AFDEX
Adviser for metal Forming process Design EXpert

Newsletter
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Contents

1. AFDEX_V24R02 Update: Now with Heat Treatment and Microstructure Modules

In October 2025, the AFDEX_V24R02 update and the new Heat Treatment and Microstructure Modules were officially released. Following the major version update in June, this release focused on user-friendly functional improvements. The Heat Treatment / Microstructure Analysis Module, which has undergone two years of beta testing, is now available for general use.

The microstructure prediction program includes advanced features such as dynamic recrystallization (DRX), static recrystallization (SRX), and grain growth prediction. The heat treatment program supports analysis of hardening, annealing, quenching, tempering, and spheroidization, enabling users to comprehensively analyze material behavior during both forming simulation and post-processing.

2. AFDEX Simulation Cases

2.1 Expanded Anisotropy Features

All materials exhibit some degree of anisotropy. However, in bulk metal forming processes, such as forging, anisotropy is generally minor, so isotropic analysis is usually sufficient. In contrast, sheet materials can develop significant anisotropy during manufacturing, making it essential to consider anisotropy in sheet metal forming or blank drawing simulations. Recently, the AFDEX research team, led by Professor W. J. Chung, developed an anisotropic elasto-plastic finite element analysis program, which was presented at ICPMMT 2025.

The team plans to release a new module incorporating various anisotropy models in February 2026, and Professor Chung will present related research at the 2025 KSTP Autumn Conference (November 6). Figure 2.1 shows the results of an anisotropic elasto-plastic finite element analysis of a circular cup drawing process using a tetrahedral mesh. The tetrahedral elements in AFDEX support automatic remeshing, which is essential for shear or localized deformation analyses. This newly developed anisotropic analysis capability is expected to enhance AFDEX's applicability to a wide range of sheet metal forming simulations.

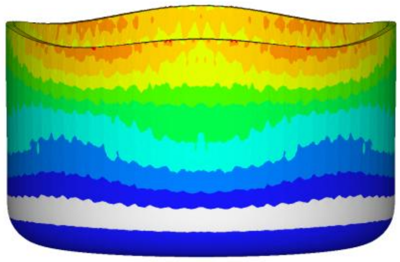


Figure 2.1 Anisotropic elasto-plastic finite element analysis using tetrahedral elements

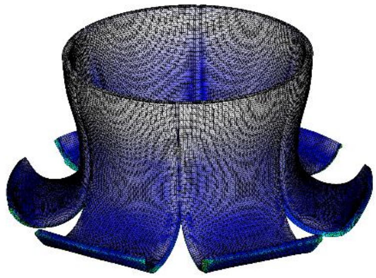
2.2 Determination of Damage Constant and Critical Damage Value

For ductile fracture analysis, picking the appropriate damage model and determining the critical damage value are crucial. The AFDEX research team has developed a practical method to calculate both the damage constant and critical damage value simultaneously, based on two experimental tests. This method is primarily based on tensile testing, combined with another test where the fracture initiation point can be clearly identified. The predicted tensile test results, obtained using the flow curve derived from related research, showed only a 2.4% error compared with the actual experiment, demonstrating strong agreement.

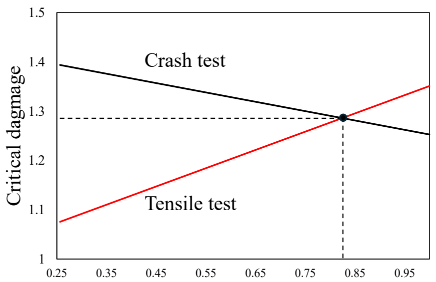
Therefore, the damage obtained through tensile test simulations is considered highly reliable. Figure 2.2(a) presents the simulation result of an energy-absorbing crash device. According to the analysis, as shown in Figure 2.2(c), an initial crack appears when the displacement reaches 58 mm, which indicates the fracture point in this process. To determine the relationship between the damage constant and critical damage value, the following Oyane-Okimoto-Shima damage model was used:

$$D = \int \left(1 + C\frac{\sigma_m}{\bar{\sigma}}\right) d\bar{\varepsilon} \qquad (1)$$

