The Effect Of Ultrasound On The Irrecoverable Deformation Of Metals

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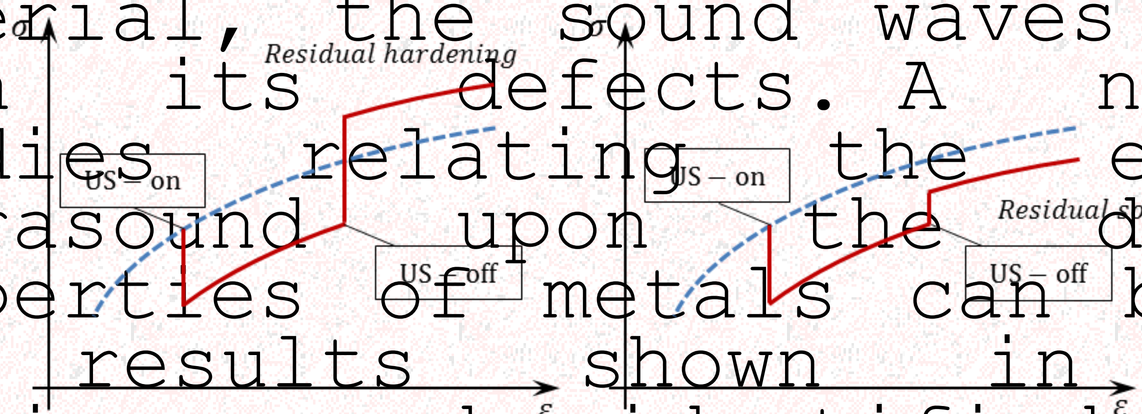
Contents

Introduction

As a result of the high efficiency and simple implementation of ultrasound, it has been widely accepted in the fields of biomedicine, chemistry, metal forming and metallurgy. The principle underlying the effect of ultrasound is that, when a sound wave propagates through a substance, the acoustic energy is being scattered and absorbed by the material, the sound waves interfere with its defects. A number of studies relating the effect of ultrasound upon the deformation properties of metals can be resumed by results shown in Fig. Two portions can be identified:



The Question

From the short review of experimental results above, the conclusion cannot be escaped that, at least in terms of experiments considered, the metals with high SFE, such as, e.g., aluminum, are inclined to ultrasonic residual hardening. In contrast, metals with low SFE (titanium, copper, gold) manifest the phenomenon of ultrasonic residual softening.Many researches have attempted to explore a realistic mechanism caused to change mechanical behavior (**acoustic softening** or **residual softening / hardening)** whenever the ultrasonic vibration is imposed on metal, but its accurate underlying mechanism was **still not so clear.** The residual effect caused by ultrasonic vibration is quite contrary between some metals, what is the reasons?

Step Before

Rusinko* developed an analytical model which introduced a new term, ultrasonic defect intensity, into the **synthetic theory** of plastic deformation. This model described the ultrasonic temporary softening and the ultrasonic hardening **when ultrasound acts alone and did not** consider the residual softening / hardening **after** ultrasonic-assisted plastic deformation.

The plan was to develop a model accounting for the phenomenon of acoustic plasticity such as

Ultrasonic Temporary Softening And Residual Hardening In Terms Of The Synthetic Theory

The goal was (**i**) to construct model σ~ε curves in the compression tests for pure aluminum according to the sonication regimes shown in fig, (**ii**) to compare results with those o

$$r\varphi_N = H_N^2 - S_S^2 = \begin{cases} (\vec{S}\cdot\vec{N})^2 - S_S^2 & \text{if } H_N = \vec{S}\cdot\vec{N} \\ 0 & \text{if } H_N > \vec{S}\cdot\vec{N} \end{cases} \quad ..1$$

