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THE USE OF 3D PRINTERS IN THE UNBENDING OF THIN SHEETS MADE FROM METALLIC MATERIALS

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Abstract

The aim of the work is to explore the possibility of using 3D printers in an innovative way to restore thin metallic sheets to their original shape when they have been accidentally deformed. One of the methods applied in the automotive industry for unbending metal sheets is the Paintless Dent Repair (PDR) technology, which involves repairing dents or impacts on car bodies without repainting the affected areas. To restore painted steel or aluminum sheets to their original shape, various devices are used that allow for massaging and pulling the metal. Devices used for pulling the sheets often employ suction cups, which can be easily designed and printed using 3D printers with common materials such as PLA, ABS, or PETG.

Key words: Metal sheet, 3D printing, suction cups, hail, unbending

1. Introduction

It is well known that dents in car bodies are commonly encountered in the automotive industry. As a result of climate change, hailstorms are becoming increasingly frequent, causing a series of dents on car metal sheets, as shown in Fig. 1.

Fig. 1: Car damaged by hail [12]

In most cases, there is no access to push or strike the metal sheet from the inside to restore it to its original shape.

Large household appliances can also suffer various dents on visible surfaces, which are often nearly impossible to disassemble to allow the metal sheet to be unbent.

These deformations can be repaired and restored to their original shape:

- through disassembly, straightening, filling, and repainting, a process that is typically expensive and time-consuming;
- through non-invasive techniques that do not affect the paint or the anti-corrosion layer, using various devices.

The materials used in the automotive industry [1], [2] for manufacturing car body sheets include alloy steel sheets [3], [4], aluminum and aluminum alloys [5], and composite materials [6]. These materials are selected to ensure high corrosion resistance and good mechanical strength while maintaining a low weight to minimize carbon emissions [7]. The steels used for automotive sheets are alloyed to enhance corrosion resistance [7], [8], [9], [10].

Studies and research [11] have been conducted to highlight the impact of protective layer removal methods on the corrosion resistance of the sheets. These studies indicate that when sanding is performed with abrasive paper or discs, the zinc layer that protects the steel can be compromised.

Removing the protective layer or heating the sheet may affect the composition of the alloying elements and thus the sheet's properties. For this reason, many people prefer, whenever possible, to use non-invasive techniques for unbending metal sheets.

2. Devices Used for Unbending Car Body Sheets

Depending on the forces that need to be applied for unbending and the access available, various devices are used. For example, washers can be welded to the sheet, after which large forces can be applied to unbend the sheet (pulling the sheet), as shown in Fig. 2.

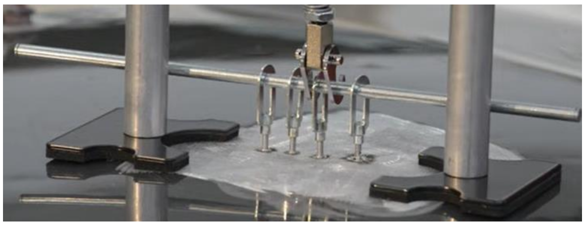


Fig. 2: Unbending the sheet by pulling using welded washers [13]

This technique requires the sheet to be repainted afterward. One of the techniques used to restore car body sheets to their original shape is Paintless Dent Repair, which actually means repairing the body without repainting.

Elastic rods can be used to repair the dents, with the metal sheet being reshaped by pushing it, as shown in Fig. 3.

Fig. 3: Elastic rods [14]

Hammers and nylon punches of various shapes and sizes, as shown in Fig. 4, can be used, with the unbending process achieved through repeated striking of the sheet.

Fig. 4: Hammers and nylon punches [15]

For pulling the sheet, various devices can be used to apply pulling forces on suction cups made of plastic materials, such as inertial hammers, as shown in Fig. 5, or devices like those in Fig. 6.

Fig. 5: Inertial hammer [16]

Fig. 6: PDR device [17]

Inertial hammers and various PDR devices use suction cups made of plastic materials, as shown in Fig. 7. These suction cups are attached to the sheet using cold or hot adhesive, allowing the sheet to be pulled afterward.

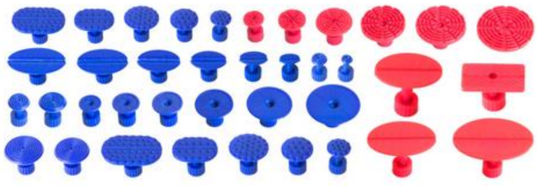


Fig. 7: Suction cups [17]

3. The Use of 3D Printers in Unbending Metal Sheets

3D printers can be used in an innovative way for unbending metal sheets, not necessarily directly, but indirectly by creating suction cups or custom heads for punches based on the shape and dimensions of the deformation. The quality of the work performed using this PDR technique largely depends on the skills and experience of the user.

