking are an important end use for sawn timber. For example, in the United States alone, wood has approximately 80% of the market for residential decking, valued at approximately $7 billion per annum (3.5 billion lineal feet) according to the Freedonia Group (2020). However, wooden deckboards made from preservative-treated softwoods are losing market share to deckboards made from wood–plastic composites (WPCs) because of their higher maintenance costs and poorer weathering resistance compared with deckboards made from WPCs (Kavanaugh 2019). In contrast to WPCs, wood discolors (grays) outdoors, and deckboards made from some wood species distort and check (crack). Graying of wood is due to photodegradation of wood surfaces and colonization of the weathered wood by melanin-rich fungi (Kühne et al 1970). Checking and distortion of wooden deckboards occur because of surface stresses generated by moisture-induced anisotropic swelling and shrinkage of wood (Schniewind 1963). Checking of deckboards is exacerbated by the surface photodegradation of wood (Evans et al 2008).

A variety of treatments are used to increase the weathering resistance of wooden deckboards including the use of preservatives containing wax/oil and brush-on pigmented surface finishes (Christy et al 2005; Nejad and Cooper 2011). These treatments are only partially effective, and surface finishes need to be cleaned and reapplied at regular intervals. A complimentary or alternative approach to reducing the adverse effects of the weather on the appearance of wooden deckboards is to machine profiles (small V- or U-shaped grooves) into the surface of boards (Böttcher 1977; McFarling and Morris 2005; Cheng and Evans 2016) before preservative treatment and finishing. Profiling reduces the number of large visible checks that develop in deckboards exposed to the weather (McFarling and Morris 2005; McFarling et al 2009; Evans et al 2010; Akhtari and Nicholas 2014a, 2014b; Cheng and Evans 2018; Heshmati et al 2018). Furthermore, the checks that develop in profiled deckboards are mainly located in profile grooves where they are difficult to see (McFarling and Morris 2005). Hence, profiling also masks the deleterious effects of weathering checks on the appearance of wooden deckboards. However, some studies have shown that profiled deckboards are more susceptible to cupping—the curving of the wide face of a flat-sawn board to form a trough shape—than unprofiled deckboards (Cheng and Evans 2018; Heshmati et al 2018). Cupping of wood deckboards creates an uneven deck surface (Marsh 2009), and therefore, a solution to this problem is needed.

Profiling increases the drying strains that develop at the surface of wood products, which may explain why it increases the cupping of deckboards (Mallet et al 2018). Cupping of profiled (striated) plywood cladding exposed outdoors to the weather was also described by Bailey (1944). Bailey (1944) solved this problem by "increasing the thickness of the striated (profiled) veneer to create a balanced panel, which equalized stresses in opposing veneers." A similar approach is unsuitable for solid wood decking, but it is possible that profiling both sides of deckboards might create a more balanced board that is less susceptible to checking. In support of this suggestion, stress-relief saw kerfs (narrow slots) or grooves machined into the undersides of flat deckboards are recommended as a way of reducing the cupping of deckboards (Nystrom 1995; Ratu et al 2007).

In this study, we hypothesized that machining profiles on both sides of deckboards, hereafter called double-sided profiling, would reduce the cupping of profiled wood decking exposed outdoors to the weather. We selected three important commercial wood species for our research: Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and white spruce (*Picea glauca* (Moench) Voss). These species are used to manufacture decking in Canada (Morris and Ingram 2002), and precommercial trials of profiled Douglas fir decking have commenced in North America (Anon 2019). We used boards that are representative of those used in industry. In particular, we chose flat-sawn boards with different growth ring orientations (concave ["pith-side-up"] vs convex ["bark-side-up"]) because growth ring orientation of flat-sawn boards affects their susceptibility to cupping and checking (Williams and Knaebe 1995; Yata 2001). Growth ring orientation of flat-sawn boards also affects their susceptibility to shelling—a severe type of raised grain resulting from separation of growth rings at the surface of deckboards (Williams and Knaebe 1995). Our experiment examined the effects of profile type, wood species, and growth ring orientation on the cupping and checking of deckboards exposed to natural weathering and seeks to determine whether double-sided profiling can reduce the undesirable cupping that develops when profiled deckboards are exposed to the weather.

