Session XXXX

Effects of Surface Treatment on Repair Methods for Trumpet Piston Valves

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Abstract

The piston valve of a trumpet experiences wear over time during its use, leading to poor performance or failure of the valve. Various surface treatments exist and are used to optimize performance and address defects. The surface treatments alter the surface topology to maximize durability and minimize friction. In this study, we examine the most common surface treatment methods including lapping, scouring, buffing, ultrasonicating, polishing, and chemical treatment. Based on this study, we show and compare the effects of these different surface treatment methods and provide recommendations for repair of piston valves for trumpets.

Introduction

While many of our nation's largest engineering schools have the problem of too many students, The trumpet is one of the oldest musical instruments; the earliest trumpets date back to 1500 BC [1]. Earliest trumpets consisted of rudimentary conical-shaped pipes and were used to amplify the sound produced by lip vibration [2–4]. The sound quality and functionality of trumpets have improved vastly over time [4]. The piston valves were added to allow the musician to change the length of the pipe, giving them the ability to play notes out of its acoustic scale [3, 5]; however, this functionality comes at a cost. The piston valve system is prone to damage and needs periodic repair to maintain the functionality [6]. Misalignment of trumpet piston valves causes a sluggish operation, where dents may cause a failure of operation altogether. Various surface treatments on the trumpet piston valves are performed to correct these issues. In some cases, newly manufactured instruments are also subjected to surface treatment due to subpar build quality. The amount and duration of the treatment can vary depending on the severity of wear or damage to the trumpet's piston valve. Common methods of trumpet piston valve repair consist of various surface treatments. The resulting surface structure greatly varies depending on the wear direction of the repair method and materials used.

The surface roughness and orientation of scratches on the piston valves are an important factor in determining the quality of the repair. The goal of the repair is to minimize friction while maintaining the integrity of the piston valves. Modeling presented by Keribar et al. [7] and Hacioglu et al. [8] shows that a transverse orientation of surface finish to the piston valve results in higher pressure from the lubrication oil. Due to the squeeze effect, the minimum required lubrication film thickness becomes smaller with higher pressure. Hence, the transverse orientation of the surface finish results in the most efficient lubrication. On the other hand, surface roughness correlates directly to friction.

Hence, a lower coefficient of friction is achieved via a smoother surface finish. Optimize functionality requires a balance between these two effects.

In this study, we examine the most commonly performed surface treatment methods including lapping, scouring, buffing, ultrasonicating, polishing, and chemical treatment. Two sets of piston valves are investigated: one composed of nickel-plated Nickel Silver and the other Monel. Characterization using scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS) is performed on the piston valves before and after the surface treatment. We show and compare the effects of these different surface treatment methods and provide recommendations for repair of piston valves for trumpets.

Experimental Methods

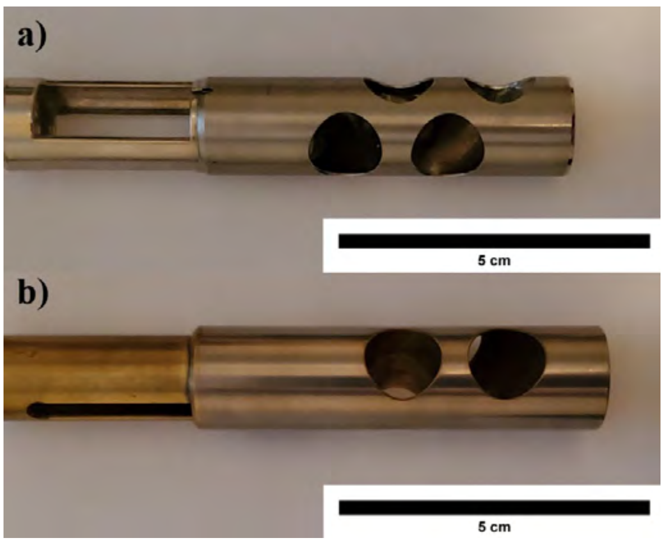

Figure 1. Photograph of a) Monel and b) nickel-plated Nickel Silver piston valve.