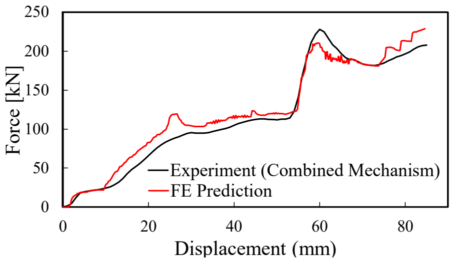
In this model, the damage value is linearly proportional to the constant C. The resulting relationship between the damage constant and critical damage (at fracture) is shown in Figure 2.2(b). The intersection of the two lines gives C = 0.82 and critical damage = 1.29. Using these values, the stroke–load curve in Figure 2.2(c) was obtained, showing excellent agreement between the simulation and the experiment.



(a) Crash test (final stage)



(b) Relationship between damage constant and critical damage



(c) Stroke–load curve during crash test

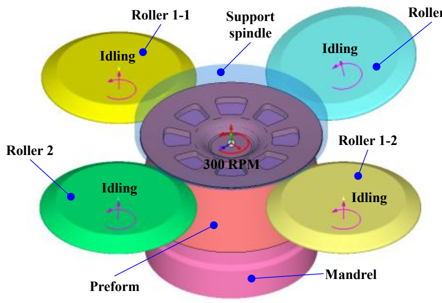
Figure 2.2 Crash test of energy absorption device

2.3 Multi-Stage Roll Flow Forming Simulation

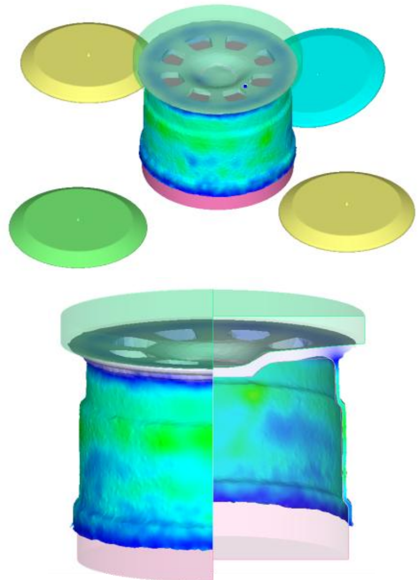
The flow forming process enables gradual shaping of materials using rollers with various geometries and numbers. Previous studies typically analyzed the initial thickness reduction using a pair of rollers. In contrast, the improved process introduced two additional rollers (Roll 2 and Roll 3) with different geometries, supplementing the first pair (Roll 1-1 and Roll 1-2). This configuration allows for three-stage progressive forming, where the material thickness is reduced step by step.

A 3D model of an automobile wheel rim was used for the simulation, and time-dependent speed profiles were assigned to each roller.

As shown in Figure 2.3(a), the full 360° model was analyzed as follows: Rolls 1-1 and 1-2 operated simultaneously, followed by Rolls 2 and 3, which sequentially formed the material. Figure 2.3(b) presents the final simulation result of the multi-stage flow forming process for the virtual wheel.



(a) 3D full model



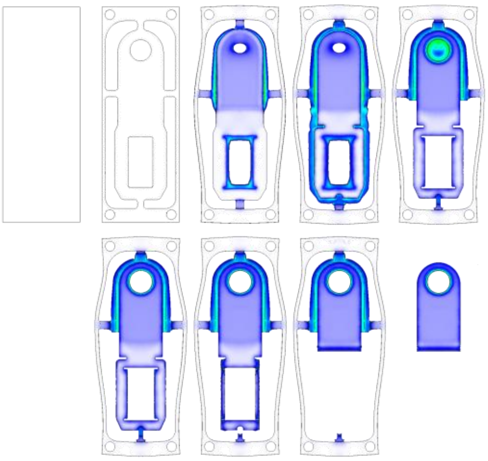
(b) Simulation result

Figure 2.3 Flow Forming simulation of virtual automobile wheel rim

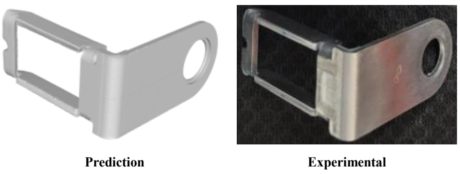
2.4 Forming Analysis of Electrical Parts for EV Battery

Lithium-ion batteries use metal foil current collectors. Typically, aluminum (Al), which offers excellent electrical conductivity and formability, is used for anode current collectors, while copper (Cu), which provides high conductivity and stability at low potentials, is used for negative current collectors.