MATERIALS AND METHODS

Manufacture of Profiled Deckboards and Measurement of Cupping

The boards used to manufacture profiled decking were a separate but matching set to those used in a previous study of the effects of different profile types (rib, ribble, and ripple) on the checking of Douglas fir, western hemlock, and white spruce deckboards (Heshmati et al 2018). We obtained six parent boards for each species, approximately $40 \times 140 \times 4877\ mm^3$ in size, from commercial retailers of lumber, as described previously (Heshmati et al 2018). The boards were stored in a conditioning room at 20 ± 1°C and 65 ± 5% RH for 1 mo, and the wood properties of the six boards for each wood species were measured, as described and reported previously (Heshmati et al 2018). The six parent boards for each wood species were each crosscut to produce six samples, each 400 mm in length. The six samples from each parent board for each wood species were randomly allocated to the six different board types x growth ring combinations (Fig 1). The machined profile used was a rib profile with a groove depth and radius of 2.0 mm and 0.16 mm, respectively, and a peak radius of 2.4 mm (Heshmati et al 2018).

The two knives for the first profile type (flat, single-, or double-sided profiles) were inserted into a 125-mm diameter cylindrical rotary cutterhead with a hook angle of 15° and secured in place. The cutterhead was placed on the machine spindle of a spindle molder (as described previously) (Heshmati et al 2018), aligned and then secured in place. The decking sample for the first sample type (profile type $\times$ growth ring orientation) from the selected species was fed into the machine by hand and machined at a spindle speed of 6000 rpm to produce the decking sample. The process was repeated until all 18 samples (3 profiles $\times$ 2 growth ring orientations $\times$ 3 species) from the first parent board were profiled. Two passes were required to produce samples with double-sided profiles, and all boards were machined to a final thickness of 35 mm. Then, samples from the second parent board for each species were profiled as mentioned earlier, followed by samples from boards 3, 4, 5, and 6 until all 108 deckboard samples (6 parent boards $\times$ 3 profiles [flat, single-, and double-sided profiles] $\times$ 2 [growth ring orientations] $\times$ 3 species [Douglas fir, western hemlock, and white spruce]) had been machined. The final dimensions of the profiled boards were 400 (length) $\times$ 136 (width) $\times$

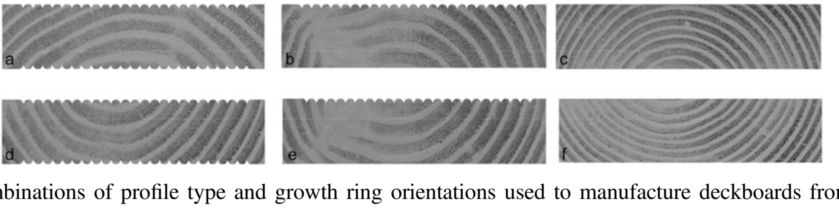

Figure 1. Combinations of profile type and growth ring orientations used to manufacture deckboards from Douglas fir, western hemlock, and white spruce: (a) double-sided profile, convex growth rings; (b) single-sided profile, convex growth rings; (c) flat profile, convex growth rings; (d) double-sided profile, concave growth rings; (e) single-sided profile, concave growth rings; and (f) flat profile, concave growth rings.

35 (thickness) mm^3. Deckboard samples were air-dried in a conditioning room at 20 ± 1°C and 65 ± 5% RH for 1 mo. Each conditioned sample was placed on a flat surface against a steel fence, and planer deviation (cupping) was measured in three places using a dial gauge micrometer attached to a precision-machined steel square, as described previously (Heshmati et al 2018). Deckboard samples were returned to the conditioning room for a further 3 mo, and the ends of the samples were brush-coated with two coats of sealer (as described previously) to reduce preservative uptake via end-grain and to prevent checks from developing in end-grain (Heshmati et al 2018). Samples were conditioned, as earlier, for a further 2 mo, weighed, and their cupping was remeasured, as mentioned previously.

Preservative Treatment of Deckboards, Weathering Trial, and Measurement of Checking

All deckboard samples were treated with 1.8% alkaline copper quaternary (ACQ) preservative solution in a commercial pressure treatment cylinder, as described previously (Heshmati et al 2018). Treated deckboard samples were weighed, and preservative retentions of samples were calculated. Preservative retentions of Douglas fir, western hemlock, and white spruce samples were 3.14 kg/m^3 (minimum = 0.85; maximum = 5.4; SD = 1.0), 7.23 kg/m^3 (minimum = 4.8; maximum = 8.8; SD = 1.1), and 2.61 kg/m^3 (minimum = 0.4; maximum = 5.0; SD = 1.35), respectively. Differences in preservative retentions of the three wood species were statistically significant ($p < 0.001$), whereas there were no significant ($p > 0.05$) effects of profile type or growth ring orientation on preservative retentions. After treatment, samples were conditioned at 20 ± 1°C and 65 ± 5% RH for 2 mo, reweighed, and their cupping was remeasured, as mentioned previously.