As illustrated in Figure 1(a)-(b), two types of piston valves were examined and consisted of two different materials: nickel-plated Nickel Silver and Monel. Both piston valves were made for a Bb trumpet and six of each type were purchased. The nickel-plated Nickel Silver piston valves are produced by the Getzen Company (Elkhorn, WI). Monel piston valves are produced by the Vincent Bach Company (Elkhart, IN). The piston valves have an average length of 64.6 mm and diameter of 16.5 mm. Imaging (SEM) and elemental mapping (EDS) of the piston valves were generated using a Hitachi TM3000 tabletop scanning electron microscope.

The piston valves were imaged before and after every surface treatment.Weight and diameter change of the samples were measured before and after every surface treatment. All repairs were performed at the Instrument Repair Shop in the Department of Music at the University of North Texas.

The following commonly performed surface treatments of trumpet piston valves were examined in this study: Lapping with lapping compound, scouring with a Scotch Brite pad, buffing on a wheel brush, sonicating in an ultrasonic bath, polishing with Miracle cloth, and chemical treatment in a sulfamic acid solution. After each treatment, cleaning is performed with dish soap and denatured alcohol to remove lubrication and debris followed with a rinse in water.

2.1. The Lapping Treatment

The lapping treatment used a garnet-based lapping compound made by Unilap. The compound has 5 µm particles, 1200 grit with heavy viscosity. The lapping treatment is performed using a woodblock with a cylindrical cutout. The compound is applied on the piston valve then the piston valve is inserted into the woodblock and moved axially in a helical motion to treat the surface. After the surface treatment, the piston valves are cleaned with dish soap and denatured alcohol to remove lubrication and debris. The lapping treatment can be seen in Video 1.

2.2. The Scouring Treatment

The scouring treatment was performed with a piston valve mounted on a rotor. 800 grit Scotch Brite pads are used. The pads are wrapped around the piston valve with oil-based lubrication and the rotor is set at 1725 rpm. With the rotor spinning, the piston valve is stroked along the length for five seconds. The scouring treatment can be seen in Video 2.

2.3. The Polishing with a Miracle Cloth Treatment

The polishing with a Miracle cloth treatment follows the same procedure as the scouring treatment; however, a Miracle cloth is used instead of a Scotch Brite pad. The Miracle cloth is produced by Dunlop Manufacturing, Inc. (Benicia, CA). The polishing with a Miracle cloth treatment can be seen in Video 3.

2.4. The Buffing Treatment

The buffing treatment was performed with a brass wheel brush mounted on a rotor. The rotor is set at 1725 rpm. The piston valve is lubricated with oil, then the piston valve is passed on the spinning brush spinning perpendicular to the length of the piston valve for five seconds with consistent strokes. The buffing treatment can be seen in Video 4.

2.5. The Acid Bath Treatment

The acid bath treatment involves using Sulfamic acid (H_3NSO_3). 453 grams of salts were added to 3.7 liters of tap water, creating a solution of 122 grams/liter. The concentration is recommended by the producer of sulfamic acid salts. The piston valve is submerged in the solution for 5-minute increments at room temperature. The piston valve is then rinsed with water and is subsequently cleaned and allowed to dry.

2.6. The Sonicating Treatment

The sonicating treatment involved ultrasonication, which was performed with a specially made ultrasonic tank with soap for five minutes at room temperature to clean the piston valve. The piston valve is then rinsed with water and is subsequently cleaned and allowed to dry.

Results and Discussion

Table 1. Elemental composition of the sample surface of nickel-plated Nickel Silver and Monel piston valves.

	Element	*Atomic %*
Nickel-plated Nickel Silver	Ni	100.00
	Total	100.00
Monel	Ni	64.30 (± 0.45)
	Cu	31.81 (± 0.45)
	Mn	1.28 (± 0.09)
	Fe	2.62 (± 0.11)
	Total	100.00

Table 1 shows the composition from EDS measurements prior to any surface treatments of the two types of materials (nickel-plated Nickel Silver and the Monel) used for the piston valves in this study [4]. It should be noted here that Nickel Silver or "German Silver" is a misnomer in that the alloy contains no silver; it only has the appearance of silver. Nickel Silver commonly consists of 55 to 60 at.% copper, 20 to 30 at.% zinc, and 15 to 20 at.% nickel [4, 9]. In any case, the Nickel Silver is then nickel-plated. The EDS analysis confirms that the surface is nickel- plated. The Monel composition is in agreement with ASTM B163 [10], which suggests that the piston valve is composed of Monel 400 [11].

