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Visor Scratch Repair and Prevention

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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 scratches, 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.

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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.
PHOTO GROUP COURTESY OF MARTA LUCZYNAKA

Since deminers rely heavily on their eyes, they have two choices when their visors become scratched. Either they leave the visors down and work with impaired vision, which could increase the chances of an accident, or they raise the visors, which breaks standard operating procedures and leaves their eyes and face vulnerable to injury in the event of an accident. The following scratched visor story is one of many in the Database of Demining Incidents and Victims[3]:

"It was August 10, 2000, in Iraq. Work started at the site at 05:45. [The Section Leader had] been conducting his duties for three hours when … a deminer informed [him] 'that there was a strange object in his excavation lane.' The Section Leader tried to excavate the object but had some difficulty 'seeing it clearly because his visor was dirty and scratched. So he raised his visor halfway to see better."

The strange object turned out to be a detonator, which exploded while the Section Leader was investigating. Because his visor was raised, he sustained severe injuries to his right eye. The Board of Investigation concluded that the victim's "visor was dirty, poorly cleaned and scratched, which would have made it extremely difficult for him to identify … a small object." The Board concluded that the state of the victim's visor was partly attributable to the reason that he carried out his actions with his visor up. Furthermore, all visors of the group were of similar condition.

Scratches can be caused by the visor shield contacting abrasive sand and other materials or by grit being rubbed into the soft plastic when the visor is being wiped clean. Not only does scratching significantly reduce the optical clarity of the visor, but scratches also catch glare from the sun (see Figure 1).

This article explains our research in enough detail for people in the demining field to experiment with our procedures and make informed decisions about whether the methods described can help increase the effectiveness, ease of use and longevity of visors. This paper focuses on two methods for improving and maintaining visor clarity. The first is to repair scratches in the visors using a heating process, and the second is to use a protective roll bar to prevent abrasive objects from scratching the visor. Even with increased longevity, visors need to be replaced regularly, regardless of whether they are scratched or not, because the plastic becomes embrittled from extended exposure to ultraviolet light during use, which can reduce the level of protection provided. The authors did not investigate the effects of UV damage to visors or the effects of the repair techniques on this type of damage.

Visor Repair

Visor shields are typically made of polycarbonate, which is relatively soft and easily scratched. Scratch-resistant coatings are difficult to use in demining visors because they harden the material, making them more brittle and likely to fracture in the event of an accident. Scratch-resistant polycarbonate is also difficult to thermoform into a visor shape.

There are a number of well-known methods for polishing polycarbonate surfaces. These include wet or dry sanding, buffing, applying solvents (by dipping, wiping and vapor deposition) and heating with a flame or hot air or by baking. Several of these techniques were considered in an effort to identify a process that was effective and inexpensive, and thus suitable for demining teams to use in the field. Polishing by reflowing 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, satinized finishes and could damage the shields if the operator was impatient.

Solvent polishing 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.[4] Nevertheless, we did experiment with dipping polycarbonate samples in acetone. This technique removed fine scratches from the samples but made fluid flow marks that would distort vision.

Heat-polishing proved to be effective at 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 jig[5] 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, so they do not result in misshapen visors. Heat guns were deemed to be more controllable and appropriate to the task than the torches needed for flame polishing. However, it is possible that the process for using a heat gun could be adapted for flame polishing.

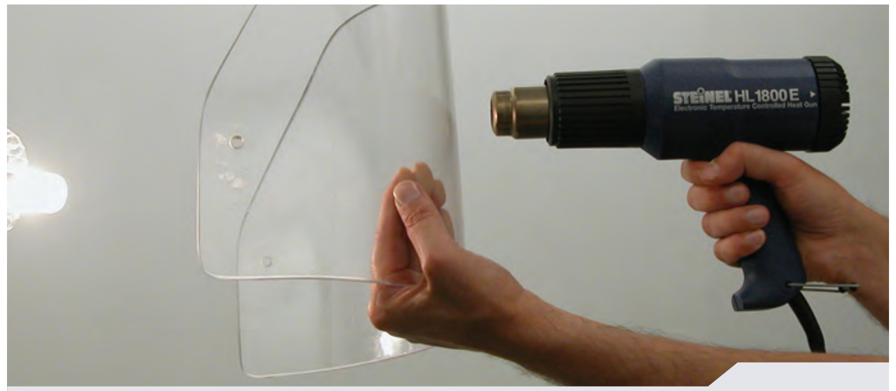

Figure 2: Clearing scratches from a visor with a heat gun. The backlight illuminates the scratches.
PHOTO COURTESY OF ANDREW HEAFITZ AND BENJAMIN LINDER