Profiled samples and the matching flat controls cut from each of the six parent boards for each species were screwed to separate wooden subframes made from pressure-treated 2 × 4 lumber to create six mini-decks. Each mini-deck was 2.9 m long, 35 cm wide, and 47 cm high. Boards were fastened at each corner to the subframes using 34-mm-long, 3.1-mm-wide galvanized decking screws applied using the CAMO® Edge Deck Fastening System (National Nail Pty Ltd, Grand Rapids, MI). A gap of 10 mm was left between each of the 18 boards in each rack. Unprofiled spruce boards, measuring 360 × 90 × 40 mm^3, were screwed to each end of the row of 18 boards on each rack to prevent the edges of samples at the ends of the racks from being exposed to the weather. The weathering racks were exposed outdoors in Vancouver at FPInnovations' test site for 6 mo from May 1, 2017 to October 31, 2017. All samples were removed from the racks after 14 wk on August 7th, after a prolonged period of dry weather, and cupping of samples was remeasured, as described earlier. Samples were returned to the racks on August 11th. At the end of the 6-mo trial, weathered samples were removed from the racks, conditioned at 20 ± 1°C and 65 ± 5% RH for 2 mo, and the sizes of visible checks were measured, as described previously (Heshmati et al 2018).

Statistical Analysis of Cupping and Checking

Our experiment used factorial principals to investigate the effects of three fixed factors, profile type (boards with flat, single-, and double-sided profiles), wood species (Douglas fir, western hemlock, and white spruce), and growth ring orientation (boards with concave or convex growth ring orientations) on response variables: cupping during air-drying and after weathering and check sizes after weathering. The main effects of, and interactions between, each of the fixed factors on cupping and checking of deckboards were tested for significance ($p < 0.05$) using multifactorial analysis of variance. Statistical computation was carried out using Genstat (19th edition). Before the final analysis, diagnostic tests were performed on data to ensure it met the assumptions of analysis of variance (normality and homogeneity of variances), and as a result of such tests, data for check sizes (area of five largest checks) were transformed into natural logarithms before analysis. The factorial design of the experiment allowed data to be averaged across nonsignificant ($p > 0.05$) effects, giving the experiment greater precision. Results presented in graphs contain error bars (Fisher's least significant difference, LSD), which can be used to estimate whether differences between individual means are statistically significant at the 5% level (Williams and Hervé 2010).

RESULTS

The effects of, and significant interactions between, the three experimental factors on the cupping and checking of deckboards samples are summarized in Table 1. Each of the individual experimental variables (profile type, wood species, and growth ring orientation) had significant ($p < 0.001$) effects on cupping of boards during initial air-drying, drying after preservative treatment, and after weathering, with three exceptions (NS in Table 1). There were no significant ($p > 0.05$) two- or three-way interactions of experimental variables on cupping (Table 1). The individual experimental variables all had significant ($p \leq 0.01$) effects on checking, and there were two significant ($p < 0.05$) interactions of these experimental variables on checking (Table 1).

Cupping of Deckboards

Boards that were profiled on one side cupped significantly ($p < 0.05$) more after air-drying for 1 and 6 mo than the flat boards and also boards that were profiled on both sides, as shown in Table 2. They also cupped more than flat and double-sided profiled boards after preservative treatment and drying (8 mo in Table 2). These effects of profile type on cupping did not depend on the species of wood that was profiled or the growth ring orientation of boards because, as noted previously, there were no significant ($p > 0.05$) interactions of profile type with wood species or growth ring orientations of boards (Table 1). The effects of "wood species" on cupping varied depending on the length of time boards were dried. Initially after 1 mo of drying, Douglas fir boards cupped significantly ($p < 0.05$) more than western hemlock and spruce boards, but spruce boards cupped significantly ($p < 0.05$) more than Douglas fir and western hemlock boards after 6 mo of air-drying (Table 2). There was no significant ($p > 0.05$) difference in cupping of boards made from different wood species after preservative treatment and air-drying (8 mo in Table 2). The effects of "growth ring orientation" on cupping also varied depending on the length of time boards were dried. Boards with convex growth ring orientations cupped more than boards with concave growth ring orientations after 6 mo of air-drying: the difference is small but statistically ($p < 0.05$) significant (Table 2). There was no difference in the cupping of the two profile types after 1 mo of air-drying or after preservative treatment and air-drying (Table 2).