This analysis focused on an electrical component for the anode current collector, made of A1050-H18 aluminum sheet with a thickness of 2.0 mm. The process was designed during the prototype development stage and optimized for a 250-ton mechanical press. The forming sequence consisted of eight stages. Figure 2.4(a) shows the forming simulation results for each stage, while Figure 2.4(b) compares the predicted results with experimental observations.



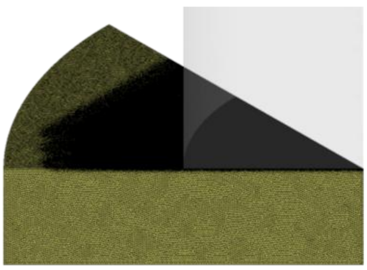
(a) Forming history from stage 1 to stage 8



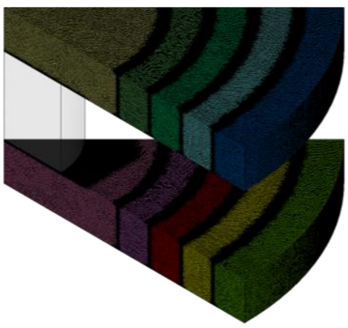
(b) Comparison between simulation and experiment
Figure 2.4 Forming analysis results for the current collector component

2.5 Verification of Extreme Mesh Generation for Die Models

As demand for high-precision simulations increases, the maximum number of elements executable in AFDEX was tested. Two cases (a single-die setup and a multi-die setup) were analyzed under the condition that the total element count was fixed at 2 million.



(a) Single die

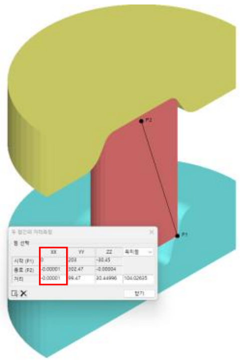


(b) Multiple dies
Figure 2.5 Extreme mesh generation for dies

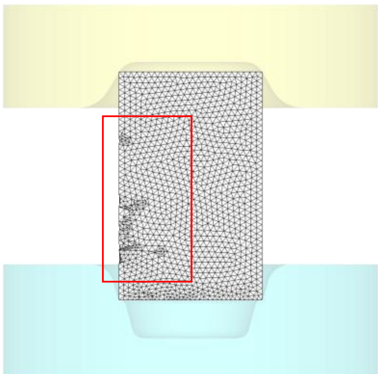
In the single-die case (Figure 2.5(a)), approximately 7.2 million elements were generated. On an Intel i7-7700 CPU, the mesh generation took about 2 hours and 40 minutes. Beyond this size, meshing failed due to memory limitations, but the number of elements can be increased depending on PC performance. In the multi-die case (Figure 2.5(b)), 10 dies were used, each assigned 2 million elements, resulting in a total of 20 million elements. Mesh generation for this example took approximately 7 hours, and further increases were not possible due to memory constraints. Thus, the maximum number of elements depends on the user's PC capabilities. Although AFDEX mesh generation may take longer than in other tools, this is because mesh quality is maximized and, as widely known, mesh quality directly affects solution accuracy. AFDEX team keeps reducing them computational time, while extremizing solution accuracy.

2.6 Things to Note When Modifying STL Files with 3D Builder

In 3D simulations, AFDEX uses STL files. Editing STL files is often challenging in most modeling tools, but 3D Builder, a default Windows application, provides a convenient solution for simple STL editing. 3D Builder automatically fixes overlapping or open surfaces and allows users to cut STL models along desired planes. Figure 2.6 illustrates an example where a 360° model was converted into a 180° model using 3D Builder. As shown in Figure 2.6(a), when checking the symmetry plane coordinates, some points have x = 0 while others have x = -0.00001. Although this difference is minimal, it caused meshing failure along the symmetry plane, as shown in Figure 2.6(b). Therefore, users modifying STL files with 3D Builder should carefully check for such discrepancies to avoid similar issues.



