Joint Analytical/Experimental Constitutive and Failure Model Development

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1 Introduction

The prediction of failure is without any doubt the decisive ingredient of any numerical simulation performed within the framework of safety analysis. Whereas this has always been true for aeronautical and defense applications, it became so in automotive crash more recently through the introduction of lightweight materials. There is definitely no shortage of failure models in the LS-DYNA software and the wide range of applications has driven many of these models towards ever increasing generality including a strong tendency towards tabulated input formats. This has the advantage of a high predictive potential provided that 1/ the necessary experimental data are available, 2/ the model has been carefully calibrated with respect to these data and 3/ the data cover the entire range of temperatures, stress states, strain rates a.s.o. , that the structure might be subjected to in a real life application. In other words, the experimental program must be carefully designed keeping the actual application in mind. This is the first level where a close cooperation between analysts and experimentalist is absolutely crucial.

2 Experimental techniques ; DIC

Digital Image Correlation (DIC) is an optical, non-contact technique to measure full-field deformation on the surface of a work piece. One camera can be used to measure planar displacements and strains on flat objects. Three dimensional DIC measurements are necessary for specimens with 3D geometric features or where significant out of plane deformation is expected. 3D measurements can be made with two cameras in a calibrated stereo rig. DIC measurements can be made in static tests and dynamic tests at strain rates ranging from 1E-4 s^{-1} to 5000 s^{-1}. The technique is only limited by the camera hardware used in the experiment. 3D DIC can be used for servohydraulic load frame and split Hopkinson bar (SHB) experiments. In addition, 3D DIC can be used to measure specimen deformation at elevated temperatures (up to 860 deg C) with a custom designed furnace.

Fig.1: 3D DIC experimental setups: (a)typical low strain rate setup on a load frame, (b) dynamic setup with a tension SHB aparatus.

3 Direct Benefits to the CAE implementation

As the DIC can output full strain fields for any chosen base length (virtual strain gage length) and these strain fields can be directly compared to numerical results obtained with a similar mesh size (element characteristic length), the potential for numerical modeling is obvious. As shown in Figure 2 the maximum strains recorded prior to failure in experiments corresponding to different stress states can be used to generate a first estimate of the failure curve for any material. The curve remains a first guess as the experimentalist cannot measure stresses and the exact value of the stress triaxiality therefore remains unknown.

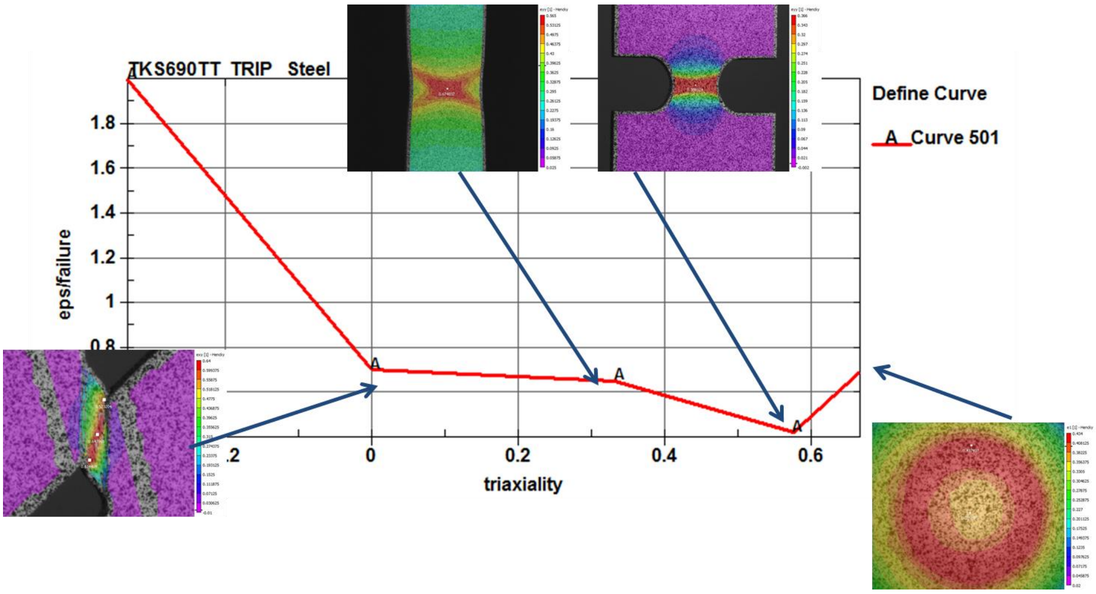

Fig.2: First estimate of a failure curve based on DIC data

Similarly, as strain fields can be output from the same test for different values of the virtual strain gage length, this can be used to construct a first guess of regularization curves , primarily in uniaxial and biaxial testing where larger gage lengths are physically possible (this is typically not the case in a shear test)

4 Summary

The generation of a predictive material and failure model depends upon the close cooperation between the analyst and the test lab. This cooperation does not stop with the test report but continues with discussions during the model development process to deepen both sides' understanding of the results that were obtained. In particular the introduction of DIC has allowed to reduce lead times for the development of GISSMO and/or MAT_224 datasets from 6 to 2 weeks with a considerable increase in confidence levels of the models.

5 Literature

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