The effects of profile type, wood species, and growth ring orientations on cupping of deckboards after weathering are shown in Figs 2-4, respectively. These figures show the effects of each individual variable on cupping because there were no significant ($p < 0.05$) interactions of variables on cupping (Table 1).

Table 1. Significant effects of, and interactions between, profile type, wood species, and growth ring orientation on the cupping and checking of deckboards during air-drying and weathering.

	Experimental factors[a]				
Variable	Profile type (P)	Species (S)	Orientation (O)	$P \times S$	$P \times O$
Cup, 1 mo air-drying	***	***	NS	NS	NS
Cup, 6 mo air-drying	***	*	**	NS	NS
Cup, 2 mo after treatment	***	NS	NS	NS	NS
Cup after weathering	***	***	***	NS	NS
Area of five largest checks	***	**	***	*	*

[a] *** = factor had a very highly significant ($p < 0.001$) effect on variable; ** = factor had a highly significant ($p < 0.01$) effect on variable; * = factor had a significant ($p < 0.05$) effect on variable. NS, not significant ($p > 0.05$).

Table 2. Effects of experimental variables on cupping of deckboards during drying before treatment (1 and 6 mo), and after preservative treatment and drying (8 mo).

	Cup profile type (mm)			Cup species (mm)			Cup growth ring (mm)	
Time (months)	Double	Flat	Single	Douglas fir	Western hemlock	White spruce	Convex	Concave
1	0.42[a]	0.41[a]	0.57[b]	0.56[a]	0.403[b]	0.442[b]	0.48[a]	0.46[a]
6	1.40[a]	1.41[a]	1.58[b]	1.44[a]	1.46[a]	1.50[b]	1.48[a]	1.45[b]
8	1.50[a]	1.61[b]	1.72[c]	1.61[a]	1.58[a]	1.64[a]	1.59[a]	1.63[a]

Values within each factor that share the same superscripted letter are not significantly different ($p > 0.05$); values with different superscripted letters are significantly different according to Fisher's least significant difference test ($p < 0.05$).

Cupping of boards that were profiled on both sides (double-sided) after weathering was significantly ($p < 0.05$) less than those of similarly weathered flat boards and ones that were profiled on one side (single-sided in Fig 2). Boards profiled on one side cupped significantly ($p < 0.05$) more than flat boards, as we have observed previously (Cheng and Evans 2018; Heshmati et al 2018).

There were significant ($p < 0.05$) differences in the cupping of all three wood species, as shown in Fig 3 (Douglas fir < white spruce < western hemlock), and boards with convex growth orientations (bark-side-up) cupped significantly ($p < 0.05$) more than boards with concave growth ring orientation (pith-side-up) (Fig 4). The magnitude of cupping after weathering was less than that after preservative treatment and air-drying (compare values in Table 2 with those in Figs 2-4) possibly because of the restraining effect of fixings on cupping of deckboards exposed outdoors (Englund 2010).

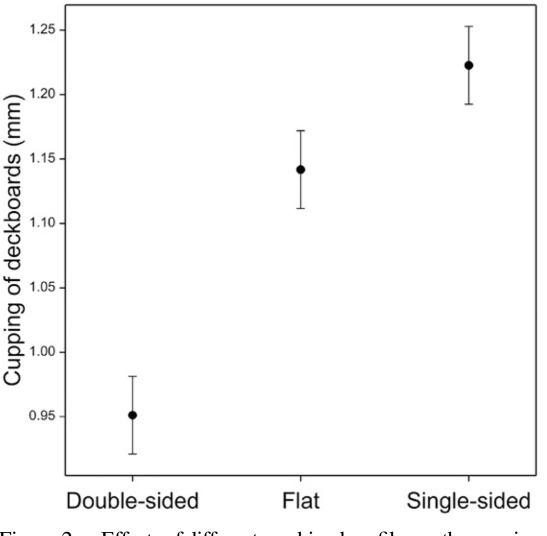

Figure 2. Effects of different machined profiles on the cupping of deckboards exposed to natural weathering: double-sided = profiled on both sides; flat = unprofiled control; single-sided = profiled on the upper surface exposed to natural weathering. Results averaged across different species and growth ring orientations because of insignificant interactions of these factors and profile type on cupping.