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, predrying 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 in the polycarbonate when it is heated to high temperature. Drying for an extended period of time drives off this moisture and prevents bubbling during subsequent heating. 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 a 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 nonabrasive, liquid dish soap applied with the fingertips. 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 an 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 materials supplier or through experimentation. Instructions for drying different grades and shapes of plastic are available from plastic materials suppliers.[6] A five-millimeter-thick dried shield can be stored for up to 24 hours in moderately humid conditions (50 to 60 percent humidity) and still be treated effectively.

Cool the shield. Remove the shield from the drying oven and let it cool for 20 to 30 minutes until cold to the touch. The 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 from the back of the shield.

Remove the scratches. With the other hand, use a heat gun set to a high setting with its outlet held about three to five centimeters (one to two inches) from the surface of the shield (see Figure 2). Move the tip of the heat gun in a constant 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 3a). Dwelling with the gun in one location for 10 seconds or more on undried plastic will

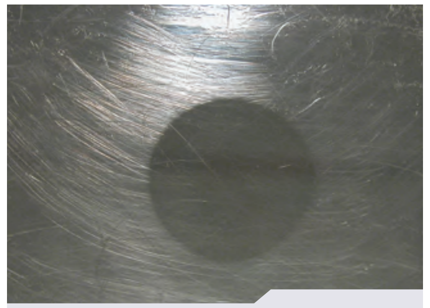

Figure 3a: Heating the plastic with a heat gun clears light scratches first.
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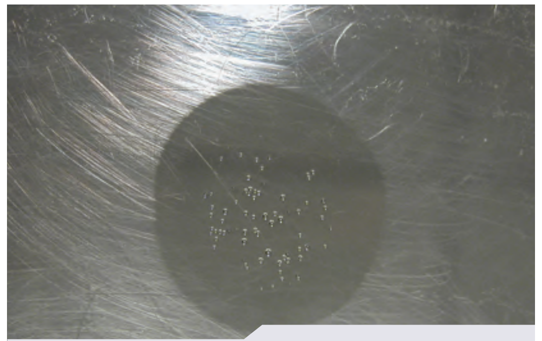

Figure 3b: Overheating undried plastic will cause bubbles. The visor must be oven-dried to clear medium to heavy scratches.
PHOTO COURTESY OF ANDREW HEAFITZ AND BENJAMIN LINDER

cause it to bubble (see Figure 3b). Dried plastic will not bubble, but it will get soft enough to distort and create a wavy surface. Waves create an undesirable lens effect that significantly distorts the image seen through a shield.

This process was used successfully in an environment with temperatures ranging from 15 to 27 C (60 to 80 F) and 50 to 60 percent relative humidity. Heat guns rated for 1,000 to 1,500 watts were used successfully, as were conventional and air-circulating ovens. It may be difficult to find ovens in some areas large enough to hold shields without putting plastic too close to a heating element.

Performance

A heat gun is highly effective at removing all haze and small scratches from polycarbonate visors (see Figure 4) and can be used effectively with medium-sized scratches with the addition of pre-drying. Deep scratches are reduced somewhat but not eliminated by the process.

To verify the process, a sample visor was heavily scratched and then treated using the full set of steps including pre-drying. The scratches were created by rubbing and pressing the face of the shield into a tray of mixed-sized gravel and sand until it was not possible to see through it and a range of small, medium and large scratches had formed. The treatment removed the small- and medium-sized scratches and restored the visor to a clear state comparable to a new visor with only a few large scratches remaining.