While there are other factors such as part construction and fit, three factors which are dependent on the material used determine the overall quality of the piston valve: hardness, smoothness, and stability after finishing [12]. High hardness is necessary to avoid mechanical damage due to normal use. The hardness of both Nickel Silver and Monel are high relative to stainless steel. The nickel-plating of the Nickel Silver is added to increase the hardness at the surface but can wear off during use over time. The surface should be relatively smooth, but also ridged preferably in the transverse direction to motion, such that lubrication can create a film pressure, which improves the overall seal and air pressure of the piston valve [8]. The final condition of the material determines the smoothness, which is dependent on grain size and orientation and final finishing processes, such all the surface treatments discussed here [3, 4]. The final finishing process commonly used for piston valves prior to first use involves lapping, where rough surfaces on the piston valve are ground and polished in a mixture of abrasive particles and water-based or oil-based liquid typically using a lapping bock to improve the overall fit and fluidity of the part [13, 14]. Lastly, the stability after finishing is determined again by the final condition of the material. Stability includes wear-resistance due to friction and corrosion-resistance, especially in oily, salty, and humid environments, which again is determined by the material and the grain structure and surface finish of the material. Both the nickel-plated Nickel Silver and the Monel show good wear resistance and excellent corrosion-resistance, especially in oily, salty, humid environments such as those experienced in a trumpet piston valve [15].

Figure 2 shows SEM images of the surface of the nickel-plated piston valves before and after each treatment, where a) and b) are before and after 5 rounds of lapping, c) and d) are before using the Scotch Brite scouring pads and after 5 rounds of scouring, and e) and f) are before and after 5 rounds of buffing, respectively.

