Glass Grinding Using Structured Superabrasives

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Abstract
In this paper, the feasibility of using microstructured (resin bond) and flexible, metal bond belts for glass grinding is explored. The results indicate that excellent surface finish can be achieved at high stock removal rate (up to 100 microns/minute infeed). Microstructured belts generate the best surface finishes, while the metal bond belts provide good surfaces with longer belt life. Grinding forces were measured and found to be typically less than 4 N.

Introduction
In this project, the performance of 3M diamond abrasive belts in glass grinding was studied. Two belt types are considered, including resin bond micro-replicated products. Previous work indicates that slow speed lapping can achieve a polished surface with minimal sub-surface damage. However, the material removal rate of the lapping process is slow and requires multiple lapping steps to achieve a finished product. Because of the relatively long processing time, this project explored the feasibility of belt grinding, which may offer substantially improved material removal rates.

Factors that influence the quality and rate at which glass parts may be ground include:
1. Coolant type, flow rate, orientation, and pressure
2. Abrasive type, concentration, bond material, geometry, and condition
3. Machine operation parameters such as grinding surface speed and infeed
4. Glass material type

In this study, special attention is given to the abrasive belt and the machine operating parameters; coolant and glass type are pre-selected based on the recommendation of 3M. In this study, four parameters were considered:

1. Abrasive belt type
    - metal flex
    - microstructured
2. Grinding speed:
    - 1000, 2000, & 3000 m/min
3. Abrasive grit size:
    - 20, 10, & 6 microns – metal bond
    - 15, 6, & 3 microns – resin bond
4. Infeed rate
    - 10, 30, and 100 microns/min

Experimental Setup
The tests were carried out on a custom designed belt grinding machine designed and built by Professional Instruments. The belt grinding machine features two air bearing spindles that are used with 1 meter long, 25 mm wide diamond abrasive belts. The belt grinding spindles are capable of surface speeds of 3000 m/min (10,000 ft/min). The belts and coolant are completely enclosed by an acrylic and aluminum box. Figure 1 shows a schematic of the Professional Instruments belt grinding machine.

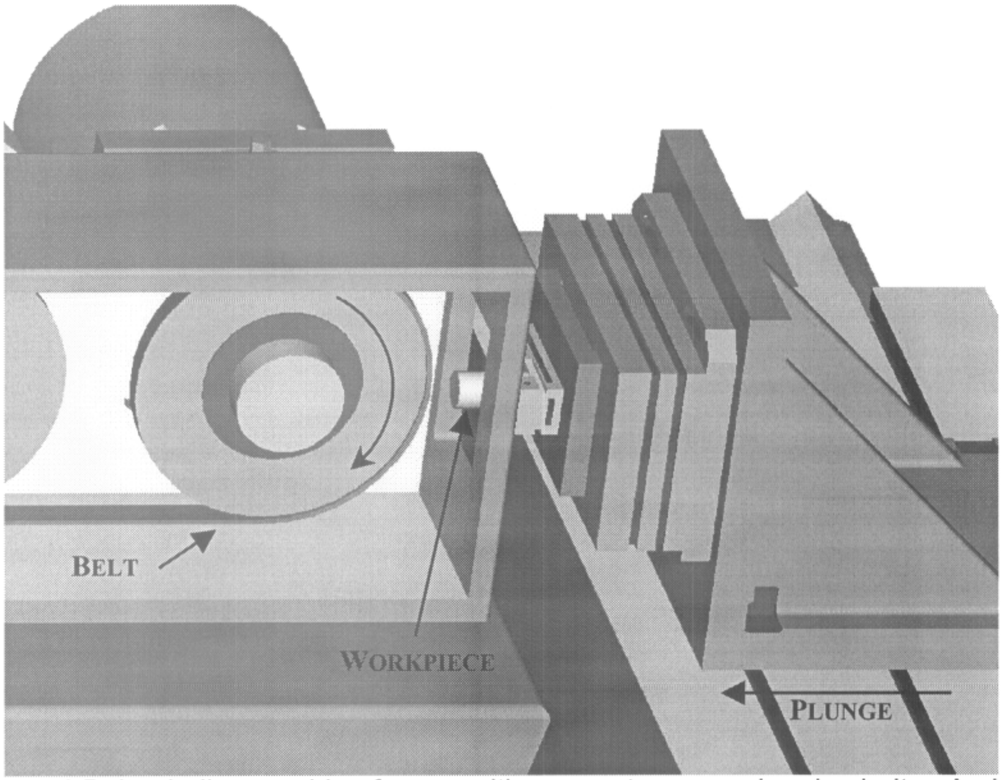

Figure 1 Belt grinding machine for use with one meter superabrasive belts. A glass workpiece is shown prior to being plunge ground against the rotating drive spindle.

