Technology and the Machine for Rasterized Facsimile Engaving of Art Images on Minerals

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Abstract

Facsimile copying of images on polished mineral surfaces can be performed by rastration (dithering). when the original halftone image is replaced by the microstroke image. Different halftones are reproduced by pulse modulation of 2-dimensional signal without loss in the visual perception due to the Nyquist theorem. Technological process of rasterised facsimile engraving provides the integral optical density on the length of raster element step. such that it is approximately equivalent to the optical density of the original on the same length. In the facsimile engraving, the destruction of mineral is considered in "small deviations". Theoretical analysis of the process results in the transfer function of required energy of chisel from the depth of penetration into mineral. Analysis of work in "small deviations" results in the formulation of three technological stages of transfer function, which allow to separate the deformation and destruction of compression kernel into the primary and the secondary with a minimal effect of additional chip.

Key words: *engraving, rastration.*

Facsimile copying of images on polished mineral surfaces can be made by rastration (dithering), when the original halftone image is replaced by the microstroke image, consisting of line and dot elements [1]. The Halftone image is replaced by the microstroke image, consisting of linear and dot elements.

Pulse modulation is used in the process of rastration. Different halftones are reproduced by the pulse modulation of a 2-dimensional signal, where the hit impulse can be defined as:

$$i_{video} = f_{sign}\ Z(f(U_{video}), A(U_{video})) \qquad (1)$$

where f_{sign} is thefrequency of hits, Z is the chisel move, f is the frequency of control impulses, A is the amplitude of control impulses, U_{video} level of continuous videosignal (current brightness) (Mikov et. al., 2001).

The rastration process is connected with the transformation of optical parameters of halftone image made by the electromechanical converter, controlled by hardware and software.

The replacement of continuous halftone image characterized by U_{video} co by a sampled microstroke image can be performed without the loss in the visual perception due to the Nyquist theorem.

Technological process of rasterized facsimile engraving provides an integral optical density D_i on the length of raster element step δ for each scan line on the surface of the blank material, such that it is approximately equivalent to the optical density of the original D_{orig} on the same length. Integral optical density D_i is obtained as a sum of the optical density of the blank material and the optical density of the traces (fmicrostrokes), left by a chisel in the process of surface destruction (Protasov, 2001).

The process of destruction of minerals by slotting is described in detail in (Morozov, et al., 2001), But this work and other similar studies consider cases when it is necessary to maximize removal of material to provide a maximum performance. Using control theory terminology, deviations in **large** are studied.

In the same terms, in the process of facsimile engraving deviations in small should be studied. Small amounts of mineral are removed by means of **small** masses of working mechanism and a chisel to provide small, not highest possible, area of the destruction crater, which must be proportional to U_{video}

A further research brings us to the transfer function of material (Mikov, Morozov, 2001) – a dependence of required force or energy of a chisel from the depth of penetration into material. The work in the "small deviations"allows us to separate the deformation and destruction of compression kernel into **primary** and **secondary** (with a minimum additional chip) on different parts of the transfer function.

Chisel should work on the part of transfer function corresponding to the mineral destruction, since the work in the parts of transfer function corresponding to elastic and plastic deformations does not result in chips and, hence, the trace of the chisel does not have the "whiteness"' of chip - optical density of the chip on the material surface. Apart from it, when the chisel works in these parts of transfer function, it is difficult to provide a proportional dependence between the area of the destruction crater and the control signal U_{video} due to the ambiguity of relation between the initial and final deformation.

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(Recenzovaná a revidovaná verzia dodaná 17. 1.2005)

When the chisel works in the part of transfer function, corresponding to the mineral destruction an additional chip C appears, which is connected to the additional destruction of mineral, and the size of that chip increases disproportionately to the chisel penetration increase. The size of the additional chip also depends on the relation between the crystal (or grain) axis and the hit vector.

Technological stages of machine raster engraving on the mineral, corresponding to the process of the destruction crater creation, are presented in Fig. 1. The electromechanical converter, which performs the raster engraving., consists of magnetic circuit, core with a chisel, springs and induction coils. The control current I_{hit} creates the electromagnetic impulse force $F_{em\ hit}$ in the induction coil w_1. The core with a chisel possessing a total mass m_c, accelerates in the working clearance Δ_H between the edge of the chisel and the surface of the mineral and, in the moment of hit, it has the energy Q. The chisel penetration depth is Δh_d and the area of destruction crater is S_{sp}.