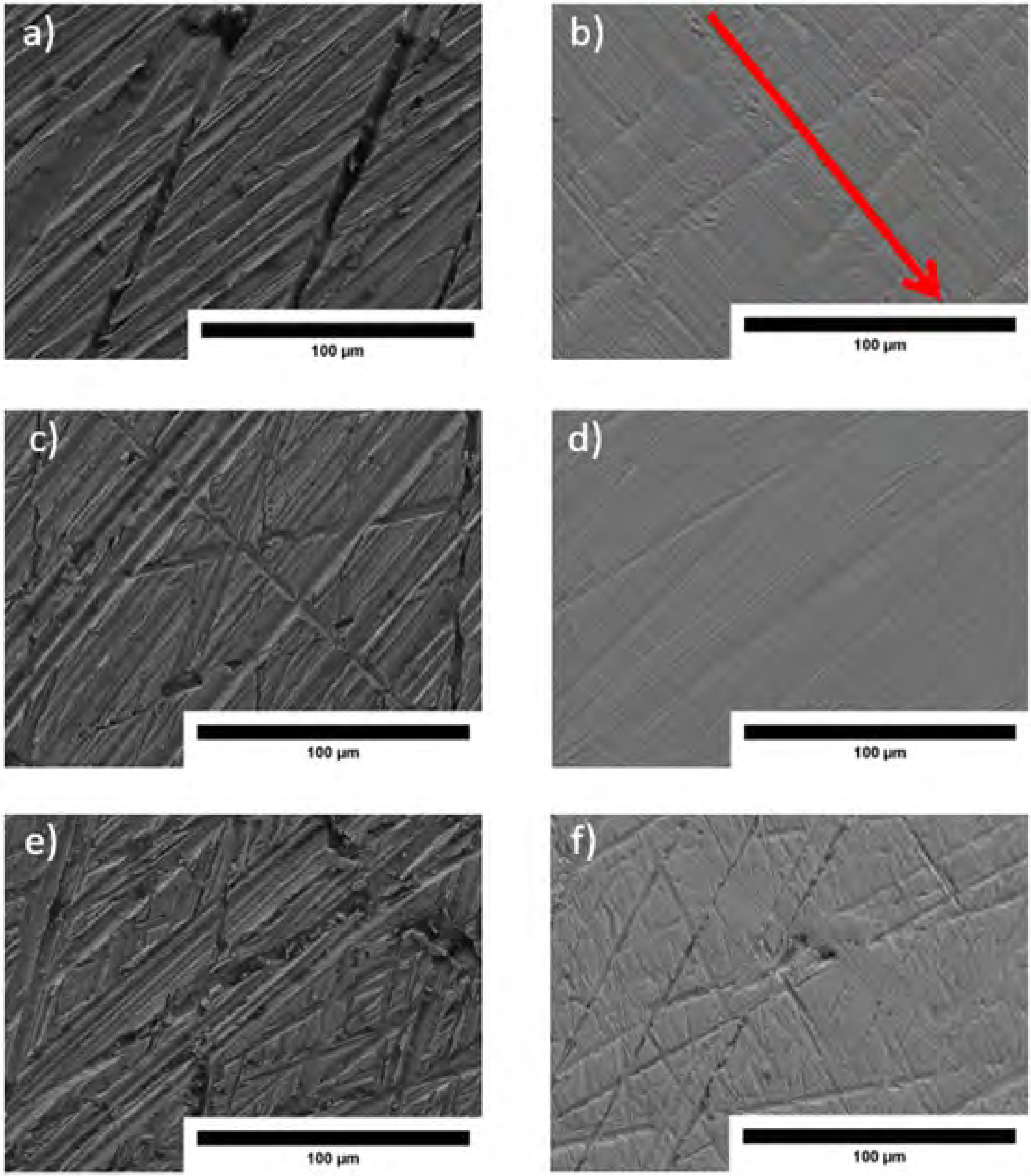

Figure 2. SEM imaging of nickel-plated Nickel Silver piston valves showing surface finishes: a) initial surface of sample before lapping, b) surface of sample after 5 rounds of lapping, c) initial surface of sample before using the Scotch Brite scouring pads d) surface of sample after 5 rounds of scouring, e) initial surface of sample before buffing, and f) surface after 5 rounds of buffing. The red arrow shows the axial direction of the piston valve from top to bottom and is the same for all images.

Figure 3 shows SEM images of the surface of the nickel-plated piston valves before and after each treatment, where a) and b) are before and after 5 rounds of miracle cloth, c) and d) are before and after 5 rounds of ultrasonication, and e) and f) are before and after 3 rounds of acid bath, respectively.