Checking of Deckboards

The effects of profile type (flat, single-, or double-sided) on checking of deckboards exposed to weathering interacted with effects of wood species ($P \times S$) and growth ring orientations ($P \times O$)

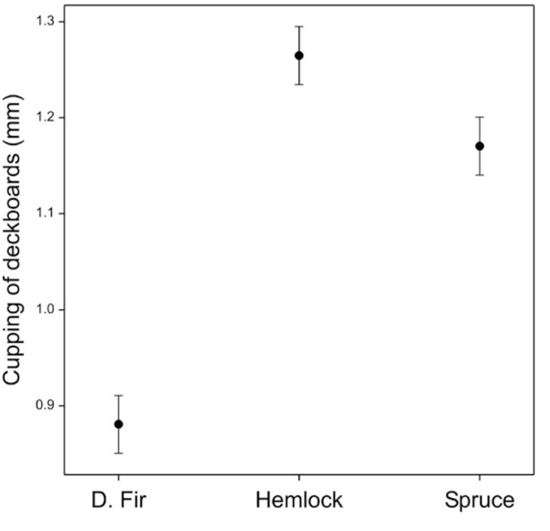

Figure 3. Cupping of deckboards made from Douglas fir, western hemlock, and white spruce and exposed to natural weathering. Results averaged across boards with different profiles and growth ring orientations because of insignificant interactions of these factors and species on cupping.

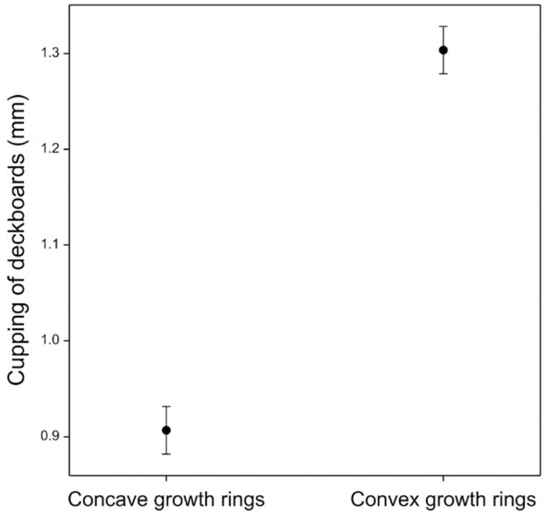

Figure 4. Effects of different growth ring orientations on the cupping of deckboards exposed to natural weathering. Results averaged across boards with different profiles and made from different species because of insignificant interactions of these factors and growth ring orientation on cupping.

of deckboards (Table 1). The interaction of profile type and wood species on the area of the five largest checks in deckboards is shown in Fig 5. It is obvious from Fig 5 that flat unprofiled boards had larger checks than profiled boards. However, what is noteworthy in terms of the aims of this study is that both double-sided and single-sided profiling significantly ($p < 0.05$) reduced check sizes, although single-sided profiling was more effective than double-sided profiling at restricting the checking of western hemlock boards (Fig 5). Checking of profiled boards was mainly confined to the grooves of profiles and was more difficult to see than checking at the surface of flat boards.

Boards with convex growth ring orientations (bark-side-up) checked significantly ($p < 0.05$) more than boards with concave growth ring orientations (pith-side-up), except for those that were profiled on one side (single-sided profiling) (Fig 6). However, all flat (unprofiled) western hemlock and white spruce boards with concave growth ring orientations developed shelling, and five of the six flat Douglas fir boards with concave growth ring orientations also developed shelling. By contrast, none of the flat boards with convex growth ring orientations or profiled boards developed this defect.

