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Visor Scratch Repair and Prevention

Severe eye injuries occur in 30 percent of demining accidents.1 Visors are known to be effective personal protective equipment when worn properly, but deminers often lift or remove their visors because glare or fog make them hard to see through, or because they are hot, heavy and uncomfortable to wear.2 Addressing each of these specific design problems could increase visor use and prevent a significant number of debilitating injuries. This paper presents methods for preventing and eliminating scratches on demining visors.

by Andrew Heafitz [Massachusetts Institute of Technology] | Benjamin Linder [Franklin W. Olin College of Engineering] | Maria Luczynska [Massachusetts Institute of Technology] | and Mark Scott [Cambridge University]

Scratches are a number of well-known methods for polishing polycarbonate surfaces. These include: dry sanding, buffing, applying solvents (by dipping, wiping and vapor deposition) and heating with a flame or hot air or hot gas. Several of these techniques were considered in an effort to identify a process that was effective and inexpensive, and thus suitable for deminers to use in the field. Polishing by buffing the plastic surface with a heat gun was determined to be the most effective and is discussed in detail in the next section.

Several polishing techniques that mechanically contact a surface were tried including sanding and buffing. However, these methods were found to produce inadequate, unsterile finishes and could damage the shields if the operator was imprecise.

Scratching requires the use of chemicals that soften the plastic's surface. Most of these techniques were eliminated from consideration due to the difficulties associated with the chemicals involved, including significant health and safety hazards, such as those associated with using methylene chloride for vapor polishing.3 Nevertheless, we did experiment with dipping polycarbonate samples in acetone. This technique removed fine scratches from the samples but did not diminish scratches that would disrupt vision.

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Figure 1: Scratches and sun glare impair visibility through visors during a training exercise at the Humanitarian Demining Training Center, Ft. Leonard Wood, Missouri.

This polishing procedure proved to be effective as removing scratches both when the samples were baked and when they were heated using a hot air gun, or heat gun. However, baking involves bringing plastic to an elevated temperature for an extended period of time, which requires a special jig4 and additional skills to prevent a shield from sagging and losing its shape. Heat guns work quickly and warm only a portion of the visor at a time, and they do not result in misinformation. Heat guns were deemed to be more controllable and appropriate to the task than the torches needed for flame polishing. However, it is possible to do both baking and heating a shield could be adapted for flame polishing.

Process

The heat-gun process for repairing moderate scratches on polycarbonate visor shields is straightforward and only requires the use of a heat gun and the ability to wash the shield. For more heavily scratched visors, polishing is necessary, which requires the use of an oven.

Polycarbonate absorbs a small amount of moisture (typically 0.1 to 0.35 percent by weight), which results in bubbles forming on the surface (see Figure 2). Move the tip of the heat gun in a concentric circular motion so that heat does not build up in any one location. As soon as the scratches disappear from one location, move to a new location and continue until all small- to medium-sized scratches are removed (see Figure 3).

Cook the shield. Remove the shield from the drying oven and let it cool for 20 minutes after removal of the heat. An intermediate cooling step is necessary to avoid heat buildup during the scratch removal step, which can lead to overheating and damage.

Position the shield. Hold the shield up to a light source with one hand so that you are looking at the scratched side of the shield and towards the light (see Figure 2). Scratches are easiest to see when illuminated from behind. However, an operator must be careful to not mistakenly try to remove a scratch that is visible through the plastic front by the light of the shield.

Remove the scratches. With the other hand, use a heat gun set to a high setting with its outlet three to five centimeters (two to three inches) from the surface of the shield (see Figure 2). Move the tip of the heat gun in a concentric circular motion so that heat does not build up in any one location. As soon as the scratches disappear from one location, move to a new location and continue until all small- to medium-sized scratches are removed (see Figure 3).

