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Cutting and grinding wheels for angle grinders with a bioresin matrix

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ABSTRACT

By using biosourced raw materials such as condensed tannins and furfuryl alcohol a biosourced thermoset resin was developed and used and tested for a new application: as a resin matrix of solid grinding wheels for angle grinders. The manufacturing procedure developed is particularly easy. Cutting and grinding discs based on this green resin were used for bonding different sizes of abrasive particles of aluminium trioxide. These discs were characterized and showed excellent abrasiveness and cutting properties. Their mechanical resistance was found to be comparable to that of commercial grinding discs bonded with synthetic phenolic resins. They tolerated well the severe stresses induced on them at 11,000 revolutions per minute (rpm) by operation in an angle grinder when grinding or cutting steel.

1. Introduction

During the last decades there has been a continuous increase in oil prices. As a consequence of this, considerable research has been carried out in order to develop biobased and biosourced materials. Replacing petrochemicals is possible in many different industrial sectors. Natural and renewable materials coming from agriculture or forestry such as furfuryl alcohol and condensed polyflavonoid tannins have been used to develop new biobased materials: biobased adhesive resins (Pizzi, 1983, 1989, 1994; Zhou et al., 2013), insulation foams and floral foams (Tondi et al., 2008, 2009a,b; Basso et al., 2014a,b; Lacoste et al., 2013; Lagel et al., 2014a,b), fibre composites (Sauget et al., 2014), polyurethanes (Pizzi, 1979a,b; Basso et al., 2014a,b) even without isocyanates (Thebault et al., 2014a,b) and finally high tech paper laminates (Abdullah et al., 2013, 2014) and more recently new thermoset plastics based on a natural tannin-furanic thermoset resin (Li et al., 2013; Lagel et al., 2014a,b). These resins, based on the coreaction of tannins and furfuryl alcohol were developed to replace industrial oil-derived resins like phenolic resin in different applications, such as grinding wheels. In this article, firstly the possibility of preparing grinding discs made with biobased resin as a bonding system was studied. This is a difficult application as the stresses induced on a grinding wheel at 11,000 revolutions per minute (rpm) especially in contact with a hard material such as steel are rather severe. Secondly, the formulation of the resin was further modified to cure quicker and with no faults than the original resin of Li et al. (2013). This is an important point in order to develop it for industrial production. Abrasiveness characterisation tests by grinding and cutting steel bars and tubes, and mechanical properties of the grinding discs were investigated.

2. Material and methods

2.1. Materials

Quebracho (*Schinopsis lorentzii* and *balansae*) wood tannin extract (Fintan QSTW) powder was supplied by SilvaTeam (San Michele Mondovi', Italy). It must be pointed out that this tannin extract after water extraction from the wood, undertook a second extraction in ethanol to eliminate the majority of carbohydrates present. This type was used as while slightly more expensive it gives resins of much better performance.

Furfuryl alcohol (98%), polyethylene glycol 400 (PEG), ethylene glycol and *para*-toluene sulfonic acid (pTSA, with a purity of 97.5%) were purchased from Acros Organics, (Geel, Belgium).

Tung oil was purchased from Oleobois, (Vendargues, France).

Xiameter OFX-0193 Fluid (DC193) was purchased from Dow Corning, (Midland, United States).

Phenol liquified 80% w/w in water, pure was purchased from Fisher Scientific, (Loughborough, United Kingdom).

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Table 1
Grinding discs with quebracho tannin resin.