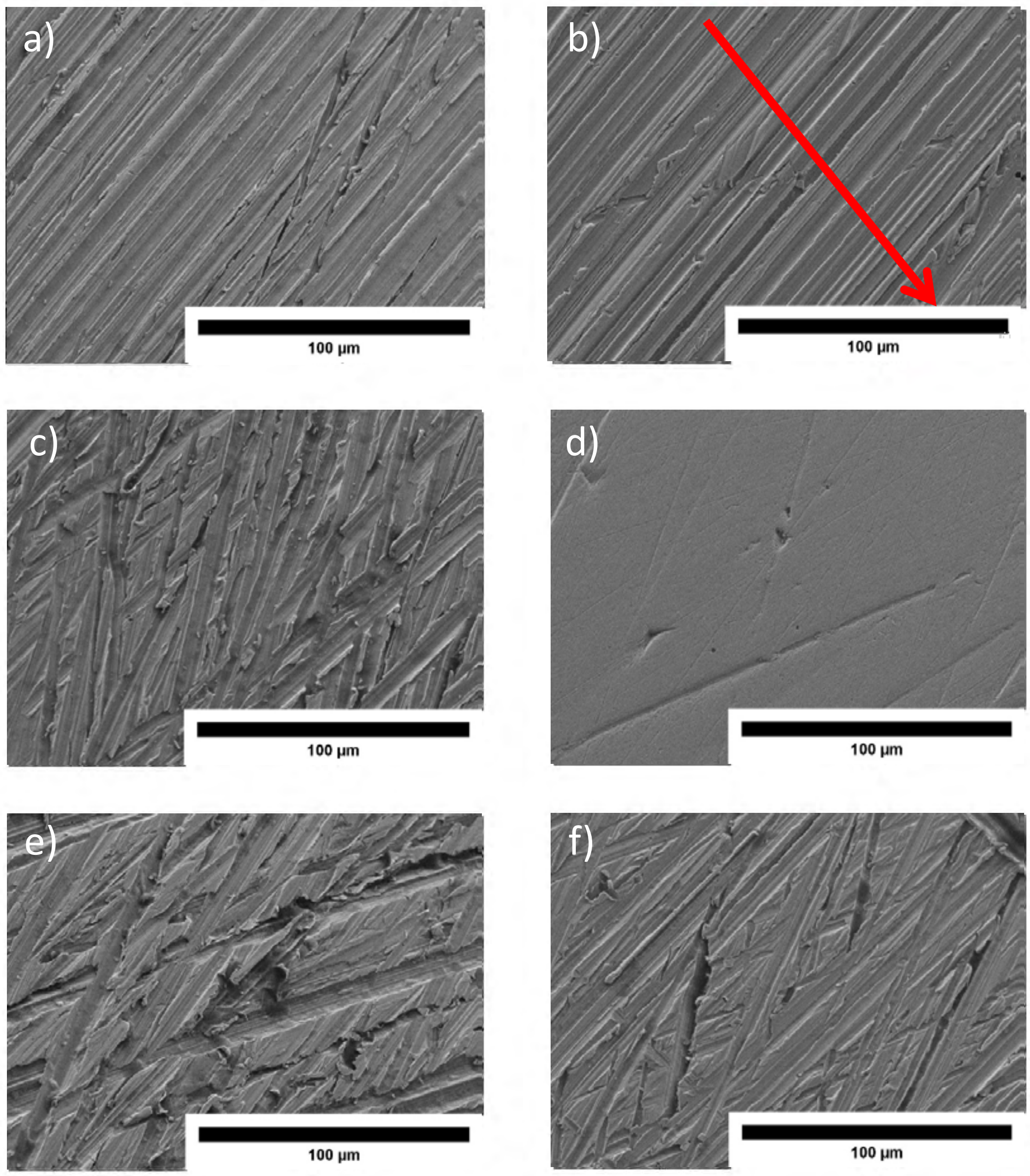

Figure 3. SEM imaging of nickel-plated Nickel Silver piston valves showing surface finishes: a) initial surface of sample before using miracle cloth, b) surface of sample after 5 rounds of miracle cloth, c) initial surface of sample before ultrasonication d) surface of sample after 5 rounds of ultrasonication, e) initial surface of sample before acid bath, and f) surface after 3 rounds of acid bath. The red arrow shows the axial direction of the piston valve from top to bottom and is the same for all images.

Figure 4 shows SEM images of the surface of the Monel piston valves before and after each treatment, where a) and b) are before and after 5 rounds of lapping, c) and d) are before using the Scotch Brite scouring pads and after 5 rounds of scouring, and e) and f) are before and after 5 rounds of buffing, respectively.

