AFDEX Newsletter Q4 / 2022
MFRC
www.afdex.com, mfrc@afdex.com
Tel: +82-55-755-7529, Fax: +82-55-761-7529

Contents

1. AFDEX_V23 Release

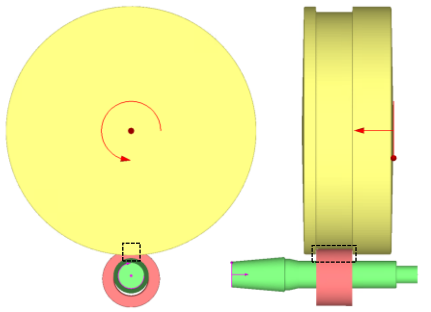
AFDEX_V21R03 was released on May 12th, 2022. It offers a new set of improvements in solver and Pre/Post-processors, which are described in Sections 2 and 3. AFDEX_V23, the next version is planned to be released in March 2023.

2. New Features and Improvements

2.1 Local Material-Motion Constraining Function and its Application

The feature of resisting the rigid-body motion of material is essential for the analysis of mechanically unstable processes. In the 3D analysis of the upsetting process for the entire materials, for example, rigid-body motion inevitably occurs, which leads to difficulty in convergence or inability to analysis. This issue can be resolved by imposing artificial constraint to the rigid-body motion of the material. Recently, a function to block rigid-body motion at specific directions has been developed.

The analysis of the ring rolling process is exposed to the problem of an extremely small contact surface compared to the volume of the material. Since the material is not trapped like forging, it has a difficult problem of predicting the deformed shape with accuracy. Since the work roll and the material are in contact with the outside in two circles, the smooth contact condition cannot be achieved in the finite element simulation. In this case, it is difficult to impose frictional condition accurately that controls the spread. From an empirical point of view, the finite element model is close to the line contact between the work roll and the material, and the actual spread of the ring material is not much. Due to these problems, there is a limit to solving the ring rolling simulation problem with the existing friction law. If the function of artificially controlling the motion of the material in the contact area is used, the strength of the control of the material can be adjusted by the user, so it is possible to solve the above problem in an engineering way instead of the existing friction laws. Figure 2.1(a) defines the application region of this function. If this function is not applied, the side wall is inclined as shown in Figure 2.1(b). This is the result that the outer surface of the ring material receives resistance to spreading by the step of the work roll as the spread increases, but the material on the mandrel side does not receive that resistance. On the other hand, when this function is applied, as shown in Figure 2.1(c), the side of the ring becomes close to the vertical line. This function is quantitatively evaluated to replace the friction law in the process analysis of the ring rolling process in the future.


(a) Applied region

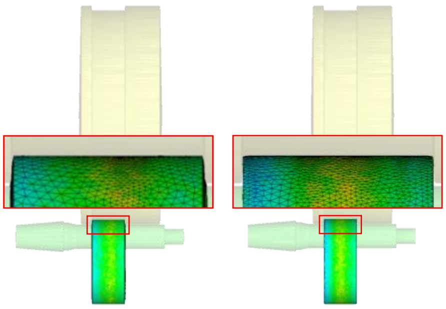
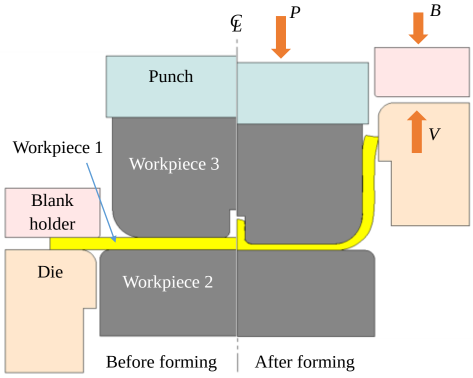