Drying for an extended period of time drives off this moisture and prevents bubbling during subsequent heat treatment. Smaller scratches—those that can be removed with a heat gun in less than 10 seconds—can be cleared without drying if done carefully. Attempting to remove larger scratches in undried plastic almost always leads to bubbles forming.

The following process to repair heavily scratched polycarbonate shield may need to be adjusted for different visors, equipment or environmental conditions. In any case, experimentation with scrap materials is advisable.

Wash the shield. After disassembling a visor, wash the shield with a drop of non-abrasive, liquid dish soap applied with the fingers. Rinse the shield until the soap and any debris are removed. Pat the shield dry with clean cloth. Washing is necessary to remove dirt marks, which an operator can mistake for scratches in the removal step, potentially causing him to overheat the plastic. Furthermore, dirt could become permanently embedded in the plastic when it is heated.

Dry the shield in an oven. This step is optional for removing light scratches and haze, but must be used to prevent bubbling in the plastic if medium or heavy scratches are to be removed. Preheat the oven to 120 C (250 F) for a five-millimeter- (quarter-inch)-thick shield. Place the shield in the oven without allowing the optical surface to touch the rack. Dry the shield for 24 hours. The drying time is a function of material thickness and must be obtained from the material supplier or through experimentation.

In order to dry different materials, the oven temperature should be raised to 50 C (120 F) for 90 minutes or until the plastic is dry. However, this value will vary depending on the material supplier or through experimentation.

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Scratch Prevention

The alternative to repairing scratched visors is protecting the polycarbonate from scratching. A natural way to remove a visor during a break or at the end of the day is to place it face down on the ground, yet this repeated action could cause severe scratching. The addition of a wrap-around rigid bar or “roll bar” (see Figure 6 on next page) above the deminer’s field of view can prevent scratches resulting from contact with the ground and the transportation and storage of the visor (see Figure 6b on next page).

Several geometries and materials for a roll bar were tried. Promising results were achieved using round aluminum tubing bent into a shape square and fastened to the visor using the bolts that secure the headband. A strip of polycarbonate was found to be too flexible to reliably protect the visor surface, and other shapes, such as a round arc, allowed the visor to rock back and forth when placed face down. Bending is undesirable because the visor could come to rest against an abrasive object, or possibly rumble out of a demining lane.

The roll bars as shown in easy to form, weigh 80 grams (3 ounces), and provides a central guidance clearance of three centimeters (1.2 inches). Demining equipment should not further endanger a deminer in the event of an accident involving a blast, so the roll bar was built around a dummy using a 240-gram (half-pound) charge of 50 percent TNT and 50 percent PETN to simulate a blast mine. As a result of the explosion, the roll bar was pushed up to the top of the visor, but did not deform or details, which shows that anchoring it firmly to the helmet allows it to be a secure enough location and the bars did not add to the weight or debris hazard of the blasts.

The roll bar has advantages over some other methods for protecting polycarbonate visors from scratches. For instance, a thin sacrificial layer of plastic could be placed over the basic visor. Once this layer becomes scratched, it is easily removed, doubling the life of the visor. However, this method introduces extra material through which the deminer has to see. Sacrificial layers are especially problematic if dirt or moisture becomes trapped between the layers. Also, since the sacrificial layer gets scratched, visibility gradually degrades until the layer is removed. The roll bar reduces scratching on any optical surface, whereas the sacrificial layer collects the scratches on a disposable surface. Leg promulgating from the sides of the visor have also been implemented in the past. However, the roll bar offers a protective geometry for a wider range of surfaces and situations than legs.

MIT “Design for Demining”

The research on this project was conducted in the “Design for Demining” class taught at the Massachusetts Institute of Technology. The primary goals of the course are to teach students about product design, increase their knowledge of the complex topic of demining and have them create and deploy products that are appropriate for the demining community. When students develop a product or process that they think promise, they distribute it by publishing the details in the public domain so the idea can be used on a wide scale as possible. Giving away intellectual property is a fast and effective alternative to the more conventional route of patenting and selling an invention.

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