	Mass (g)										
	150% Alu 24	200% Alu 24	150% Alu 36	175% Alu 36	200% Alu 36	150% Alu 60	175% Alu 60	200% Alu 60	150% Alu 36–60	150% Alu 24–60	150% Alu 60
Furfuryl alcohol	21.44	21.44	21.44	21.44	21.44	21.44	21.44	21.44	21.44	21.44	/
Tannins QSTW	25	25	25	25	25	25	25	25	25	25	/
PEG 400	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	8.76	/
Tung oil	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59	/
DC 193	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	/
PF resin, F/P of 2.2	/	/	/	/	/	/	/	/	/	/	40
pTSA (65% in ethylene glycol)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	4
Abrasive particles	89.43	119.24	89.43	104.34	119.24	89.43	104.34	119.24	44.715 + 44.715	44.715 + 44.715	66.00

Formaldehyde solution 37% was purchased from Roth, (Karlsruhe, Germany).

For this work, three different sizes of abrasive particles were used. There were purchased from Centre des Abrasifs, (Valenciennes, France). Abrasive particles are aluminium trioxide (Al_2O_3): Alu 24 (grain size of 0.7 mm); Alu 36 (grain size of 0.4 mm) and Alu 60 (grain size of 0.25 mm).

Roving of fibreglass of 270 g/m^2 used came from Sinto (Aubagne, France).

An angle grinder Bosch GWS 1400 with a rotation of 11,000 rpm was used to test samples (Stuttgart, Germany).

A steel tube was used to test samples: round tube 6 mm × 1 mm and 1 m length, cold rolled steel from Alfer, (Wutöschingen-Horheim, Germany).

A commercial grinding disc of Opsial: A24R-BF27; thickness of 6.4 mm; diameter of 100 mm and a centre hole of 22.2 mm was used as a control.

2.2. Resins synthesis

2.2.1. Quebracho tannin resin

Firstly, furfuryl alcohol (21.44 g) and quebracho tannins (25 g) were mixed together with a mechanical stirrer during 15 s. Secondly, PEG (8.76 g), tung oil (3.59 g) and DC193 (0.13 g) were added. After each addition the mixing time is 15 s.

Finally, a 65% ethylene glycol solution of pTSA (0.7 g) was added as a catalyst under mechanical stirring for 15 s. The proportions were inspired by a previous work (Lagel et al., 2014a,b) and they are shown in Table 1. The viscosity of this tannin resin is about 3700 mPa s at 25 °C. This value was given by the use of a Brookfield DV-II + Viscometer, with S6 spindle and 60 RPM.

2.2.2. Acid catalysed phenol-formaldehyde (PF) resin

The PF control resin (molar ratio F/P = 2.2) was synthetized as following reagents: 1 mole of phenol as 80% phenol mixed with 2.2 mole of formaldehyde as a 37% aqueous solution. Formaldehyde was added in 4 equal parts. The time between the additions of parts is 15 min.

Firstly, phenol and the first part of formaldehyde were heated at 94 °C under reflux and continuous stirring. The reaction mixture was slowly brought in about 45 min to reflux at 94 °C under continuous stirring. This time corresponds to the time necessary to the complete addition of formaldehyde.

Once 94 °C is achieved, the mixture is left to react until a viscosity about 57,000 mPa s at 25 °C (Brookfield DV-II + Viscometer, S6 spindle and 10 RPM). In this case it was 2 h and 15 min.

During all the process, the pH was controlled at 2 by adding some drops of pTSA at 65% in water.

2.3. Grinding discs development

By observing commercial abrasive discs and their product specification sheets, it was found that they were composed of a bonding resin which was a phenolic resin. Aluminium oxide particles were the abrasive particles. And the reinforcement of the disc was composed of three layers of roving of fibreglass (Fig. 1).

2.3.1. Grinding discs made with quebracho tannin resin

The amount of abrasive particles was added to the resin and it was well mixing. Samples were done in a silicone mold. Firstly, one layer of fibreglass was put in the bottom of the mold, after the half of the abrasive resin was placed. Then, a second layer of fibreglass was placed and above this the second part of abrasive resin. Eventually, a third layer of fibreglass was put on the top of that. A silicone sheet was placed in order to close the mold. This system was put in a press during 1 h at 150 °C and with a pressure of 80 kg/cm^2 on