Institute of Thermomechanics Seminar

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Lecture No. 99

Czech Society for Mechanics and Institute of Thermomechanics, CAS
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LASER SHOCK PEENING:
Laser explosion and shear wave propagation

given by

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Although the parameters of the laser pulse are known: the total light energy (5 J), the beam diameter (2.45 mm) and the pulse length (14 ns), the dynamics of the laser explosion itself is unknown. From the point of view of the studied application, the unknown quantities are: the magnitude of the generated pressure in the area of strongly superheated steam (or plasma), the rate of its expansion and its subsequent attenuation. The dynamics of the generated pressure pulse depends on the viscoelastic properties of the irradiated medium (304L austenitic steel) and the absorbing covering medium (water). Physical analysis and numerical simulation show that the magnitude and shape of the residual stress (reinforcement) depends on the choice of material model.

To describe the dynamics of an explosion, the starting point is the balance of the internal energy of the superheated gas (partially ionized water vapor) is needed. The amount of internal energy is given by the absorption of light energy. This energy is then transformed into the required expansion work and is reduced by radiation due to the high temperature.

The consequence of the high pressure magnitude (3-7 GPa) and the high expansion rates (10^6-10^9 s^{-1}), shock waves are generated in both water and steel. Due to the existence of these waves, which propagate at a speed greater than the corresponding speed of sound, the pressure reaches extreme values and causes strong deformation of the material.

From the point of view of the subsequent strengthening of the material, the dynamics of the shock wave propagation in the steel is decisive. Modeling the consequences of a shock wave is, in addition to the standard elasticity, dependent on the plasticity model of the steel. Both the Ramberg-Osgood hardening model and the Bodner-Parton dislocation movement model are presented in the lecture.

The movement of dislocations can be characterized by the viscosity depending on the rate of deformation. In this way, the material strengthening is explained by overcoming atomic bonds, which coressponds to the hardening work. The movement of dislocations can be modeled by shear waves, which are strongly dispersive. In areas of high viscosity (before the shock wave) they precede the pressure shock wave. The concept of shear waves allows to describe with some accuracy the strengthening of the material due to extremely fast compression.

The presented analysis shows, that to achieve a higher residual stress at the same laser energy, it is more advantageous to use a pulse of shorter length. For greater depth of reinforcement, it is necessary to use a longer pulse. Currently, an experiment is always needed to model LSP. The experimental residual stress data used were provided by the HiLASE Center Institute of Physics CAS. After calibration, the LSP process can also be used to determine the properties of the material under extremely fast loads.

The lecture will be held on Wednesday, May 26, 2021 at 10:00
Online via ZOOM meeting
with link https://us02web.zoom.us/j/87903155732
Meeting ID 879 0315 5732

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