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Influence of Dynamic Material Properties on Perturbation Growth in Solids

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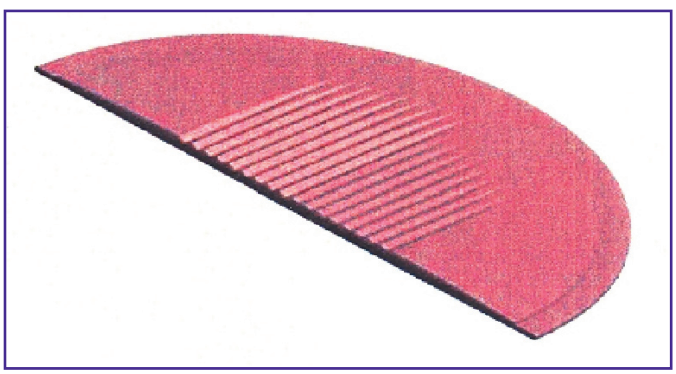
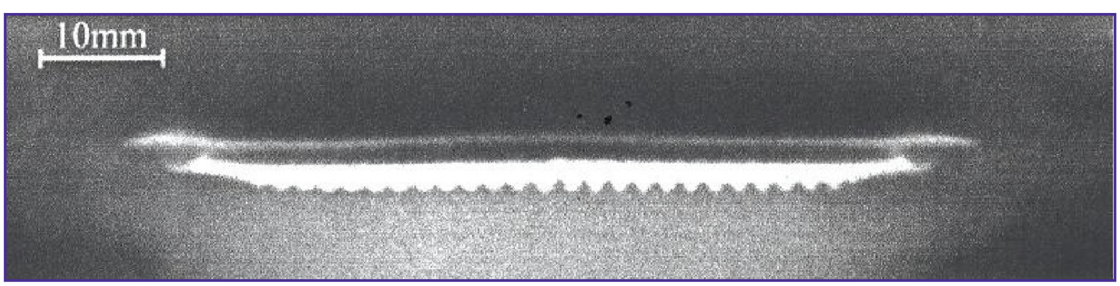
Project Description

The development of mathematical models capable of accurately predicting constitutive behavior over a wide range of strain rates (e.g., from quasistatic to 10^6 s^{-1}) is a particularly difficult task, and an area of active research today. A number of factors contribute to the difficulty, but two of the foremost are (1) constitutive theory demands a homogeneous field if one is to extract material properties from experimental results, and experimental methods that produce a homogeneous field have not been developed for strain rates above about 10^3 s^{-1} and (2) the fundamental mechanisms that govern material flow at high strain rates (i.e., on the order of 10^6 s^{-1}) are often different from those that are dominant under more modest strain rate conditions. To develop a constitutive model that is valid over a quasistatic to 10^6 s^{-1} strain rate regime, one must supplement material property tests (tests conducted at modest strain rates wherein homogeneity of the stress field is present) with specific experiments carefully designed to highlight high strain rate behavior. One of the most promising methods for evaluating constitutive behavior at high strain rates, especially at strain rates above about 10^5 s^{-1}, is the method of perturbation growth.

The method of perturbation growth relies on the Rayleigh-Taylor instability that occurs when a less-dense fluid (in this case, high-explosive detonation products) pushes on a pre-perturbed solid. Because of the instability, initial perturbations grow with time. Since the dominant factor governing perturbation growth is the constitutive behavior of the solid, this method is ideal for the evaluation of constitutive models in a high strain rate regime, especially in the 10^5 to 10^7 s^{-1} range. The researchers at VNIIEF are recognized leaders in applying this method.



Pre-perturbed sample.



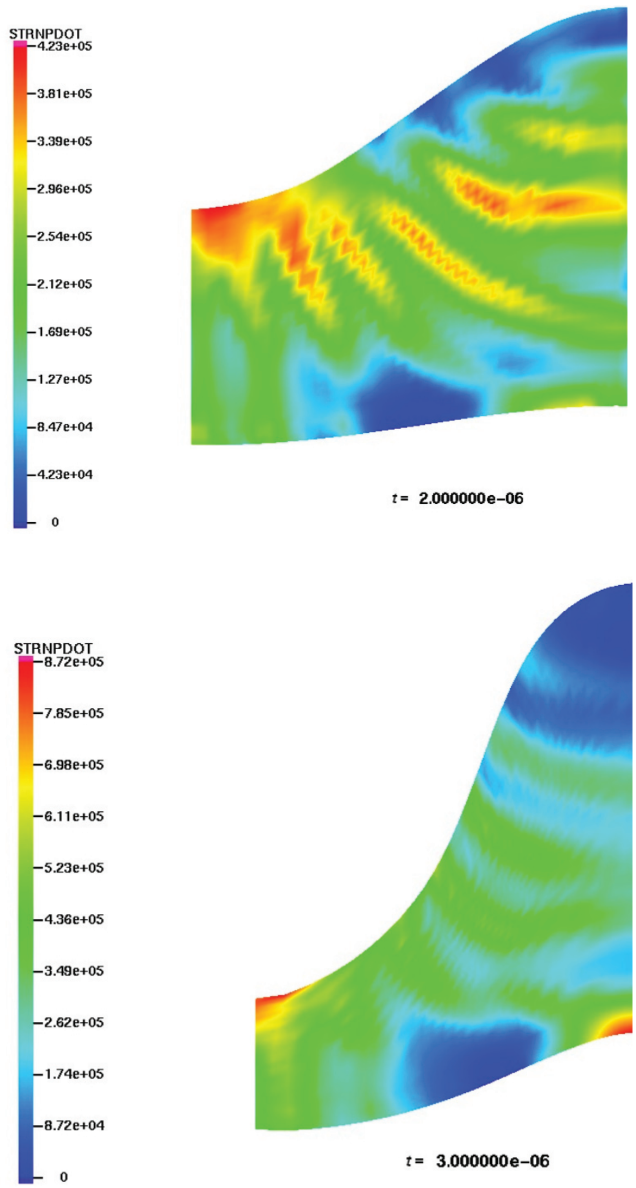
Radiograph showing perturbation growth.

The perturbation growth method will be applied for the purpose of developing constitutive models that are validated over a wide range of strain rate (quasistatic to 10^6 s^{-1}). As was alluded to earlier, the fundamental mechanisms that govern material flow at high strain rates are often different from those that are dominant under more modest strain rate conditions. It has been observed that phenomena such as heterogeneous deformation become extremely important at strain rates approaching 10^6 s^{-1}. Models that do not account for these phenomena will prove to be rather poor predictors of overall constitutive response under high strain rate conditions.

The fundamental objective of this work is the development of models that can be trusted over a wide strain rate regime. To achieve this end, these models must account for phenomena (such as localization) that are not accounted for in existing models.

Technical Purpose and Benefits

The development of better predictive capability is essential if LANL is to meet its obligations to NNSA and the country. Current constitutive models do a rather poor job of predicting high strain rate behavior because they do not account for some of the fundamental mechanisms that are responsible for material flow under these conditions. Under this project, new models are being developed. A new Relaxation Model has already been developed. This model incorporates a relaxation time that corresponds to a length scale associated with deformation localization. A new Two-Temperature model is under development. This model is nonlocal, and accounts for localization and the strong temporal heating associated with that localization. This work supports the objectives of the NNSA and both research institutions (LANL and VNIIEF) as they endeavor to improve their predictive capabilities in the area of high strain rate constitutive response, an area where existing capabilities are clearly lacking.



Simulation of perturbation growth at two different times.

ВНИИ
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