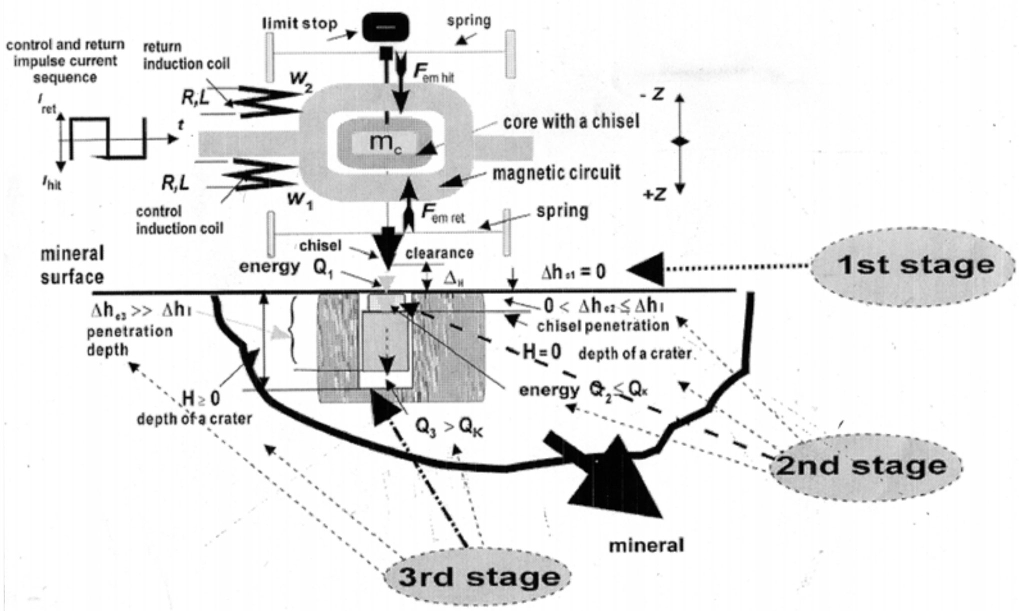


Fig. 1

First technological stage. In this case chisel takes out the working clearance Δ_H and just touches the surface of the mineral, the penetration into mineral absent *(Δh_d=0)*.

The chisel energy Q_1, provides the chisel move along the $+Z$ axis on ΔH in time τ. In that case, the chisel energy equals

$$Q_1 = 2.m_c \frac{\Delta_H^2}{\tau^2} + c.\Delta_H^2 \tag{2}$$

Second technological stage. In this case, the chisel takes out the working clearance Δ_H. and insignificantly penetrates the material surface in the limits of elastic or plastic deformations, no chip is present (the removed volume of material V and the chip crater depth H equal zero). The force F_{em2} is applied to the chisel, and its energy is $Q_2=Q_K$, where Q_K is a critical energy. The time of impact on the mineral $\tau_2>\tau_K$ i.e, the time of impact is longer than the critical time, which is a minimum impact time required for the destruction but the energy of impact, that is entered in mineral, is not enough for the destruction. The time required to take out the working clearance Δ_H in the move along $+Z$ axis τ is the same.

The second stage is limited by the critical energy Q_k and critical deformation Δh_k. Mineral is compressed by Δh_{cc} with the edge of the chisel, which produces the compression kernel with the height *h. The t*ime of impact is longer than the critical time *($\tau_2> \tau_K$)*. The energy required at is step is defined by the degree of deformation of compression kernel - Δh_{cc}, which is the depth of the penetration. The end of this stage, when $\Delta h_{cc}=\Delta h_k$, energy is defined as:

$$Q_2 = 2.m_c \frac{(\Delta h_k)^2}{\tau_2^2} + c.(\Delta h_k)^2 + Q_{cc1} \tag{3}$$

The energy entered in to the mineral is not enough for the destruction.

