Journal of Cultural Heritage 31 (2018) 215–219

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

Case study

Use of magnets for reversible restoration in sculpture. The case of the "Virgen de los Desamparados" in Valencia (Spain)

M. Azahara Rodríguez [a], Sandra Ruiz-Gómez [b], Lucas Pérez [b,c], Xavier Mas-Barberà [a,*]

[a] Instituto de Restauración del Patrimonio, Universitat Politècnica de València, Camino de Vera s/n 46022, Valencia, Spain
[b] Depto, Física de Materiales, Universidad Complutense de Madrid, 28040 Madrid, Spain
[c] Instituto de Magnetismo Aplicado, UCM-CSIC-ADIF, Madrid, Spain

ARTICLE INFO

Article history:
Received 5 May 2017
Accepted 10 January 2018
Available online 1 February 2018

Keywords:
Prosthesis
Adhesion
Sculpture
Theoretical model
Magnetic system

ABSTRACT

In this paper, we present the use of a magnetic system for restoring a real piece of art: the Virgen de los Desamparados sculpture (1954) by the Valencian sculptor Silvestre d'Edeta (Valencia, Spain). This sculpture is made of artificial stone reinforced with iron rods in the matrix and, before the intervention, showed a high degree of degradation due to various physical, chemical and biological processes causing internal strain, cracks and fragmentation. Several non-destructive imaging techniques (photography, photogrammetry, digital radiography and 3D virtual reconstruction) have been used to study the original status of the artwork. The materials to produce the prosthesis to restore the sculpture, and the procedure to attach them with magnets and various adhesives, have been addressed in this study. Different theoretical models and simulations have been developed to help the restorer to select the most appropriate magnets and their optimal position. The restoration returns legibility to the piece by restoring the missing head-hair-crown section.

1. Introduction

Current methods of restoring sculptures and ornaments involve using synthetic adhesives, sometimes reinforced by rods of various materials, to assist the joining of different pieces [1–3]. These rods can be made of fiberglass [4] or stainless steel [5], amongst other materials [6,7]. This kind of intervention provides robustness and stability to the artwork, but goes against the principle of minimal intervention and reversibility, as inserting rods is usually a fairly invasive procedure. Therefore, less invasive new technologies and strategies that provide the artwork with similar robustness, while maintaining the reversibility of the restoration, are necessary. The use of magnetic materials is one potential alternative solution to this problem.

Among magnetic materials, permanent magnets — henceforth referred to as magnets — are essential components in many technological fields, because of their ability to provide a large magnetic response without the application of an external magnetic field. Specifically, a large force appears between two magnets or between a magnet and a ferromagnetic material providing that the temperature is below the Curie temperature, a characteristic temperature above which the magnetic properties of a magnet disappear [8]. NdFeB magnets are an excellent choice for technological applications because they combine a large magnetic response — saturation magnetization above 1.5 T — with high stability in the presence of external magnetic fields — coercivity above 7 T — and a relatively low cost. There are two main drawbacks to these magnets: their relatively low Curie temperature (312 °C) that prevents their use in high-temperature applications, and their low corrosion resistance [9]. To avoid corrosion, all commercial NdFeB magnets have protective magnetic coatings.

The use of magnetic materials in the conservation and restoration of cultural heritage is quite recent. Since the late 1980s, magnets have been used in preventative conservation and musealisation, improving the display methods for graphic documents, scrolls, textiles and mural painting [10]. More recently, restorers have used magnetic systems as a tool to produce adhesion between layers of painting, to remove deformations [11], to look for metallic parts in archaeological items, or as a cleaning tool [12]. However, there are only a few examples in which magnetic materials, mainly permanent magnets, are used as an alternative tool for joining fragments or to help in the insertion of reconstructive prostheses in sculptures [13,14]. The use of magnets in the conservation and restoration of sculptures has the potential to fulfill the criteria of minimum intervention, respect for the original artwork, improvement of the aesthetics of the artwork and,

* Corresponding author.
E-mail address: jamasbar@upvnet.upv.es (X. Mas-Barberà).

