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Evaluation of Differences Among Struck, Fused and Press-fused Ancient Roman Coins, Investigated by Means of Scanning Electron Microscopy and Microanalysis in the Light of an Irreversible Thermodynamics Approach

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Abstract

The aim of this study is to discuss the differences among the processes of fusion, press-fusion and striking in terms of physico-chemical considerations. Owing the existence of non equilibrium conditions occurring along the changes in shapes and structures of metallic materials by the action of external driving forces (the hammering, as well as the fusion or press-fusion applied techniques) and the correlated flows of energy, it can be useful to take into account the basic principles of irreversible thermodynamics in order to have a correct correlation among the flows of energy transferred to the metallic disk by external driving forces (mechanical in the case of striking, or thermo-mechanical in the case of press-fusion). So, a flow of energy, J, is correlated to one or more driving forces, X, by means of phenomenological coefficients, L; when the systems is not far from equilibrium or in presence of linearity conditions between flows and driving forces, one can, therefore, write: $\vec{J}_t = -LX$ or, inversely, $X = -R\vec{J}_t$, being, $L=1/R$.

The validity of the proposed approach, integrated with the supporting evidence of experimental results obtained by means of SEM, EDS, XRF techniques, is verified by investigation performed on two representative gold coins, one original (a genuine Roman aureus of *Iulius Caesar*) and the other one a counterfeited (a fake aureus of *Sextus Pompeius*).

Introduction

Coins can be obtained by two different kind of processes: hammering and fusion or press-fusion. In the first case, due to the extremely low interval of time requested to perform the coinage process, i.e.. the striking, on theoretical base, is well defined by means of the "impulses" or "percussions" equation, that equals an energy flow to a variation of the motion quantity. According to equation (1) $\vec{J}_t$ is the supplied impulse that defines the flow of energy transferred from a hammer (or more in general any device suitable for striking) of mass m to the metallic alloy clamped between two engraved dies. In such a way the flow of the energy becomes responsible for an instantaneous embossing process (or coinage) and $\Delta\vec{M}_{\Delta t}$ $\Delta\vec{M}_{\Delta t}$ is the driving force acting instantaneously and coincident to the differences between the product of the beating mass, m, and the change of speed, from a high value v_2 at the time t_1 to a value v_1 at the time t_2, when the knock was accomplished, being v_1 vanishing to zero at the end of the shot.

The "label maker" mechanism of hammering determines also a hardening of metallic alloy and such a highly irreversible process is associated to an energy-dissipation, φ, given by the product of an involved flow, J, and the respective driving force, X:

The dissipation energy, φ, is given by $\boldsymbol{\varphi = JX = \sigma T = (dS/dt)T}$, where σ is the velocity of entropy production, (dS/dt), and T is the absolute temperature.

The basis of the forgery obtained by press-fusion is a melting process of the metal (or alloy) associated to an applied pressure, P, between two suitably engraved dies with a surface area, A, is defined by equation 2. The energy flow, J, in this case does not proceed instantaneously, but progressively, or stepwise according to the way of application either of temperature and/or pressure gradients, $\Delta J_{\Delta t}$, , by changing the values of the temperature and pressure. This process is described by equation 2:

$$\vec{J}_t = \int_{t_1}^{t_2} \vec{f}_t \, dt = \Delta \vec{M}_{\Delta t} = m\vec{v}_2 - m\vec{v}_1 = m\Delta\vec{v}_{\Delta t} \quad (1); \qquad \Delta J_{\Delta t} = \left(\int_{t_1}^{t_2} \frac{dP}{dA} \right)_T dt \quad (2)$$

Materials & Methods

A genuine roman aureus of Caesar (fig. 1) and a fake aureus of Sextu Pompeius were compared (fig. 2). A Scanning Electron Microscopy (SEM) LEO1450VP equipped, for micro-analytical determinations by means of a Energy Dispersion Spectroscopy (EDS) INCA300 were used. An X-ray fluorescence (XRF) apparatus, Philips mod. PW 1404, was also used.

Obverse Reverse

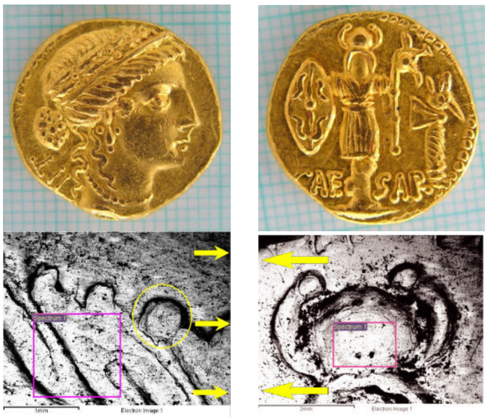

Fig. 1; Photographs and SEM images of significant zones of the genuine aureus of *Iulius Caesar*.
Obverse: Head of Venus (or Concordia).
Reverse: Trophy with Gallic arms. Below CAE-SAR.

Results

By both the XRF and the EDS analyses the following compositions were obtained for the two coins:
genuine aureus: Au= 99.99%,
fake coin: Au = 98.0%, Ag = 1.0% Cu = 1.0%.

The genuine aureus of *Iulius Caesar* evidences that here the hit was not performed in a perfect orthogonal direction with respect to the plateau of the coin, so that the embossed images of the obverse were shifted on the right side, while on the reverse the shift took place on the left side.

The fake coin of *Sextus Pompeius* does not show any shift, owing to press-fusion techniques followed to obtain it.

Conclusions

The striking is responsible for higher values of dissipation energy associated to metallic structures as compared to other techniques (fusion and press-fusion) usually employed to make counterfeits.

The high values of dissipation energies associated to coinages are consistent to the improved features of the metallic structures obtained by striking. The thermodynamic principles valid for coinages are the same applied in the ancient times to improve the features of the blades of swords and, up to date, the ones of some kinds of gun barrels or, more in general, metallic equipments that require high performances in peculiar applications.

Obverse Reverse

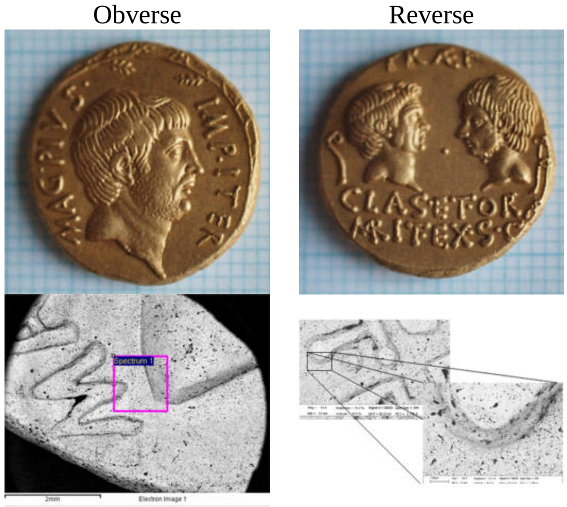

Fig. 2; Photographs and SEM images of significant zones of the counterfeit aureus of *Sextus Pompeius Magnus Pius*. Obverse: Head of Sextus Pompeius Magnus Pius.. Reverse: Head of Gnaeus Pompeius Magnus and the one of Gnaeus on right side.

References

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