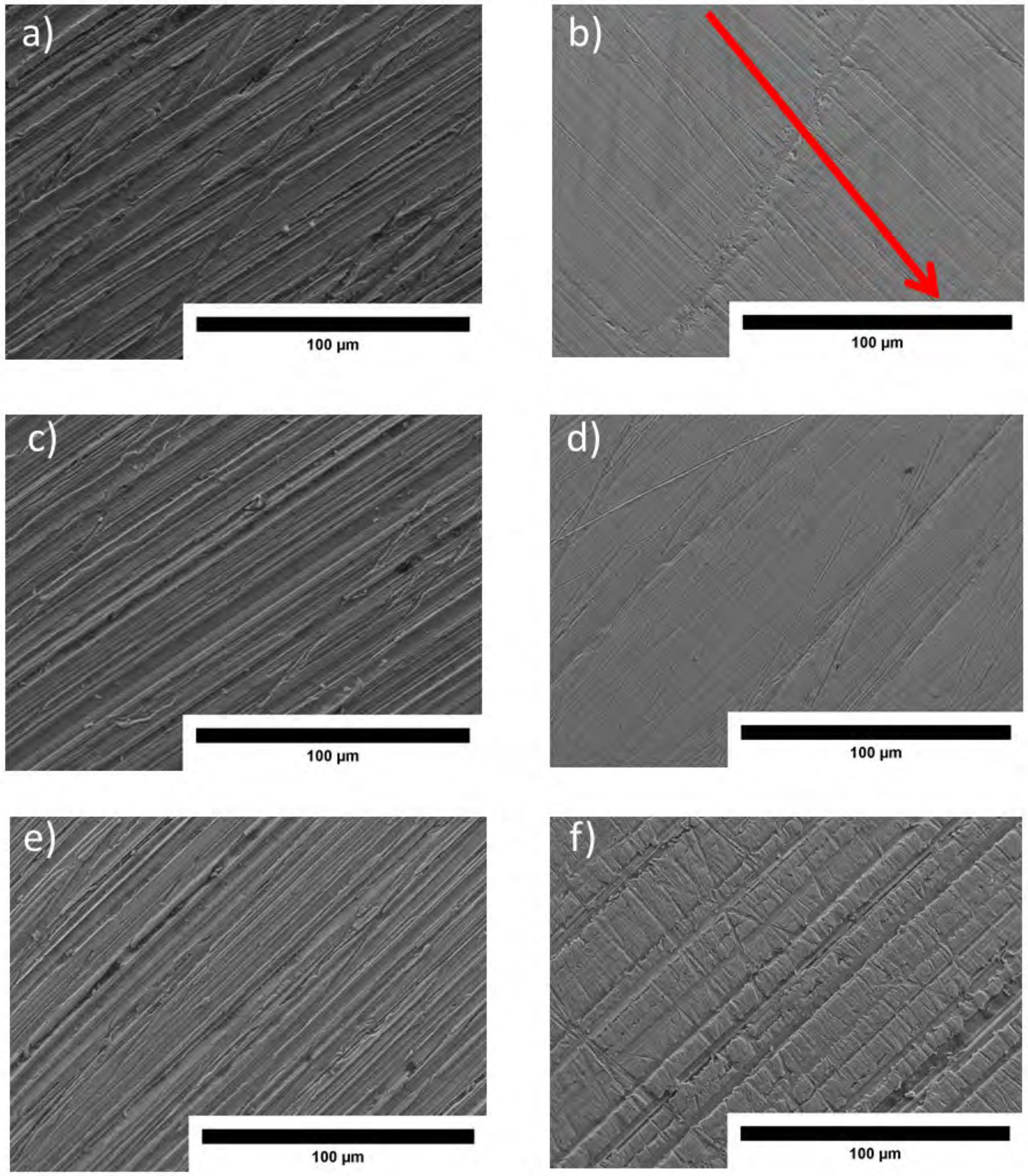

Figure 4. SEM imaging of Monel piston valves showing surface finishes: a) initial surface of sample before lapping, b) surface of sample after 5 rounds of lapping, c) initial surface of sample before using the Scotch Brite scouring pads d) surface of sample after 5 rounds of scouring, e) initial surface of sample before buffing, and f) surface after 5 rounds of buffing. The red arrow shows the axial direction of the piston valve from top to bottom and is the same for all images.

Figure 5 shows SEM images of the surface of the Monel piston valves before and after each treatment, where a) and b) are before and after 5 rounds of miracle cloth, c) and d) are before ultrasonication and after 5 rounds of ultrasonication, and e) and f) are before and after 3 rounds of acid bath, respectively. A red arrow in Figures 2-5 indicates the axial direction of the piston valve from top to bottom and is the same for all images.

