

Practical examples of sheet metal forming simulations using the subroutine library ‘UMMDp’

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Abstract. With the common frame work of the user subroutine library, ‘UMMDp’, various constitutive models for metals have been implemented in several major commercial finite element (FE) codes. The implementation has been achieved by the material modeling working group of a non-profit organization, the Japan Association for Nonlinear CAE (JANCAE). Herein, we report the results of the finite element analyses on a typical metal forming problem solved using UMMDp. Moreover, since 2017, the CAE modeling working group has been tasked to provide more practical learning for the material models as well as extensive simulation knowledge. These activities are presented in this paper.

1. Introduction

In the past 20 years, many nonlinear analysis programs have become commercially available. The expectation for nonlinear CAE has increased. To enhance the simulation, many complicated options are added to the analysis programs in every update. Consequently, the programs for nonlinear CAE have developed significantly, and resemble an encyclopedia of solid mechanics. However, with the commoditization of nonlinear analysis, the opportunities to learn the detailed theories of solid mechanics and FEM are decreasing.

To avoid the design mistakes caused by inappropriate numerical analyses, CAE engineers need to learn continuously. The type of practical learning required is different from university curriculums, academic workshops, or seminars provided by software vendors. A non-profit organization, the Japan Association for Nonlinear CAE (JANCAE) was founded in 2001 based on such needs [1].

The primary activities by JANCAE are the nonlinear CAE training courses held twice yearly. Approximately 250 engineers participate in these courses yearly. The participants are engineers who use the CAE software in the manufacturing industries, university researchers, and support engineers of software vendors. To create a more practical learning workshop, JANCAE started a working group activity on nonlinear material modeling in 2005; here, we learn the process from material testing to the numerical modeling of nonlinear materials such as rubber, resin, polymer and metal.

The materials modeling working group of JANCAE has developed user subroutines suite to learn more about the constitutive law in FE analysis [2]. The participants deal with various material models in each company and use different commercial programs. In order to learn together beyond their backgrounds, we designed a common framework for the material subroutines and eliminated the



differences due to the programs used. With the circumstances mentioned above, the Unified Material Model Driver for plasticity (UMMDp) was developed.

In the field of sheet metal forming, accurate prediction of forming defects is important for process design. The UMMDp is also effective in sheet metal forming simulations, in which the anisotropic yield functions are critically required. In this report, we report an analysis example performed by the working group and demonstrate the effectiveness of the UMMDp. In addition, we introduce the activities that are currently underway since 2017.

2. Sheet metal forming analysis example using UMMDp

We report the analysis results of deep-drawing process with a hemispherical punch. The analyses were carried out using the UMMDp in several commercial FE-codes (Abaqus, ANSYS, LS-DYNA, and Marc) by the participants of the working group in 2016.

Figure 1 shows the setup of the deep-drawing process and the material properties used in the analyses [3]. The material model used in the analyses was the Yld2004-18p yield function [4], the parameters of which were determined from the biaxial stress tests: biaxial tensile test with a cruciform specimen [5, 6], multiaxial tube expansion test [7], and combined tension-compression test [8]. The

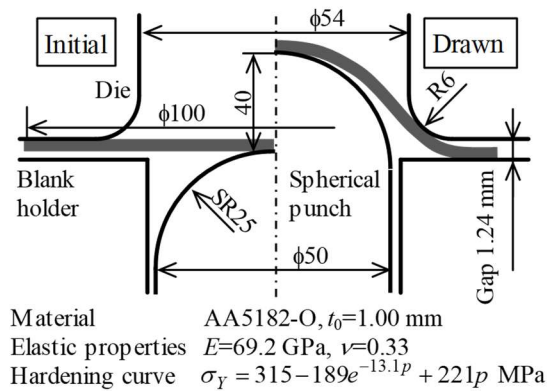


Figure 1. The setup for deep-drawing with a spherical punch.

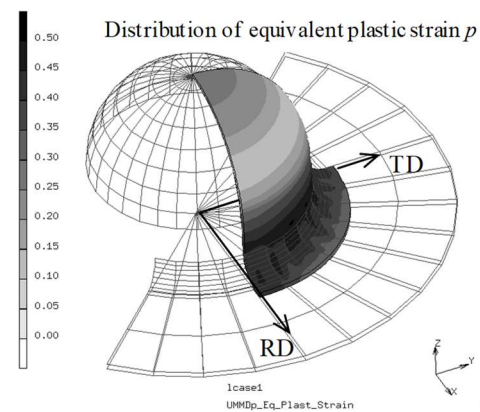


Figure 2. Example of analysis result.