(a) Pre-processing view



(b) Mesh generation result
Figure 2.6 Meshing failure at the symmetry plane

3. AFDEX_V24R02

3.1 Microstructure Prediction

The new microstructure module in AFDEX 2D/3D solvers is based on the JMAK model and enables prediction of dynamic recrystallization (DRX, Figure 3.1), static recrystallization (SRX, Figure 3.2), and grain growth (Figure 3.3). The volume fraction and grain size during DRX are calculated using both strain-based and time-based kinetics, while SRX evolution is modeled through time-based kinetics and grain size prediction. Grain growth before and after DRX/SRX is also considered, and the final grain size is determined using the rule of mixtures.

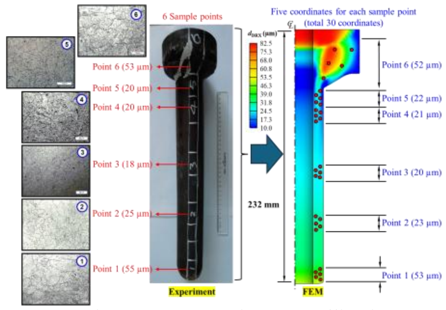


Figure 3.1 Dynamic recrystallization

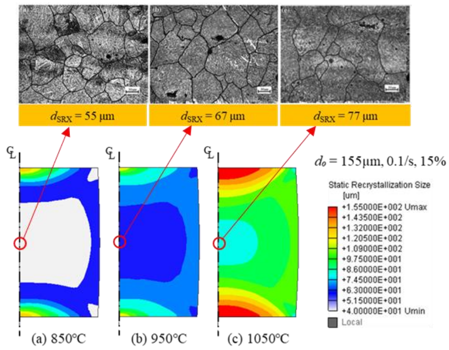


Figure 3.2 Static recrystallization

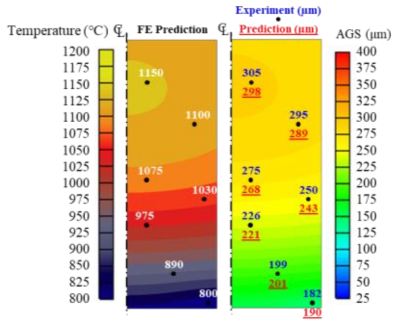


Figure3.3 Grain growth

3.2 Heat Treatment Analysis

Using the AFDEX 2D/3D heat treatment module, users can simulate major processes such as annealing, quenching, tempering, quenching + tempering (QT), and spheroidization. The hardness is calculated based on grain size and phase fraction data, using the Hall–Petch relationship.

Users can flexibly define heat treatment cycles by controlling time, temperature, and convection coefficients, and selectively activate related phenomena to accurately track microstructural changes during each cycle.

The GUI has been enhanced with new ribbons, input functions, and dedicated libraries for microstructure and heat treatment analysis. The improved post-processing view, export options, and step-by-step analysis tools now offer a more efficient and user-friendly workflow for process simulation.