Third technological step. In that case, the chisel takes out the working clearance Δ_H, significantly penetrates the surface of the mineral, overcoming elastic and plastic deformations, destroys the mineral, leaving after the return move a crater with the depth of the chip $H>0$.

The chisel energy on that stage is greater, than the critical energy ($Q_3>Q_k$), and the time of impact is longer than the critical time ($\tau_3>\tau_K$), i.e. the energy entered in the mineral is enough for its destruction.

In that case, the critical energy Q_k, which equals the energy of primary destruction of compression kernel Q_{cc1}, can be defined as:

$$Q_k = \frac{3.P.S.(1-2.\mu).A_1.\sigma_0}{8.E.\mu} \approx Q_{cc1} \quad . \tag{4}$$

A further penetration of chisel on the depth $H-\Delta_H >> \Delta h_k$ produces a removal of the volume of material V, which includes the secondary destruction of compression kernel and the removal of dust from the compression kernel:

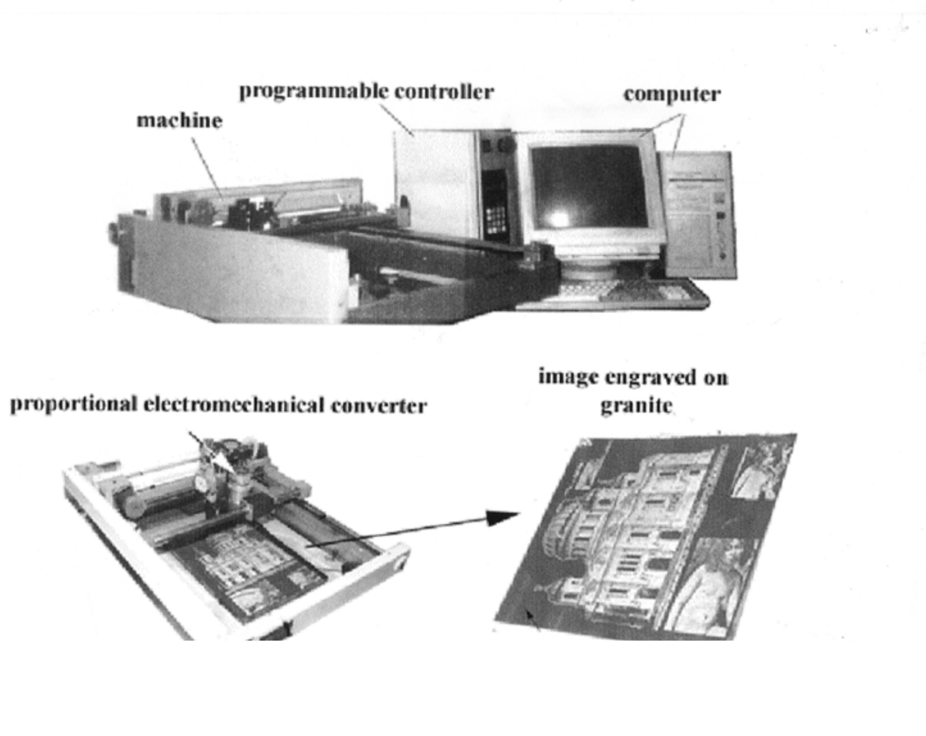
$$Q_3 = 2.m_c \frac{(H-\Delta h_k)^2}{\tau_3^2} + c.(H-\Delta h_k)^2 + Q_{cc2} \, . \tag{5}$$

The energy of secondary destruction of compression kernel (energy required to separate the volume V from the mineral body) is:

$$Q_{cc2} = \frac{H.A_1.B.\sigma_0.k.\sigma_p}{3.\mu.E.\eta} \quad . \tag{6}$$

In the formulas above H is the depth of a crater, A_1 is the width of the chisel edge, B is the length of the chisel edge, k is the plasticity coefficient σ_p is the tensile strength,σ_0 is the 3-dimensional strength, η is the efficiency factor for the compression kernel work, μ is the Poisson coefficient and E is the Young module.

The machine and the example of engraved image is shown in Fig. 2. The software and the driver in *PC* provide the control of the machine via a programmable controller (Mikov et. al., 2001).



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