(b) Not applied (c) Applied

Figure 2.1 Profile ring rolling process simulation using new function

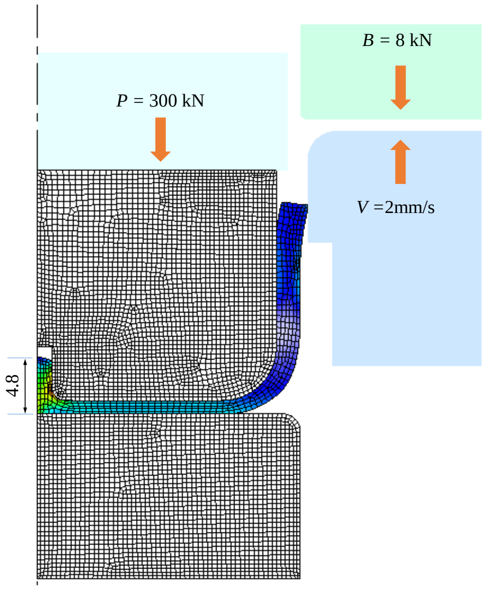
2.2 Boss Forming

Multi-body elastoplastic finite element analysis technology which has been provided from AFDEX_V21 is essential for analytical purposes of special processes, including not only for multi-body structural analysis and metal forming simulation but also for the FE analysis of special mechanical problems where the die control is greatly affected by plastic deformation of the material. Here, we introduce a 2D example among the recently applied examples. Figure 2.2(a) shows the boss forming process in which the upper punch and right upper binder (blank holder) apply the given forces on the sheet or plate material and the lower punch and right lower die support and push the material with zero and given velocities, respectively.

Mechanically, it is summarized that the binder and the movable lower die gradually strengthen the conditions of plastic deformation by applying radial stress to the material between the upper and lower punches. Figure 2.2(b) is the FE prediction of the test boss forming process predicted under the following conditions: P = 300kN, friction coefficient = 0.07 and B = 8kN. The predicted ratio of the boss height to the initial sheet thickness (h/t) is 4.8/2.0, which is similar to the work of Wang et al. (CIRP Annals-Manuf. Technol., V. 62, 291-294, 2013). Note that the B value was assumed in this simulation.



(a) Conceptual drawing of the boss forming process



(b) FE predictions

Figure 2.2 Elastoplastic finite element analysis of the boss forming process using multi-body function

2.3 Simulation of Tube Drawing Process with Nonuniform Thickness and Die Misalignment

FE analyses of tube drawing processes have traditionally been conducted under the assumptions of uniform thickness of the mother tube, fixed mandrels and right alignment of dies or tools. Analysis results obtained under such assumptions have very limited meaning.

Actual mother tube allows thickness variation within 10%. Therefore, the change in thickness variation caused by the plastic deformation during tube extrusion is a major concern. Figure 2.3 shows the tube drawing process with a mother tube with non-uniform thickness and a die inclined at 5 degrees with an emphasis on the multi-body implicit elastoplastic finite element mode. The chracteristic of this process is that the mandrel is automatically positioned properly to balance the load as shown in the Figure 2.3. That is, the initial position of the mandrel is located at the center but moved to a point where the mechanical balance was achieved with the progress of the process simulation. The FE predictions of this process showed a similar trend to the experimental works done by N. Al-Hamdany et al. (Tube drawing with tilted die: Texture, dislocation density and mechanical properties," *Metals*, Vol. 11, 2021) in terms of thickness deviation. According to the FE predictions, the thickness deviation can be improved or worsened depending on the direction of the inclination angle of the die.

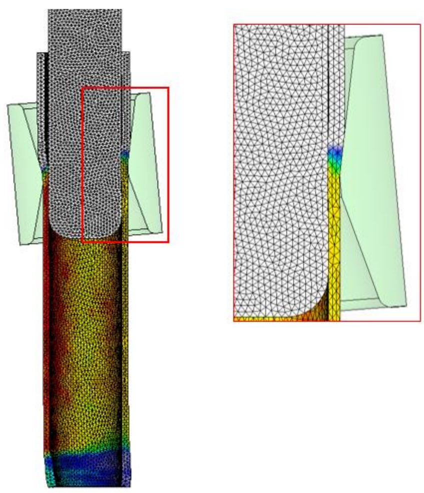
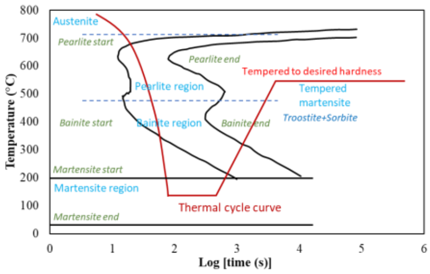