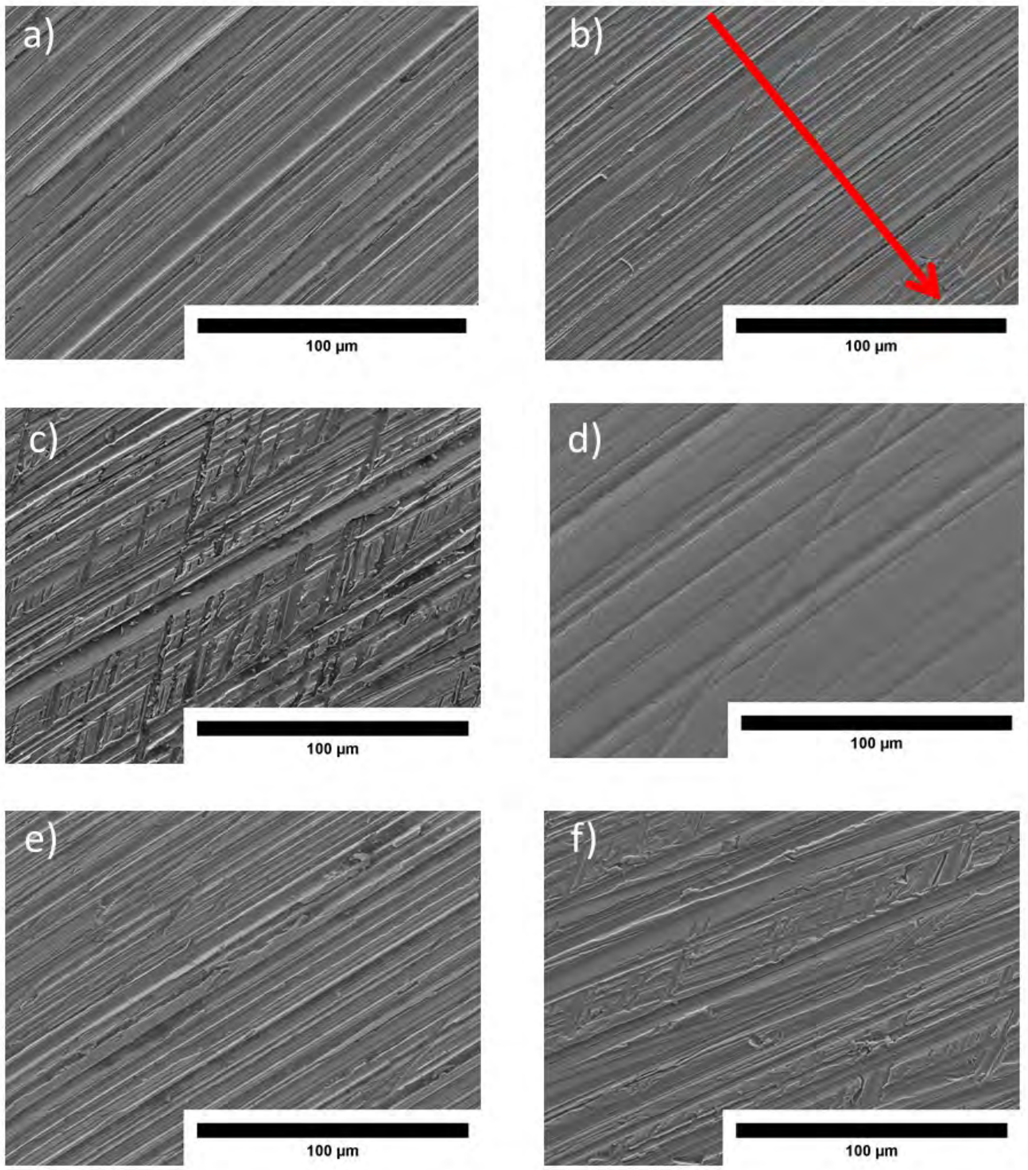

Figure 5. SEM imaging of Monel piston valves showing surface finishes: a) initial surface of sample before the use of miracle cloth, b) surface of sample after 5 rounds of miracle cloth, c) initial surface of sample before using ultrasonication, d) surface of sample after 5 rounds of ultrasonication, e) initial surface of sample before acid bath, and f) surface after 3 rounds of acid bath. The red arrow shows the axial direction of the piston valve from top to bottom and is the same for all images.

As illustrated in Figures 2(a)-(b) and 4(a)-(b), the lapping method resulted in a similar surface that would be achieved through wear in normal trumpet use. The general orientation of surface scratches changed from the transverse to the longitudinal direction. Also, there were no embedded garnets found on the surface. This is due to the hardness difference between the garnet in the lapping compound and the metal surface. Any lapping compound with harder granules such as silicon carbide or alumina may result in embedded particles and micro-voids (Agbraji 2009).