*Yao et. al. We can

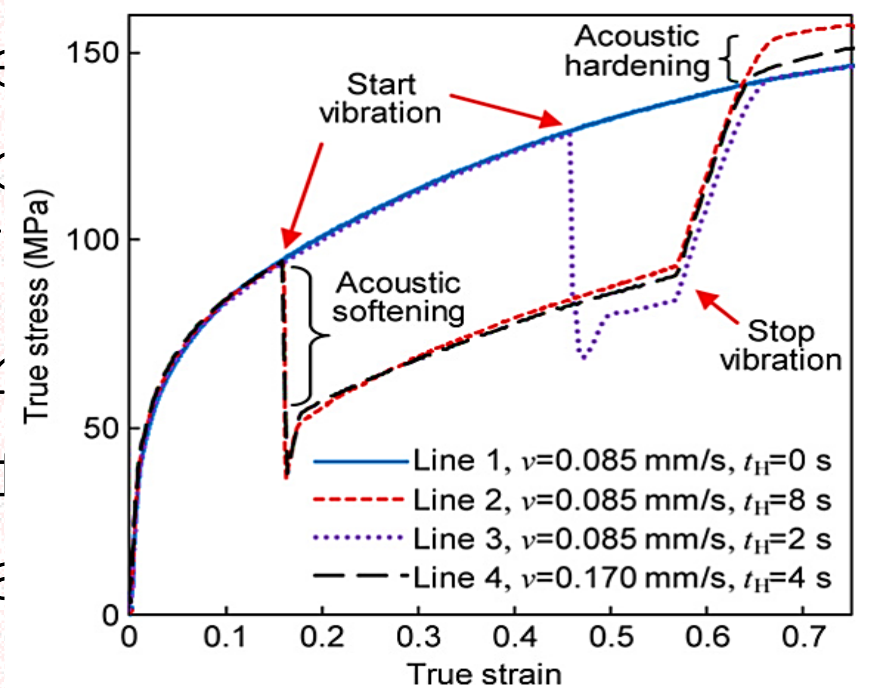
For modeling the plastic strain inter

effects of US on indeed the plastic r

the plastic level of ma

$$r\varphi_{NU} = H_N^2 + U_t^2 + f(\tau)U_r^2 - S_S^2 \quad ..2$$

straining of metals, we extend



*Yao, Z., Kim, G. Y., Wang, Z., Faidley, L., Zou, Q., Mei, D., & Chen, Z. (2012). Acoustic softening and residual hardening in

- The analytic σ~ε curve in fig. bellow which is plotted via Eqs. (1,2), shows good agreement with experimental data. Next step is the instant when the US is on, We utilize Eq. (4) to calculate the ultrasound induced stress drop. Further, Eq. (5) se[...] analytical tool to [...] under the action o[...] Portion 2-3. Final[...] deformation of pos[...] material, portion [...] This portion is pl[...] Eqs. (6,7)

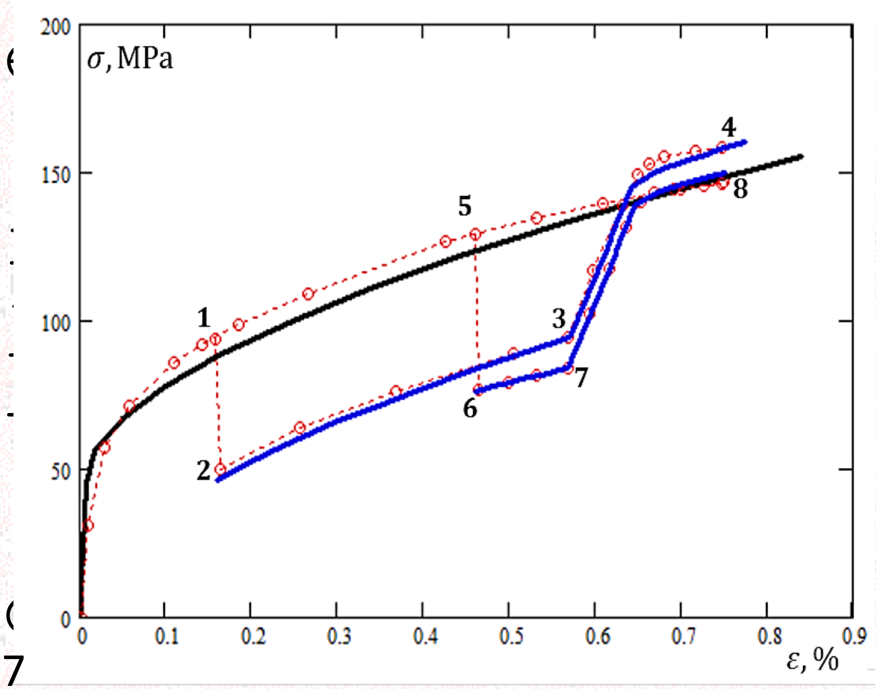
$$\sigma_U = \sqrt{\sigma^2 - \frac{3}{2}(A_1 U^{A_2})^2} \quad ....4$$

