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Characterization of Japanese Helmets through Neutron Imaging Techniques

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Investigation of the forging and assembly of armour is one of the most interesting topics in ancient Japanese technology. In this work, we present novel results from a non-invasive approach to the study of two Japanese helmets (kabuto) made in the 17th Century.

There are many different types of Japanese helmets, but they can be grouped into three main categories: those made from a single sheet of metal, those assembled from a small number of sheets, and those assembled from a number (varying between 8 and 128) of lamellar plates arranged in a circular fashion around the crown of the head.
One of the helmets studied (H1) is a Horagai Bachi, an example of the first of the three helmet types. This is a Tetsu bari shiki kawari-bachi (wonderfully shaped steel helmet) made, in the form of a shell, by Ryōei - Ohara Katsunari from Hiroshima province at the end of the 17th Century. This helmet was made available by the Stibbert Museum in Florence.
The second Kabuto (H2) is an example of the third type. It is a Saotome Bachi made in the 1st half of the 17th Century. It is made up of 62 lamellar plates finished with a visor decorated with two opposing gold dragons. The components are joined by rivets, which are invisible to outside inspection, and the entire surface is lacquered. This helmet was kindly provided by a private collector. (It was formerly part of the H.R. Robinson collection)

Such ancient armours are quite rare and when found in museums, are usually in an excellent condition of conservation. Thus, traditional (invasive) analytical methods cannot generally be applied, and, a non invasive approach is mandatory. Neutron techniques, which are able to identify the morphology and the inner structure of artefacts have been applied in order to determine their methods of manufacture.

Thanks to their high powers of penetration [G. L. Squires, 1996; V. F. Sears, 1992], neutrons represent an almost unique method for the non-invasive characterization of the microstructure of massive metal objects. These techniques have been recently applied to the study of metal artefacts of archaeological [S. Siano et al., 2002] and historical [F. Grazzi et al., 2009] origin, and have given detailed information on bulk properties (e.g. phase composition, texture, residual strain distribution) which has allowed us to obtain information about their manufacturing techniques. On a different scale, neutron tomography techniques can add useful information about the bulk conservation status [E. Lehmann el al., 2005] and the inner structure (when present) of the artefact [E. Lehmann el al., 2010].

We will discuss here the results of neutron imaging experiments (radiography and tomography) carried out at the ICON and NEUTRA beamlines operating at the neutron source SINQ (CH), applied to helmets H1 and H2 respectively.
A preliminary test measurement was carried out on the helmet H1 by irradiating it for 60 seconds and measuring the gamma emission spectrum. The activation level was measured and, from the analysis of the gamma spectrum, we were able to gain information about the elemental composition, excluding iron.
In order to limit the activation level induced by the presence of copper, the helmet H1 was investigated by only 13 neutron radiographs in total, taken at different positions of the helmet.
As a result of the radiography, we have identified a circular brazing, close to the top, connecting the upper to the lower parts of the helmet, and a linear brazing used to secure the single plate forming the lower part of the helmet. Those brazing were invisible at a visual inspection.

Concerning the helmet H2 a full neutron tomography was possible. Tomographic reconstruction of the inner volume of the helmet in 3D, with preliminary treatment of the images obtained, has allowed us to acquire further information about the structure and methods of assembly. In particular the actual arrangement of the lamellar plates, and the location of hidden rivets.

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