As illustrated in Figures 2(c)-(d) and 4(c)-(d), the scouring method with a Scotch Brite pad resulted in a reduction of surface roughness and transverse orientation of surface scratches. This is due to the wear direction of the repair method. The piston valve is mounted on a rotor and the pads are wrapped around the piston valve; therefore, no significant wear along the length of the piston valve is observed.

As illustrated in Figures 3(c)-(d) and 5(c)-(d), the use of the Miracle Cloth results in the smoothest surface finish. This is also noticeable to bare eye since the surface is much shinier than other samples. There are no significant changes in directions relative to the scratches; rather, lower surface roughness is achieved compared to the other surface treatment method.

As illustrated in Figures 2(e)-(f) and 4(e)-(f), the use of a brass wheel brush for buffing results in unidirectional scratches with pitting. The pitting may be due to particles trapped in the brush from repeated use. This surface is not desirable, and a secondary treatment would be necessary.

As illustrated in Figures 3(a)-(b) and 5(a)-(b), the ultrasonication did an exceptional job of removing particles from the surface, but no other surface changes were observed. This process is more suited for the cleaning process rather than a surface treatment process.

As illustrated in Figures 3(e)-(f) and 5(e)-(f), the acid bath showed a softening of the surface roughness. Longer times would be needed to further smooth the surface at the expense of more surface loss. This surface treatment process is more suited to be used after an initial surface treatment process, like using a Scotch Brite scouring pad or Miracle cloth, to further smooth the surface.

The surface treatments show no significant differences between the nickel-plated Nickel Silver and the Monel; i.e. regardless of the piston valve’s elemental composition, the surface treatment shows the same surface topology. The orientation and roughness of two material’s surfaces were mainly determined by the repair method.

Tables 2 and 3 show the results of the piston valve diameter change with the various treatments as a function of successive trials of surface treatments. No significant change in diameter of the piston valves was observed after 5 repetitions of surface treatments, with the exception of the first trial surface treatment for the lapping, Scotch Brite, and Wheel Brush methods.

Table 2. Nickel-plated Nickel Silver (Getzen Company) piston valve diameter change.

	Lapping	*Scotch Brite*	*Wheel Brush*	*Ultrasonic bath*	*Miracle Cloth*	*Sulfamic acid*
Trial 1	16.60	16.68	16.60	16.53	16.54	16.54
Trial 2	16.52	16.53	16.53	16.53	16.53	16.53
Trial 3	16.52	16.53	16.54	16.55	16.53	16.53
Trial 4	16.53	16.54	16.53	16.54	16.53	
Trial 5	16.53	16.52	16.53	16.53	16.53	

Table 3. Monel (Bach Company) piston valve diameter change.

	Lapping	*Scotch Brite*	*Wheel Brush*	*Ultrasonic bath*	*Miracle Cloth*	*Sulfamic acid*
Trial 1	17.11	17.10	17.11	16.89	16.89	16.90
Trial 2	16.89	16.89	16.89	16.89	16.89	16.87
Trial 3	16.89	16.88	16.89	16.89	16.88	16.87
Trial 4	16.88	16.88	16.87	16.88	16.87	16.87
Trial 5	16.88	16.88	16.87	16.88	16.87	

Conclusions

Surface treatment to repair trumpet piston valves can be performed using a variety of methods. In this study, we examined six of these surface treatments including lapping, buffing, scouring, ultrasonicating, and polishing on two compositionally different piston valves. No significant differences were observed between the nickel-plated Nickel Silver and Monel piston valves. As observed in SEM images, each surface treatment results in a change of surface topology. The change of orientation of scratches leads to change in lubrication-surface interaction. To maximize efficiency of the system, transverse orientation of scratches with low surface roughness is desired to maintain good lubrication and air pressure during instrument use. Based on this study, the use of a scouring pad with piston valves mounted on a rotor showed the best surface finish in this aspect. The ultrasonication can be used in conjunction with the scouring treatment for a better cleaning process.

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