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MULTISCALE APPROACH TO LASER SHOCK PEENING INCLUDING PLASMA SHOCK WAVE SIMULATION

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Laser shock peening (LSP) is a surface modification technique, which can be used to improve the fatigue performance of metallic structures by inducing compressive residual stresses. Short-time high energy laser pulses are used to vaporize the surface layer. The vaporised material is turned into a high temperature and high pressure plasma. The plasma pressure induces a mechanical shock wave within the material, which causes local deformations or grain reorientations. After the elastic relaxation of the deformed system, residual stress remain as a result of the plastic deformation gradients within the material. The process is highly nonlinear and difficult to optimize based on experiments alone due to the high number of process parameters and non-linear interaction of a number of short time events. Additionally, the present underlying extreme values of the physical quantities are hard to measure experimentally (e.g. shock wave propagation, plasma formation).

Starting with a laser induced plasma shock wave simulation, a 1D global model to determine the shock pressure, depending on the laser parameters and material properties, is implemented. Solving numerically the large system of nonlinear equations [1], temporal pressure distributions for different sets of LSP process parameters are determined. Based on this model the plasma pressure distribution for a laser energy of 5 J and a laser pulse of 20 ns is calculated. In Fig. 1(a) is shown that the pressure maximum is reached after the maximum of the laser profile, which can be explained by a mass flow from the water curtain to the plasma region. This pressure distribution is assumed as the pressure at the material surface, which is applied as boundary condition to a subsequent finite element residual stress simulation.

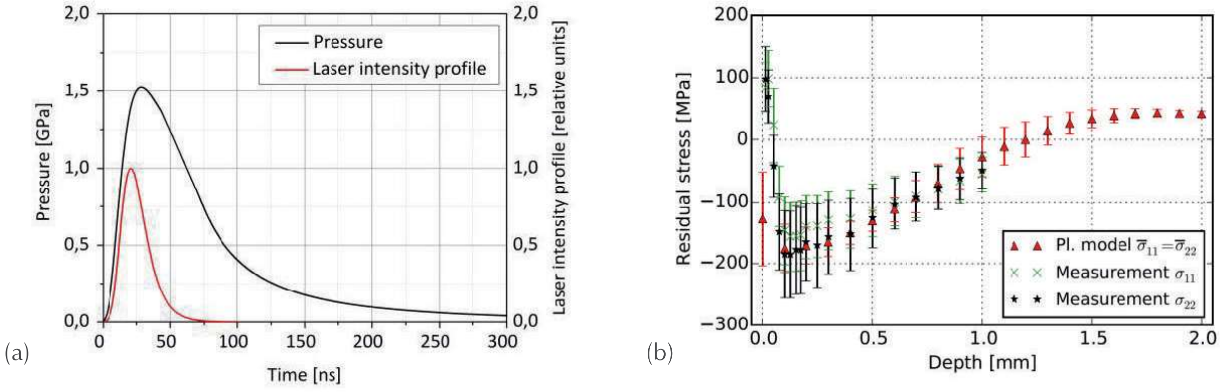

Fig. 1: Simulation results. (a) Pressure distribution and laser intensity profile for 20 ns laser pulse with 5 J energy. (b) Residual stress prediction after LSP without overlapping with 3x3 mm2 focus size for 4.8 mm specimen thickness using the calculated pressure pulse.

A finite element model is used to predict the resulting residual stresses after the LSP-treatment as described in [2]. It contains a stress averaging scheme to enable the comparison between measured and predicted residual stresses. The residual stresses were calculated for AA2198 in two different temper conditions (T3- and T8-condition) based on the pressure pulse as provided from the plasma shock wave simulation, as mentioned above. The good agreement seen in Fig. 1(b) of measured and calculated residual stresses validates the suggested multiscale approach based on a profound physical basis. Further numerical and experimental results will be shown.

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