$$e_U = a_0 \Phi(b_U)$$

$$b_U = \frac{\sigma_S}{\sqrt{\sigma_U^2 + \frac{3}{2}(A_1 U^{A_2}(2 - e^{-pt}))^2}} \quad ....5$$

$$e = e_U + \Delta e + \frac{\sigma}{E} \quad ....6$$

$$\Delta e = \frac{2\pi}{r} \int_{\beta_2}^{\pi/2} \int_0^{\lambda_2} \Delta\varphi_{NU} \sin\beta \cos\lambda \cos\beta \, d\lambda d\beta \quad ....7$$



Ultrasonic temporary softening and residual hardening in terms of the synthetic theory

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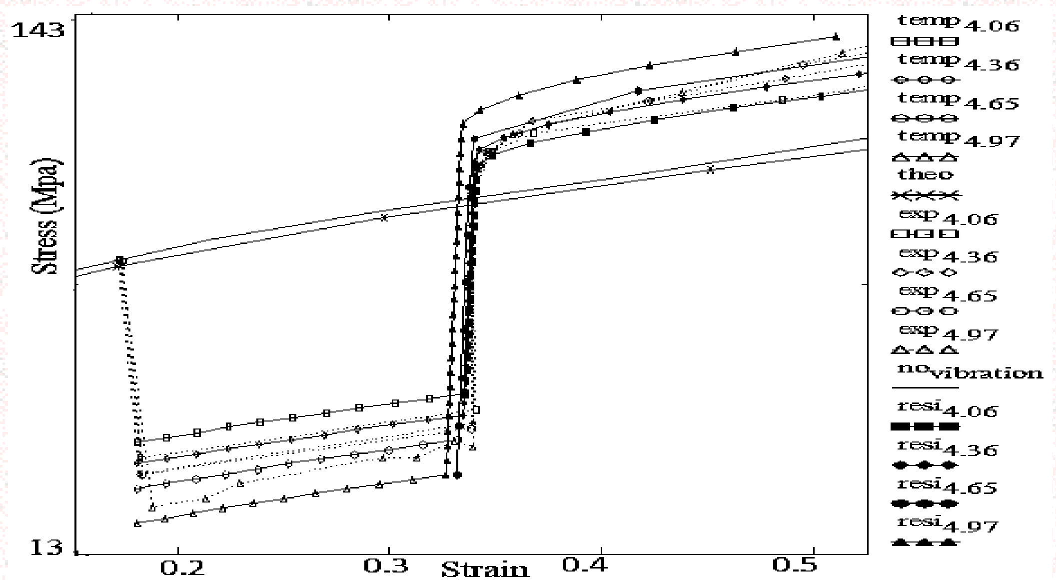
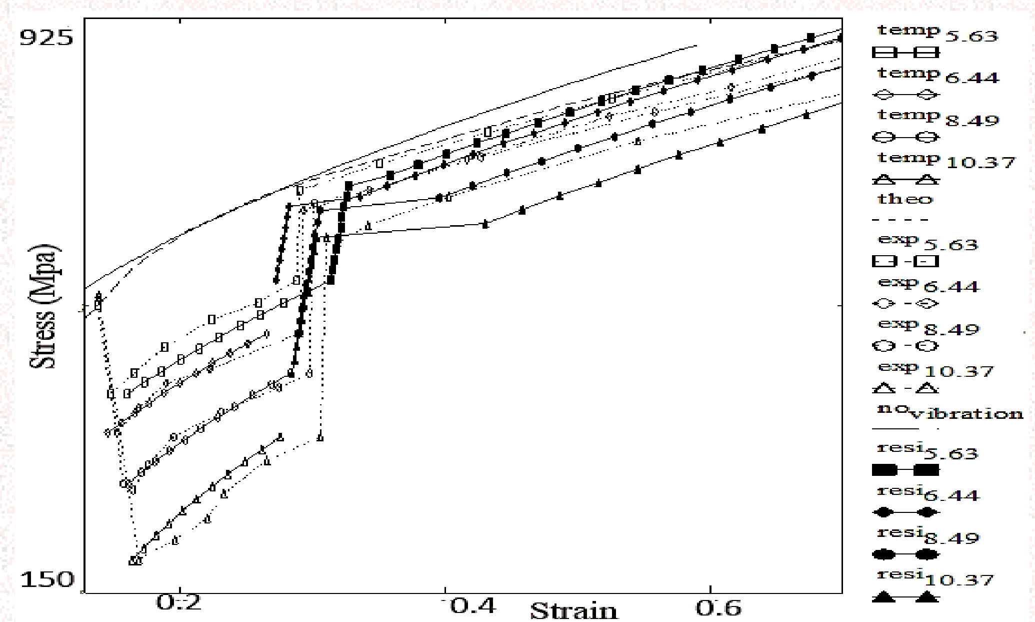
Modelling of ultrasonic temporary and residual effects