Clearing small scratches and haze from an undried visor did not create any additional stress concentrations in the treated shield, which were visualized using sheets of polarizing film (see Figure 5). Drying and treating heavy scratches in a different visor did produce some residual stresses. It is not known to what extent these stress concentrations will affect the performance of the visor and could lead to failure in the field. Security Devices (PVT) Ltd.,[7] the maker of the visor, is subjecting the treated shield to a V50 ballistic test. A possible solution is to add a step at the end of the process in which the drying oven is also used to anneal the plastic. The effect of multiple treatments on performance is not known and could degrade performance. It is possible multiple treatments could also result in yellowing of the plastic, as this is a known issue with heating polycarbonate.

From a cost perspective, the equipment needed is not expensive. The heat gun was purchased for US$70, which is roughly the cost of one or two visors. If the heat-gun treatment doubled the life of a visor, the payback time for this equipment would be as short as the time to treat two visors. The process does require some training and practice, but this cost could be spread out over many visors. A drying oven is not required for repairing haze and minor scratches; it could be as basic as a kitchen oven. A more elaborate facility, with a drying oven and a technician, could perform more extensive repairs, and allow more badly scratched visors to be re-used.

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"

Figure 4: The entire visor was severely scratched, and then the lower half was cleared of light scratches using a heat gun without oven drying.
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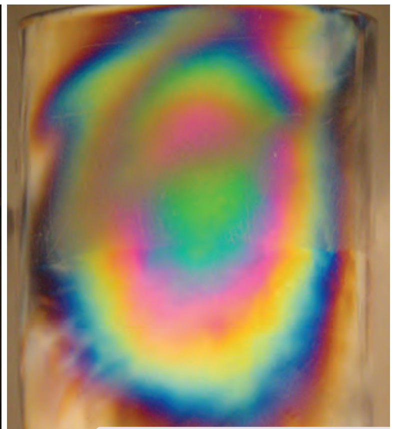

Figure 5: Viewing the treated visor in polarized light shows that clearing light scratches from the bottom half did not change residual stresses in the plastic.
PHOTO COURTESY OF ANDREW HEAFITZ AND BENJAMIN LINDER

(see Figure 6a 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 square shape 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. Rocking is undesirable because the visor could come to rest against an abrasive object, or possibly tumble out of a demining lane.

The roll bar as shown is easy to form, weighs 80 grams (3 ounces), and provides a central ground 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 blast-tested on a dummy using a 240-gram (half-pound) charge of 50 percent TNT and 50 percent PETN[8] 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 detach, which shows that anchoring it firmly to the harness bolts is a secure enough location and the bar does not add to the shrapnel or debris hazard of the blast.

The roll bar has advantages over some other methods for protecting polycarbonate visors from scratches. For instance, a thin sacrificial layer of plastic can be placed over the basic visor shield.[9] 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

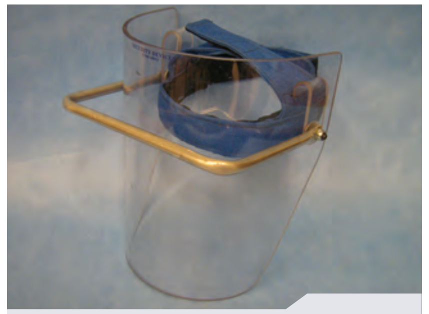

Figure 6a: A rigid "roll" bar can be attached to a visor to prevent the face shield from contacting the ground or other surfaces that cause scratching.
PHOTO COURTESY OF ANDREW HEAFITZ AND BENJAMIN LINDER

problematic if dirt or moisture becomes trapped between the layers. Also, as 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. Legs protruding 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.[10] 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 the students develop a product or process that shows promise, they distribute it by publishing the details in the public domain so the idea can be used on as wide a scale as possible. Giving away intellectual property is a fast and effective alternative to the more conventional route of patenting and selling an invention.

Figure 6b: A visor resting on the bar instead of its face shield.
PHOTO COURTESY OF ANDREW HEAFITZ

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See Endnotes, page 112

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Mark Scott is currently in his fourth year in electrical and information sciences at Cambridge University, UK. He went to MIT on a year-long exchange program in which he sought to apply his background in unified engineering to product design. MIT Demining provided the ideal opportunity to gain valuable research skills while making a difference in the global community.

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