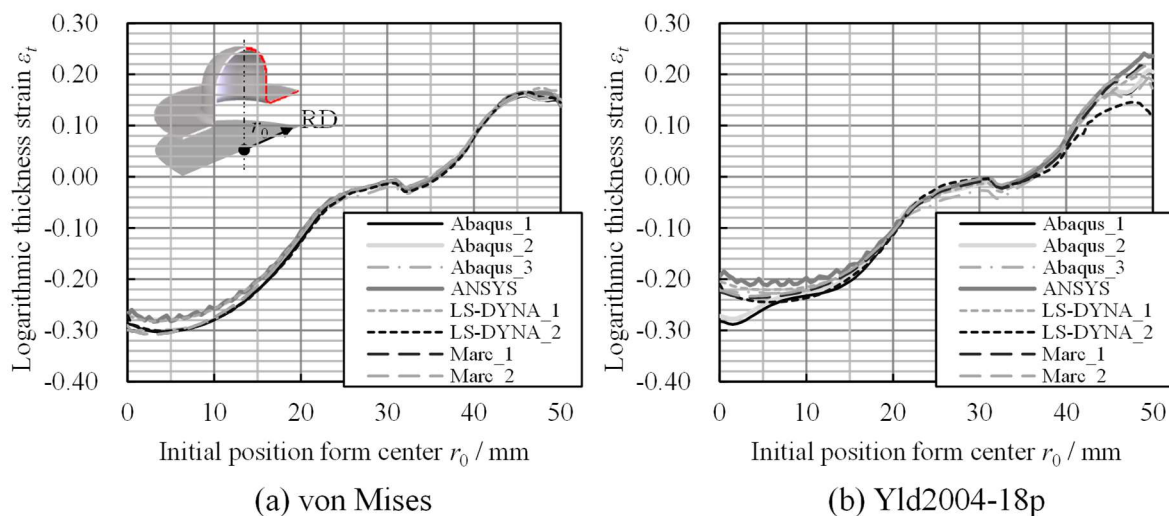


Figure 3. Analysis results of four FE-codes.

linear solid elements that divide the sheet thickness into five layers were used. **Figure 2** shows the distribution of equivalent plastic strain calculated with Marc as an example. **Figure 3** shows the distributions of the plastic strain in the thickness direction, calculated with the isotropic yield function (von Mises) and the Yld2004-18p yield function. r_0 represents the distance from the center of the initial blank to the measurement position on the initial blank. The difference between the distributions by the yield functions used is observed. Particularly, a noticeable difference is shown in the thickness reduction at the center of the sheet. The differences can be due to many causes other than the material model. Even if the same program is used, the results would deviate depending on the user's experience. The results of sheet metal forming simulation are easily affected by the options selected in the numerical analysis. The results indicate that more analysis knowledge acquisition is necessary for the users to achieve a comprehensive improvement in accuracy.

3. The new activity, 'CAE modeling working group'

In addition to the UMMDp user subroutines introduced, the material modeling working group has also developed the user subroutine for rubber materials (Unified Material Model Driver for rubber: UMMDr). As mentioned above, these subroutines were programs made by the CAE software users who participated in the working group. Therefore, some parts of the program are not efficiently coded. However, as an educational material for basic learning, UMMDp and UMMDr are effective for many engineers. These programs will be released through the JANCAE website.

The activities of the material modeling working group were completed in 2016. When using general-purpose FE programs, there are many subjects to be considered according to analysis problem, such as the selection of element type and model for contact boundary, the choice of friction model, etc. We launched the 'CAE modeling working group' as a new activity in 2017 (**figure 4**). Here, many CAE engineers with various backgrounds learn the fundamentals and applications of solid mechanics analysis, to carry out appropriate and practical analyses.

In 2017, to understand the features of each FE software, we prepared an axisymmetric model for the hemispherical punch drawing shown in 'figure 1' and studied it. Furthermore, as an application problem, we are considering past examples of NUMISHEET. Through these tasks, the participants discuss the correct modeling method and the interpretation of the results, which help improve their problem-solving abilities.

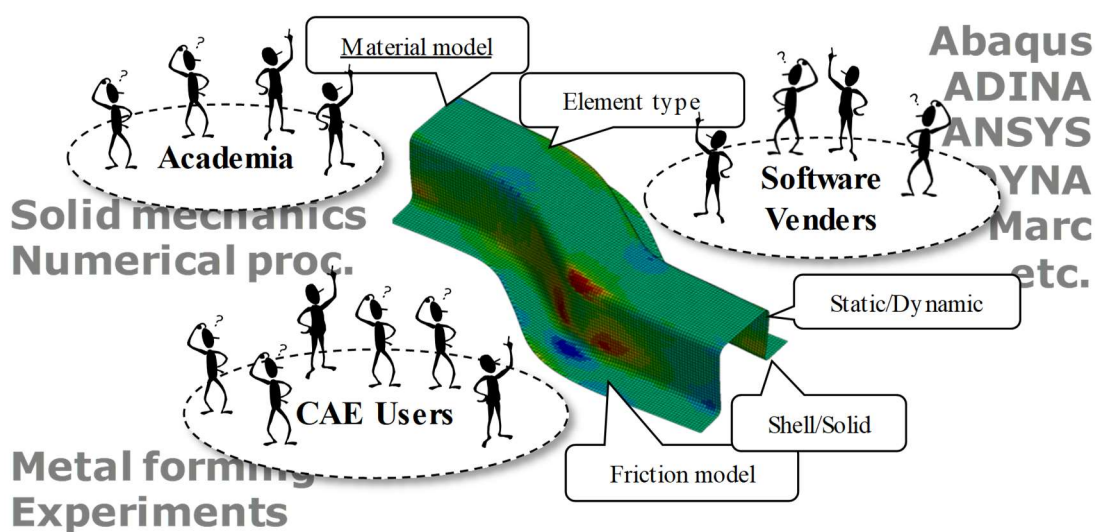


Figure 4. CAE modeling working group.

4. Conclusion

An example of sheet forming analysis with the user subroutine UMMDp is introduced. Further, we introduced the working group activities of JANCAE. The activities are unique and different from academia and industry.

Acknowledgments

All programs and results of the analysis were developed by participants of the Material and CAE Modeling Working Group of the Japan Association for Nonlinear CAE (JANCAE). The authors would like to thank everyone who supported the present project, and Dr. Oide (Mechanical Design and Analysis Corporation) for her useful advice.

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