DISCUSSION

The main aim of this research was to solve the problem of the cupping of profiled (single-sided) deckboards exposed outdoors. We hypothesized

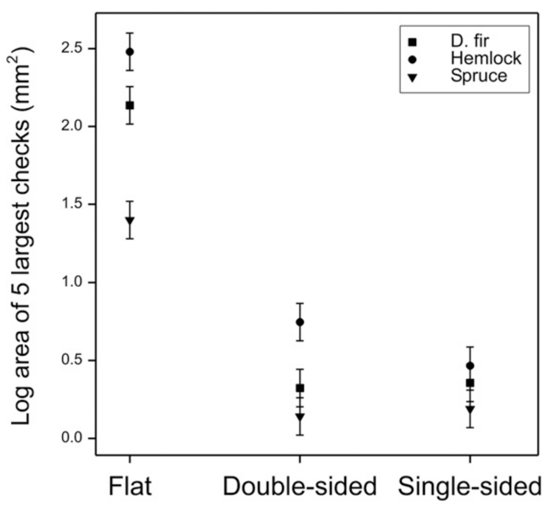

Figure 5. Interaction of profile type and wood species on the area of five largest checks in deckboards exposed to natural weathering for 6 mo.

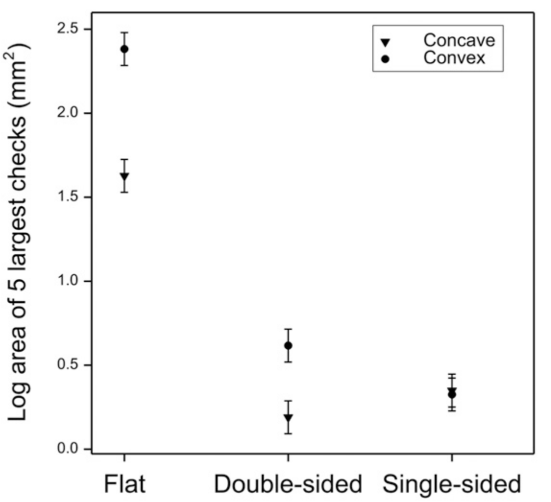

Figure 6. Interaction of profile type and growth ring orientation on the area of five largest checks in deckboards exposed to natural weathering for 6 mo.

that profiling both sides of deckboards (double-sided profiling) would reduce the cupping of profiled deckboards exposed outdoors to the weather. Our results support this hypothesis. Furthermore, double-sided profiling also restricted large checks from developing at the surface of boards. Therefore, we conclude that softwood deckboards, which are susceptible to checking, should be profiled on both sides, in preference to single-sided profiling, to reduce the checking and cupping that develops when deckboards are exposed to the weather. There is little evidence that this solution to the problem of the cupping of profiled deckboards has been used before. For example, our survey of commercially profiled deckboards (Cheng and Evans 2016) included 22 boards made in seven different countries from various softwood species including Douglas fir, spruce (*Picea* spp.), and western hemlock (Cheng and Evans 2016). None of the boards were profiled on both sides. Instead, seven of the boards (32%) used saw kerfs or rectangular- or trapezoid-shaped grooves on their undersides, presumably to offer the same kind of "stress-relief," provided here by subsurface profiling. We recently obtained six additional profiled softwood deckboard samples from Norway. None of these boards used double-sided profiling, although three of them (50%) used subsurface stress-relief grooves. The stress-relief grooves in wood decking appear to have been modeled on those used in tongue and groove flooring (Nystrom 1995), but there is no information on the extent to which they reduce the cupping of deckboards or their effectiveness compared with subsurface profiling. Further research is needed to answer these questions.

Our results for the cupping and checking of Douglas fir, western hemlock, and white spruce deckboards accord with those we obtained previously when we performed an experiment to select surface profiles that were effective at reducing the checking of all three species (Heshmati et al 2018). Western hemlock checked and cupped more than the other two species in both studies, and therefore, we conclude that it is the least suitable of the three species for the manufacture of profiled decking. In both studies, Douglas fir cupped less during weathering than white spruce and was easier to treat, but white spruce checked less than Douglas fir. Therefore, it is not possible, based on our results, to recommend one of these two species in preference to the other for the manufacture of profiled decking, although current precommercial trials of profiled decking in the United States, that are based on our previous research findings (Cheng and Evans 2018), have used Douglas fir rather than spruce (Anon 2019).