Figure 2.3 Simulation of assymmetric extrusion process

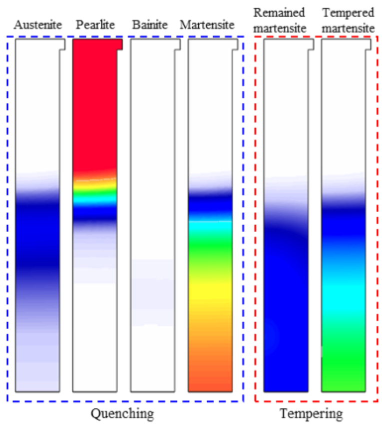
2.4 Quenching & Tempering Simulation of Jominy Test

After quenching, the hardness of a material is usually very high. Therefore, after heating the material and maintaining it for a certain period of time, tempering is performed by slow cooling in the atmosphere. At this time, the maintainance temperture and time determine the degreee of hardness decrease. Figure 2.4(b) shows the phase fraction during the heat treatment predicted using the TTT curve in Figure 2.4(a). At the end of quenching, 90% of austenite is converted to perlite, bainite, and finally martensite. This quenching induced phase transformation and thermal expansion and contraction owing to the quenching and/or tempering cuase the deformation and volumetric change of the material. Figure 2.4(c) shows an example of predicting them.

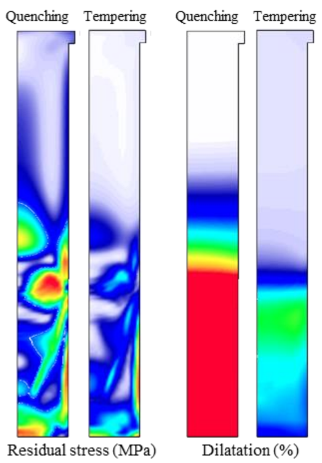
The feature regarding heat treatment is planned to be released in March 2023.



(a) TTT-curve



(b) Volume phase fraction

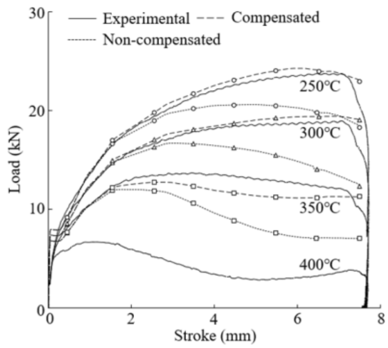


(c) Distortion analysis

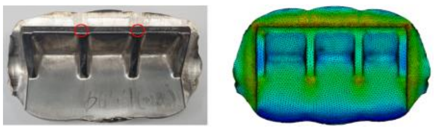
Figure 2.4 Heat treatment analysis

2.5 Effect of Temperature Compensation of Flow Curves

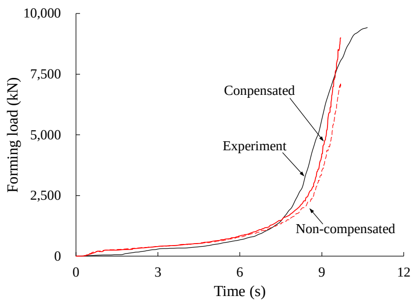
When obtaining the flow curve of AZ31B magnesium alloy, temperature compensation of the high temperature compression test result is very important (Refer to Newsletter Q2/2022). As shown in Figure 2.5(a), there is a hugh difference in flow stress depending on whether or not the temperature is compensated. Figure 2.5(b) compares the analysis results using the temperature-compensated flow information with the experimental results, which shows that the effect of the temperature compensation is not large in terms of the shape prediction. However, the forming load has a significant difference in Figure 2.5(c). The maximum forming load obtained through the experiment was 9.48 MN. The forming load predicted by the temperature-compensated flow information is 9.00 MN (95% of the experimental value), while that obtained by the temperature-compensated flow information is 7.11 MN (75% of the experimental value). The result is sufficient enough to emphasize the importance of the correct understanding and application of temperature and friction compensation. Of course, the simplest way to check is to analyze the compression test and compare it with the experimental values. For more information of this, please refer to the Newsletter Q2/2022 or related academic papers.