https://doi.org/10.1016/j.culher.2018.01.005
1296-2074/

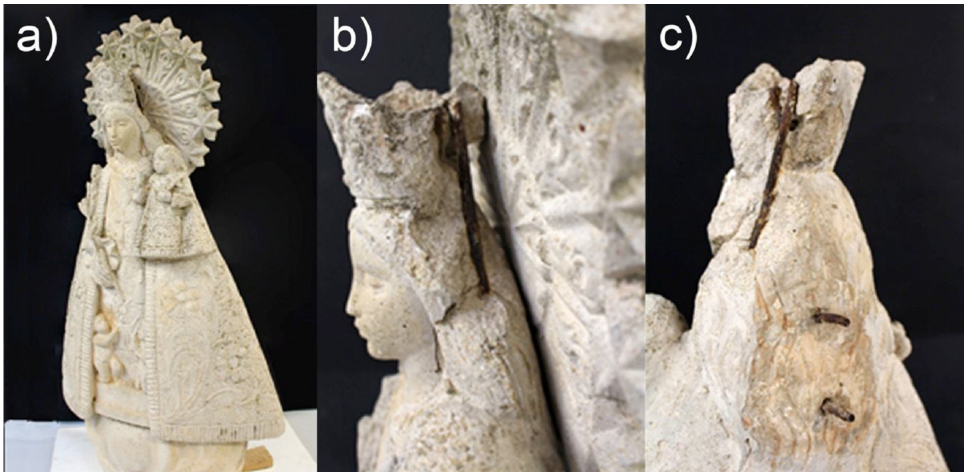

Fig. 1. (a–c) The Virgen de los Desamparados sculpture (1954), sculptor Silvestre d'Edeta (Valencia, Spain): a) General view in which the missing sections in the head-hair-crown can be seen, leading to reduced aesthetic value; b) Detail of the high degree of degradation originating from different physical, chemical and biological processes, producing internal strain, cracks and loss of fragments; c) Rusty iron rods in the matrix and loss of fragments.

most importantly, reversibility. In general, the use of magnets is limited by the skills and criteria of the conservator/restorer, and their application is controversial. Systematic use of magnetic systems in the field of sculpture and ornamental restoration is still not widespread.

In previous works, we showed the possibility of using permanent magnets for the restoration of stone sculptures, developing a systematic method to determine the optimal choice of magnets and the locations to place them in the pieces to be joined, while minimizing the impact and ensuring reversibility [15,16]. In these previous works, we used laboratory test samples and artwork created specifically to test the feasibility of the developed method. In this work, we show the potential of this approach by using it to restore a real piece of art: the Virgen de los Desamparados (Virgin of Helpless) sculpture in Valencia, Spain.

2. Research aim

This study has been applied to a real case, the *Virgen de los Desamparados* sculpture (1954), by the well-known Valencian sculptor Manuel Silvestre Montesinos, known as Silvestre d'Edeta [17]. This piece, of great artistic and historical value, reflects the religiosity of La Pobla Llarga, a town close to Valencia. It represents the image of the Virgin on a cloud. Its approximate dimensions are $75 \times 47 \times 23$ cm^3 (height, width, depth) and it was located in a square named after the Virgin. The sculpture is made of artificial stone, as a result of the hardening of an inorganic mortar (cement binder and calcareous sand), reinforced with iron rods in the matrix.

Before the intervention, the sculpture showed a high degree of degradation originating from various physical, chemical and biological causes. In particular, the stony surface substrate was lost as a result of water. Flowing water caused oxidation of metallic elements, produced internal strains, and led to the formation of cracks, which finally resulted in the loss of several fragments from the head and the crown (see Fig. 1). Although originally located outdoors, after the restoration the piece was moved to the Historical-Art Museum of La Pobla Llarga in Valencia to prevent further degradation.

3. Materials and methods

Several non-destructive imaging techniques have been used to study the original sculpture: digital photography, radiography and photogrammetry. 3D software for virtual reconstruction of the missing elements of the sculpture was also employed. These techniques were used to document the previous state of the sculpture and to record the interventions and the final results. More specifically, the X-ray imaging allowed the determination of the size and position of existing internal reinforcement, which can be seen in the fractured area of the head-hair-crown (Fig. 1). Photogrammetry and 3D reconstruction have been used to calculate the size, shape and volume of the prosthesis.

The materials used for both the test samples and the piece to restore the sculpture, were selected after carefully analyzing the artwork. A mortar composed of an inorganic binder (*Ledan C30*®), carbonate-based sand and gravel (0.5–2 mm), additives (inorganic pigments of different colours) and water were selected. We employed NdFeB magnets with a Ni/Cu/Ni coating supplied by Supermagnete, with magnetization in the axial direction. Three different adhesives were tested to fix the magnets to the prosthesis and to the sculpture: two acrylic (*Paraloid B72*® and *Plextol B500*®) and one epoxy (*Araldit Standard*®). Paraloid B-72 (50% w/v in acetone) and Plextol B500, acrylic resins from Rohm and Haas, are well-known and have been studied for conservation of historical pieces [18–20]. Araldite Standard is a strong epoxy resin, a two-part general purpose adhesive (from Araldite).

The force between magnets as well as the adhesive forces produced by the different adhesives was tested in tensile experiments using an Adamel Lhomargy DY30 system. The surface analysis of the magnets was carried out in a JEOL JSM scanning electron microscope equipped with an energy dispersive spectroscopic (EDS) system that allows local composition to be measured.

As mentioned previously, it was important to ensure sufficiently low magnetic fields extending out of the restored pieces to avoid contamination by magnetic particles, contamination that can result in unsatisfactory aesthetics. Finite element calculations were used to calculate the position of the magnets that minimise the external field using the *Comsol Multiphysics software*. This software uses the fundamental equations of electromagnetism to calculate the external magnetic field produced by a magnetic configuration. We used the magnetic characteristics of NdFeB magnets as input parameters, extracted from reference [9]. Stones are diamagnetic materials and, for the simulation, we considered the relative magnetic permeability of stone to be equal to 1.