This work is step forward in our research of modeling the effect of ultrasound on the plastic deformation of metals. here we discussed a more complicated case obtained by Zhou et al. [Influence of ultrasonic vibration on the plasticity of metals during compression process] which, in addition to acoustic temporary softening, involves the residual softening for Ti and the residual hardening for Al.

Since, so far, there is no enough experimental data on the effect of SFE upon the post-sonicated deformation for a wide range of metals, we proposed a linear relationship for f(γ) related to the value of SFE for Al:

$$f(\gamma) = k(\gamma_{\mathrm{Al}} - \gamma) - 1$$





- The first step was to select the appropriate value of r to match the ordinary σ~ε diagram to the experimental one. The theoretical σ~ε curve plotted using equ.:

$$e = \frac{4\pi}{3r} \int_{\beta_1}^{\pi/2} \int_{0}^{\lambda_1} [(\sigma \sin\beta \cos\lambda)^2 - \sigma_S^2] \sin\beta \cos\lambda \cos\beta \, d\lambda d\beta = a_0 \Phi(b),$$

- we plot σ~ε diagrams under the action of US using equ.:

$$e_U = a_0 \Phi(b_U), \qquad b_U = \frac{\sigma_S}{\sqrt{\sigma_U^2 + \frac{3}{2}\left(A_1 {\sigma_m}^{A_2}(2 - e^{-pt})\right)^2}}.$$

- Finally plotting the deformation of post-sonicated material, which is calculated via Eq.:

$$r\varphi_{Nr} = \frac{2}{3}\left[(\sigma \sin\beta \cos\lambda)^2 - \frac{3}{2}[A_3 {\sigma_m}^{A_4} \tau]^2 - \sigma_S^2\right],$$

Modelling of ultrasonic temporary and residual effects

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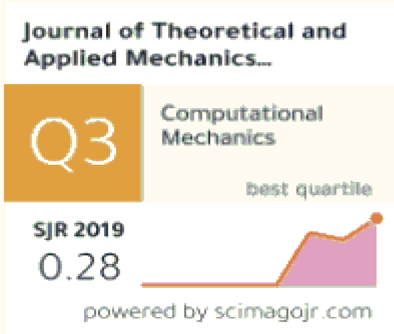