Once the belt is installed in the machine, a 20 mm diameter by 4 cm long piece of soda lime glass is mounted onto a Kistler Force Dynamometer, which allows the cutting force to be monitored during grinding in three orthogonal directions.

Each plunge test is performed by first grinding enough glass to impart the concave shape of the round belt grinder drive wheel. An additional 0.25 mm of length is also removed at the infeed rate dictated by the particular grinding test. The grinding forces are recorded at high bandwidth for post processing using a Hewlett Packard 35670a Dynamic Signal Analyzer.

The surface roughness of each ground test piece is measured at 3M using a Mahr Corporation M4Pi Perthometer. The roughness is reported as the average of three measurements taken at various locations on the ground surface of the glass.

RESULTS: METAL BOND BELTS

Table 1 shows the results of the tests conducted with the metal flex belts. Visual and microscope inspections of the belts showed negligible belt wear. The grinding forces remained constant during individual grinding tests and any combination of material removal rate and belt speed yielded a low-force grind. The surface finish ranged from cloudy to slightly cloudy, depending on grinding parameters.

Table 1 Test results from metal flex belts.

Infeed (microns/min)	10			30			100			
Spindle speed (surface km/min)	1.0	2.0	3.0	1.0	2.0	3.0	1.0	2.0	3.0	
20 micron belt	1.0	1.0	1.0	1.5	2.0	NA	5.0	5.0	5.0	Normal Force (N)
Row #1	2.92	0.54	0.44	0.64	0.44	0.27	0.25	0.65	0.28	Ra (microns)
10 micron belt	1.0	1.0	1.0	3.0	3.0	1.5	5.0	6.0	4.0	Normal Force (N)
Row #2	0.23	0.42	0.45	0.19	0.25	0.23	0.63	0.35	0.21	Ra (microns)
6 micron belt	1.0	0.5	0.5	2.0	1.5	1.0	3.5	3.0	3.5	Normal Force (N)
Row #3	0.49	0.30	0.81	0.38	0.15	0.19	0.41	0.20	0.19	Ra (microns)

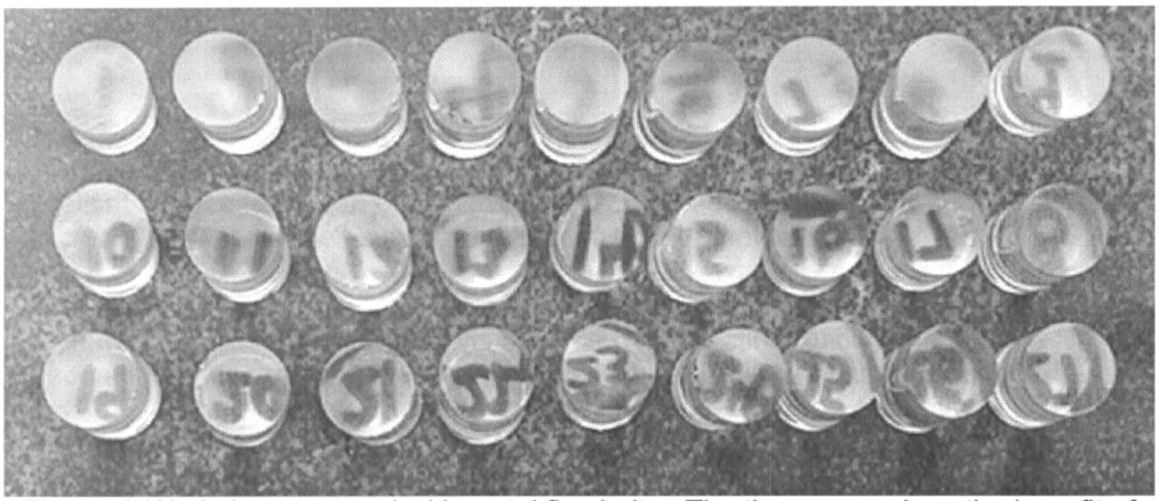

Figure 2 Workpieces ground with metal flex belts. The three rows show the benefit of decreasing the abrasive particle size, along with the benefit of *increasing* material removal rate.