(a) Temperature compensation of AZ31B Magnesium alloy



(b) Deformed shape



(c) Comparison of forming load

Figure 2.5 Comparison of analysis results and experimental results

3. AFDEX_V23 Pre/Post Processor Improvement

3.1 Pre-processor Improvement for Shape Rolling Process Analysis

Previously, the basic input setting of the analysis condition is completed through the pre-processor of AFDEX, while the other inputs for specific conditions of the shape rolling process simulation such as the boundary conditions of rolls and materials were done by text file.

For the convenience of use, AFDEX_V23 provides that all input data can be written in the pre-processor.

3.2 New Material Flow Models

Currently, AFDEX pre-processor provides 16 types of flow models including well-known traditional flow models (Ludwik, Voce, Hollomon, and Swift) for formulating the flow curves. AFDEX_23 will provide UI for 8 new flow models added in the new solver.

3.3 Pre-processor Improvement for Crack Analysis

Recently, crack analysis conditions suitable for 2D and 3D analysis and its solvers have been improved. Due to the change in the solvers, UI of pre-processor is also updated. The criteria for element removal in 2D and 3D crack analysis are as follows:

2D: $w_1 D + w_2 \frac{\sigma_1}{\bar{\sigma}} + w_3 \frac{D\sigma_1}{\bar{\sigma}} + w_5 \frac{\dot{\bar{\varepsilon}}}{\dot{\bar{\varepsilon}}_{max}} > D_{cr}$

3D: $D > D_{cr}$ & $\dot{\bar{\varepsilon}} > \dot{\bar{\varepsilon}}_{cr}$ & $\dot{\bar{\varepsilon}} > w_5 \dot{\bar{\varepsilon}}_{max}$

where D: damage, D_{cr}: critical damage, w_i: weight, $\bar{\sigma}$: yield stress, σ_1: maximum principal stress, $\dot{\bar{\varepsilon}}$: effective strain rate, $\dot{\bar{\varepsilon}}_{max}$: Maximum effective strain rate.

3.4 Scale Tool for Material After Forming

Since a hot forging product is formed with a heated material, thermal expansion becomes an important consideration for the process design. The material in the state where the current analysis has been completed is the one that has been subjected to thermal expansion. In the previous version of AFDEX, it was not possible to check the shrinkage dimensional information of the material due to cooling after forming in the post-processor. AFDEX_V23 provides the checking feature for the size of the material that has been shrunk using the scale adjustment function through the post-processor.

4. Notice

4.1 Online Training in 2022

In response to the continued evolution of the COVID19 pandemic, all the training programs stand cancelled and MFRC is shifting in-person training to online training for applicants only.

Also, the tutorials and theories are uploaded on MFRC's YouTube channel. The following subjects will be provided: mathematical background, tensile testing, statics, solid mechanics, introduction to plasticity theory, finite strain, finite element method, and all materials related to metal forming, etc. Although the online lectures originally aim to help college students understand the materials, it can also be utilized as the materials introducing theories and mechanics used in AFDEX.

For more details, please refer to the link below. (https://www.youtube.com/c/AFDEX)

4.2 Altair APA Webinar Series: Manufacturing Analytics

In this September 29th, MFRC participated Altair free webinar series entitled "Optimize Manufacturing Processes with Advance Simulation Technology." In this webinar, the presenter of this event, Dr. M. K. Razali presented about heat treatment and microstructure evolution.