Our results confirm previous findings that profiling reduces the size of checks that develop at the surface of deckboards exposed to the weather (McFarling et al 2009; Evans et al 2010; Akhtari and Nicholas 2014a, 2014b). We also confirm previous findings that checks are located in profile grooves, making them difficult to see (McFarling and Morris 2005). Our research sheds no further light on why checks are smaller in profiled boards or why they are confined to the grooves of profiles. Previous research observed that tangential strains at the surface of flat radiata pine (*Pinus radiata* D. Don) deckboards subjected to wetting and drying were relieved by the formation of visible checks (Mallet et al 2018). The same study observed that tangential strains at the surface of profiled radiata pine deckboards subjected to wetting and drying were higher than those in flat deckboards and coincided with the peaks and grooves of profiles. The positive strains that developed in profile grooves during drying were large enough to cause checking and help explain why numerous small checks formed at the base of grooves in profiled boards (Mallet et al 2018). Holmes (2018) observed similar patterns of strain development in profiled white spruce deckboards (one of the species tested here) subjected to wetting and drying. The "physical mechanism" for the checking of profiled boards suggested by Mallet et al (2018) ignores the possibility that profiling might influence checking by changing the severity of "weathering" at the surface of deckboards. There is no information on this subject. However, it is possible that grooves act as traps for water and dust, thus encouraging microbial colonization, degradation, and possibly checking of wood at the base of grooves. Further research is needed to test this hypothesis. However, in this study, all boards were treated with a commercial copper-containing wood preservative (ACQ) and were exposed outdoors for a relatively short period of time (6 mo). Therefore, it is unlikely that the pattern of checking in profiled boards was affected by microbial degradation at the base of grooves, but we acknowledge that such an effect could occur in the long term, particularly in untreated or poorly treated deckboards.

Deckboards can be installed with their growth rings oriented concave (pith-side-up) or convex (bark-side-up) to the wide upper face of boards (Williams and Knaebe 1995). The beneficial effect of concave growth ring orientations on checking of flat deckboards observed here accords with a previous study that examined the effect of growth ring orientation on the surface checking of flat-sawn unprofiled softwood timbers exposed outdoors in Japan (Yata 2001). The effect of growth ring orientation on the checking of double-sided profiled boards was small, and there was no effect of growth ring orientation on the checking of boards that were profiled on one side. The latter finding contrasts with those of Morris and McFarling (2008). They found that lodgepole pine (*Pinus contorta* Dougl.) deckboards profiled on one side and exposed to the weather with concave growth ring orientations checked less than similarly exposed boards with convex growth ring orientations (Morris and McFarling 2008). They also observed a beneficial effect of concave growth ring orientation on cupping of profiled lodgepole pine deckboards exposed outdoors, in accord with findings here. However, the positive effects of concave growth ring orientations on the checking and cupping of flat deckboards (Yata 2001; Urban and Evans 2005) are outweighed by the fact that such boards can develop shelling. Shelling is considered to be a severe defect because it can create sharp splinters that protrude from the surface of deckboards. These splinters are objectionable and dangerous according to Koehler (1929) and make refinishing difficult. Hence, current recommended practice is to install deckboards with growth rings oriented convex to the wide, upper, face of boards, especially for species such as southern pine (*Pinus* spp.) that are susceptible to shelling (Williams and Knaebe 1995). Our results suggest that this recommendation should be followed when installing flat deckboards made from western hemlock and white spruce because all flat "concave" deckboards made from these two species developed shelling. Shelling was not observed in profiled boards, and, as mentioned earlier, double-sided profiled boards with concave growth ring orientations cupped and checked less than boards with convex growth ring orientations. Nevertheless, it is possible that shelling could develop with more prolonged exposure of profiled boards to the weather. One of us (P.D.E.) has observed shelling in profiled western larch (*Larix occidentalis* Nutt.) deckboards installed pith-side-up (concave growth rings) and exposed outdoors for 2 yr. Therefore, we recommend installing double-sided profiled boards with growth rings oriented bark-side-up (convex growth rings).

CONCLUSIONS

We conclude that profiling the underside or bottom of profiled deckboards to create a "balanced" double-sided board is a simple solution to the problem of the increased cupping that develops when profiled (single-sided) Douglas fir, western hemlock, and white spruce deckboards are exposed to the weather. Our solution to this problem can be easily applied to other softwood species such as southern pine and amabilis fir (*Abies amabilis* (Dougl.) ex J. Forbe) that are profiled because they are susceptible to checking. Double-sided profiling is not used commercially; instead, some manufacturers of profiled deckboards use subsurface grooves or kerfs to create a balanced board. We plan to investigate whether subsurface grooving is as effective as double-sided profiling at reducing the cupping of profiled deckboards and examine the effects of groove geometry and numbers on the cupping and checking of profiled boards.

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