Creep deformation of metals in the ultrasonic field

This work is aimed to plot strain~time curves for copper in terms of the synthetic theory for the following cases: (i) ordinary creep, (ii) creep in the acoustic field as
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continuously from the
the creep, (iii) creep
field as the US of osc
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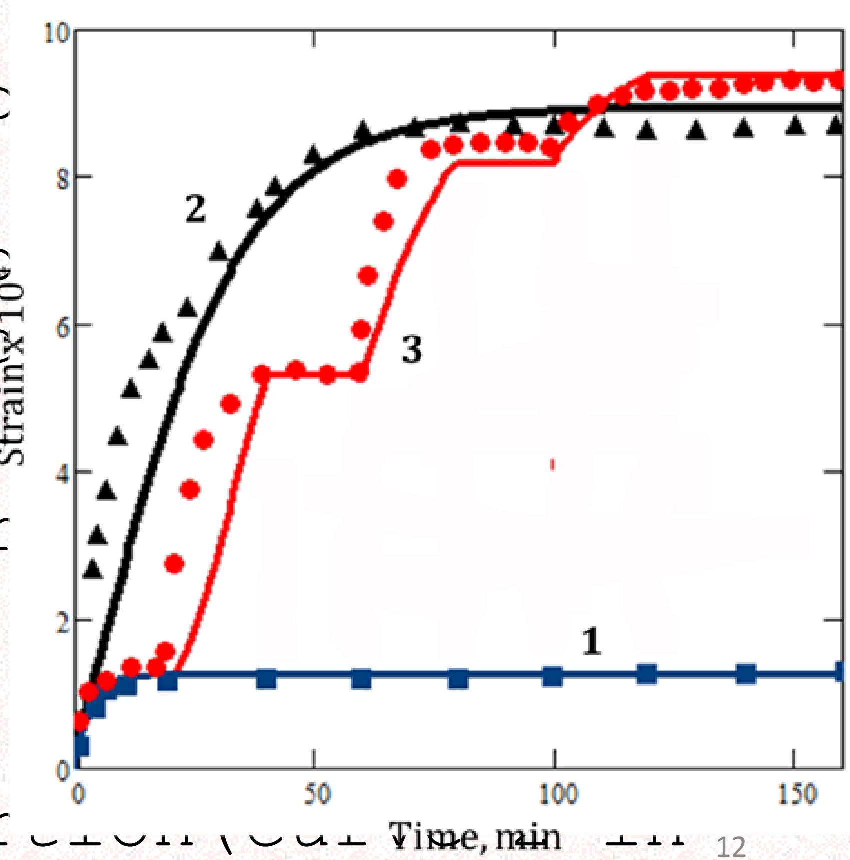
To plot the first (cur
used equ.:

$$\varepsilon = a_0[\Phi(b) - \Phi(b_0)],$$

To plot the second por
Fig.), we



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Evolution Of Loading Surface In The Ultrasonic Field

This study discusses the evolution of loading surface associated with the phenomena of ultrasonic temporary softening and ultrasonic residual hardening and residual softening registered in the experiments for plastic deformation of Al and Ti in the ultrasonic field. The aim was to model these phenomena in terms of the synthetic theory of irrecoverable deformation.

The conclusion cannot be escaped that, at least in terms of experiments considered, the metals with high SFE, such as Al, are inclined to ultrasonic residual hardening. In contrast, metals with low SFE (Ti, Cu, Ag) manifest the phenomenon of ultrasonic residual softening.