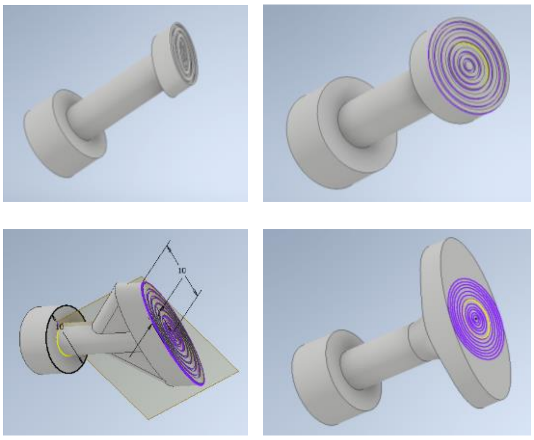
The advantages offered by using 3D printers are:

- Templates, device supports, suction cups, and even the devices themselves can be easily customized.
- Quick access to suction cups, punches, and templates made at low cost.
- High flexibility, as the support, suction cups, or punches can be quickly modified, redesigned, and reprinted if needed.

A disadvantage that can be mentioned is:

- The limited strength of the materials used in 3D printing, particularly with FDM technology. It is well known that PLA, ABS, and PETG, the most commonly used and accessible materials, do not have high resistance to high temperatures and large forces.

In order to 3D print any part, it is initially necessary to represent the 3D model in a CAD software. For this, Inventor can be used for modeling, resulting in parts such as suction cups, as shown in Fig. 8.



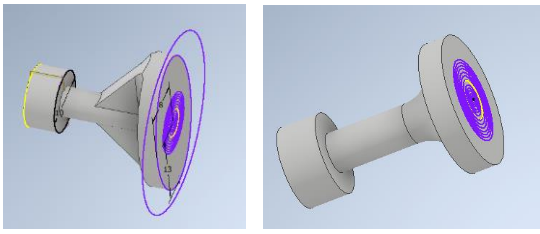


Fig. 8: Designed suction cups

Inventor allows for easy modification of parameters, so from a model with specific dimensions, various customized suction cups or punches can be quickly and effortlessly created, tailored to the user's needs depending on the shape of the deformation that needs to be repaired.

A pulling device for the sheet can also be designed and manufactured using the designed suction cups, as shown in Fig. 9.

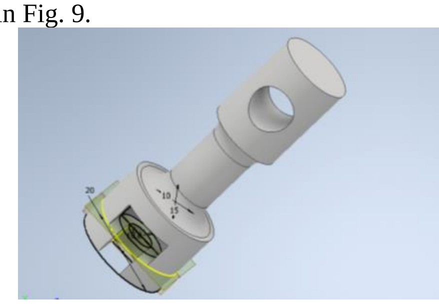


Fig. 9: Suction cup support

The designed models are saved with the ".stl" extension and imported into Cura or any other software that generates the "gcode" file, as shown in Fig. 10. To ensure good mechanical strength of the designed parts, the Infill Density must be set to the highest possible value.

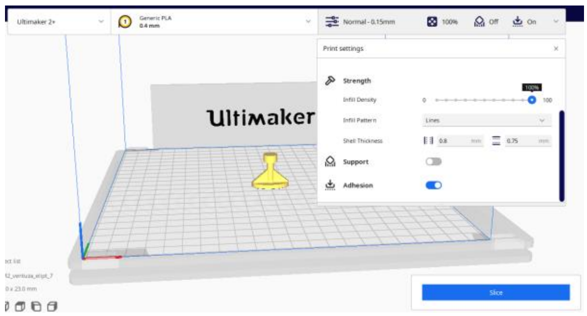


Fig. 10: Generation of "gcode" files in Cura

The *gcode* files are loaded into the printer being used and printed, resulting in the designed parts, as shown in Fig. 11.

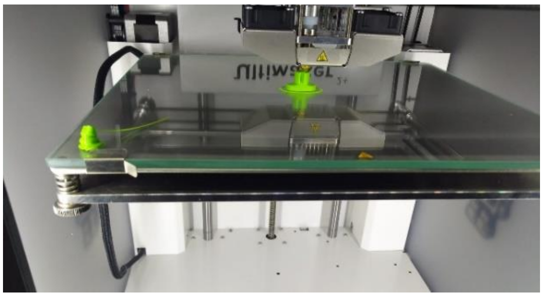


Fig. 11: Printing parts

The designed and used pulling device is the simplest device possible to create. The suction cups are inserted into the designated slot at the bottom of the tool, while at the top, a handle or any rod with a diameter smaller than the hole provided on the tool is inserted, as shown in Fig. 12.

Fig. 12: Printed parts for unbending the sheet

For using the PDR method to unbend the sheet, the surface of the sheet is cleaned (Fig. 13.a), and the suction cup is then attached to the deformed surface of the sheet using a hot glue gun (Fig. 13.b).

a. b.

Fig. 12: Attaching the suction cups

After pulling the sheet, the silicone residue is removed using alcohol or solvents that do not affect the painted and coated surface. The next step is the repeated striking with a hammer with punches of various shapes, which will cause the metal sheet to flow until it returns to its original shape.

4. Conclusions

3D printers can be used in an innovative way for unbending metal sheets, not necessarily directly, but indirectly by creating suction cups or custom punch heads based on the shape and dimensions of the deformation. The advantages offered by using 3D printers include: customization of printed parts, quick access to the necessary components, low-cost production of parts, and high flexibility, as parts can be quickly modified, redesigned, and reprinted.

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