TEST RESULTS: MICROSTRUCTURED (RESIN BOND) BELTS

Table 2 shows the results of the tests conducted with the microstructured belts. The high speed grinding at 3000 m/min (10,000 SFPM) was not possible because of breakdown of the belts from lack of adequate coolant exposure. Grinding forces remained constant during individual trials and variations in microstructure pattern were clearly visible in measured forces. Surface finish ranged from faintly cloudy to excellent, depending on grinding parameters.

Table 2 Test results from microstructured (resin bond) belts.

Infeed (microns/min)	10			30			100			
Spindle speed (surface km/min)	1.0	2.0	3.0	1.0	2.0	3.0	1.0	2.0	3.0	
15 micron belt	1.0	0.5	NA	2.5	1.5	NA	6.0	5.0	NA	Normal Force (N)
Row #1	0.19	0.35	NA	0.28	0.24	NA	0.19	0.53	NA	Ra (microns)
6 micron belt	3.5	3.0	NA	7.0	7.0	NA	45	17	NA	Normal Force (N)
Row #2	0.24	0.23	NA	0.17	0.32	NA	0.32	0.20	NA	Ra (microns)
3 micron belt	3.0	3.5	NA	11	NA	NA	30	15	NA	Normal Force (N)
Row #3	0.22	0.17	NA	0.20	0.37	NA	0.19	0.18	NA	Ra (microns)

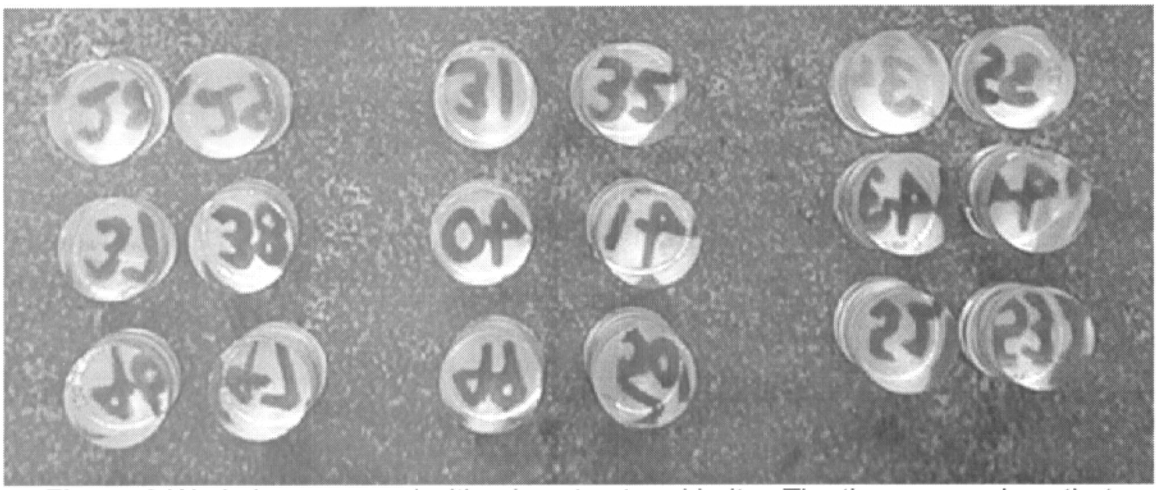

Figure 3 Workpieces ground with microstructured belts. The three rows show that excellent surface finish can be achieved with moderate abrasive particle size, moderate belt speed, and high material removal rate.

CONCLUSIONS

The current belt grinding test setup is capable of generating reasonable surface finishes on soda lime glass using the superabrasive belts with high material removal rates. For the microstructured belts, excellent results are observed for a relatively coarse (6 micron) abrasive size with a high material removal rate. Two additional observations are apparent.

1. The 30 and 100 microns/minute infeed give as good or better surface finish than the 10 micron/minute infeed.
2. Combinations of infeed (30 microns/min) and spindle speed (2000 surface m/min) exist where grinding force is very low (about 4 Newtons) and surface finish is excellent.

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