$$\vec{e} = \iiint_V \varphi_N \vec{N} \, dV \ , \qquad ..1$$

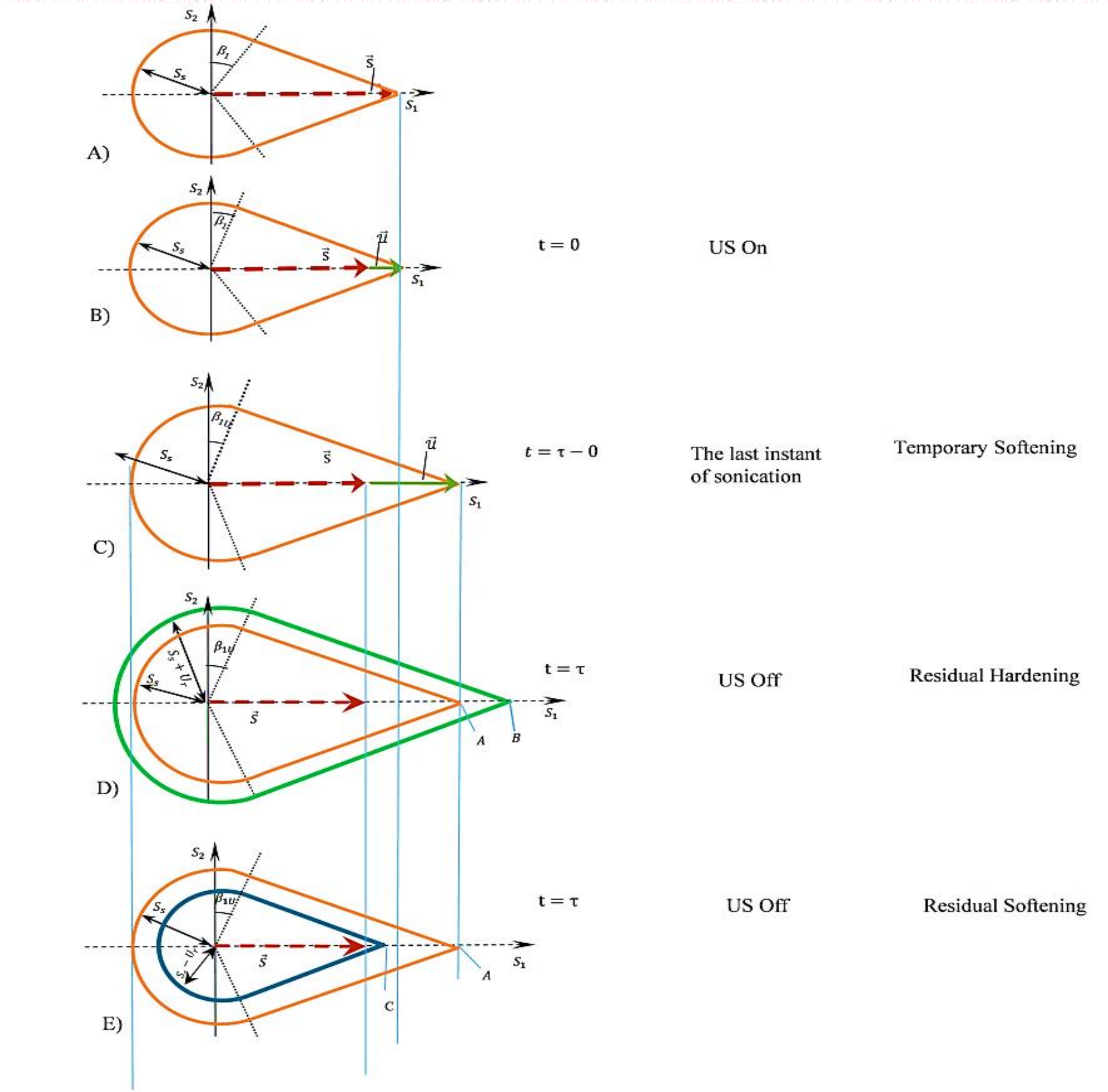
$$r\varphi_{Nr} = \frac{2}{3}[(\sigma \sin\beta \ \cos\lambda)^2 - \frac{3}{2}[A_3 \sigma_m{}^{(A_4)} \tau]^2 - \sigma_S^2], \qquad ...2$$

$$r\varphi_{Nr} = \frac{2}{3}[(\sigma \sin\beta \ \cos\lambda)^2 - \frac{3}{2} f \ (\gamma_{Ti})[A_3 \sigma_m{}^{(A_4)} \tau]^2 - \sigma_S^2], \qquad ...3$$

$$r\varphi_N = H_N^2 - S_S^2 = \begin{cases} (\vec{\boldsymbol{S}} \cdot \vec{\boldsymbol{N}})^2 - S_S^2 & \text{if } \ H_N = \vec{\boldsymbol{S}} \cdot \vec{\boldsymbol{N}} \\ 0 & \text{if } \ H_N > \vec{\boldsymbol{S}} \cdot \vec{\boldsymbol{N}} \end{cases}. \qquad ...4$$

$$H_N^2 = r\varphi_{NU} + U_r^2 + S_S^2, \frac{1}{2} \qquad ...5$$

$$H_N^2 = r\varphi_{NU} - f \ (\gamma_{Ti}) U_r^2 + S_S^2, \qquad ...6$$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Evolution of loading surface in the ultrasonic field

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The next step

The next steps is to develop a model for ultrasonic-assisted stress with a boundary problem.

Courses Completed

Code	Course	Lecturer	Number of credits
OATATVEM1ND	Finite element modeling of material technologies	Dr. Gonda Viktor	6
OAIAFRT1ND	Modeling of thermally activated transformation processes in alloys	Dr. Réti Tamás	6
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Thank You

Any Question?