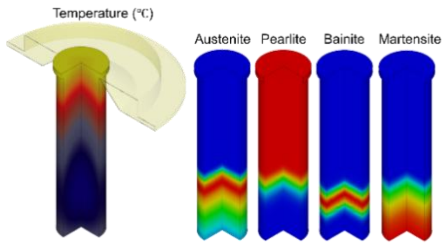


Figure 3.4 Jominy quenching test for AISI 52100 based on ASTM A-255

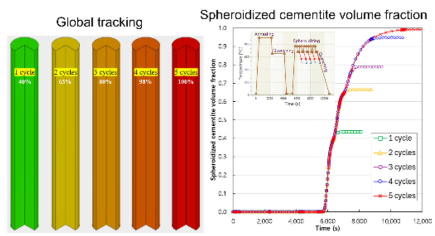


Figure 3.5 Spheroidization heat treatment

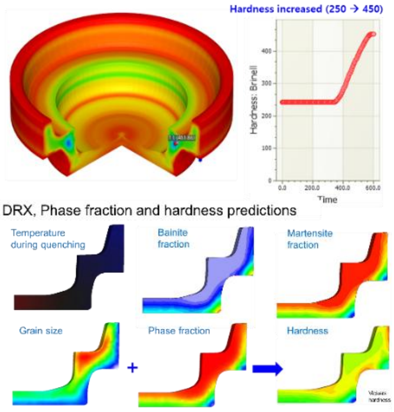


Figure 3.6 Brinell hardness - bearing race process

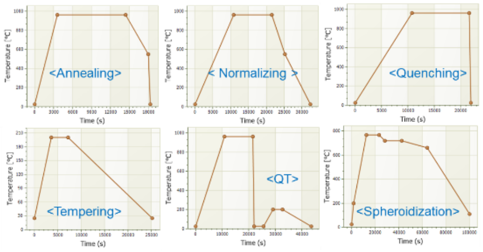


Figure 3.7 Heat treatment cycle

3.3 Surface Expansion Ratio Visualization

As shown in Figure 3.8, users can now visualize the surface expansion ratio at each position on the material surface in the post-processor. This surface expansion ratio is directly related to variations in friction conditions during metal forming and therefore plays an important role in improving the realism of friction modeling.

A new friction coefficient function, incorporating a weighting function based on the surface expansion ratio, is now supported. This feature is expected to contribute to research and applications related to lubrication regime changes.

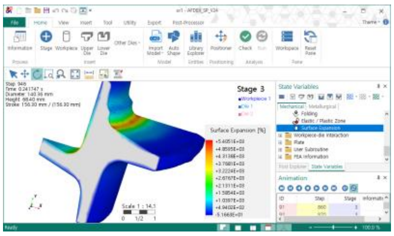
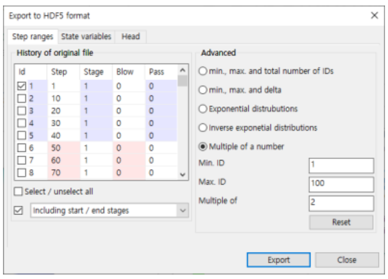


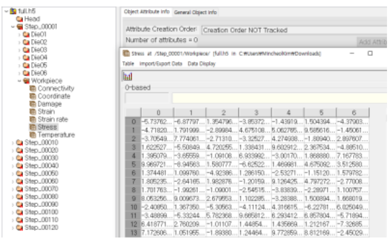
Figure 3.8 Surface expansion ratio in 3D simulation

3.4 HDF5 Format Export Function

A new function has been added to export analysis results in HDF5 format, enabling improved compatibility and data exchange with other tools.



(a) HDF5 Export dialog



(b) Data viewed in HDF Viewer

Figure 3.10 FLC input window in the post-processor

3.5 Improved FLC Input Function

In previous versions, users had to input FLC data during pre-processing to view FLD results. Now, the new version allows FLC data to be entered directly in the post-processor after simulation, eliminating the need to rerun the simulation.

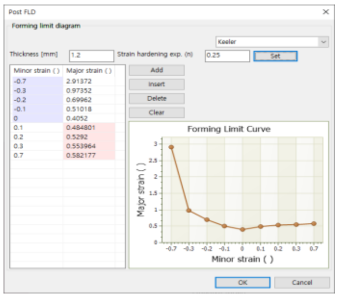


Figure 3.10 FLC input window in the post-processor

3.6 STL Model Addition in Post-Processing View

A new feature allows users to overlay the simulation result geometry with an STL model to visually compare and validate the results.

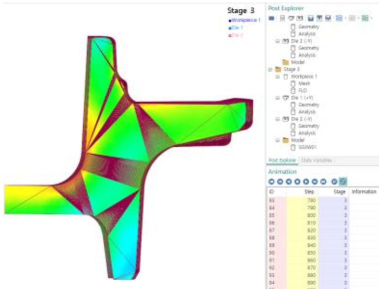


Figure 3.11 Comparison between modeled geometry and simulation result at the final step

4. Notices

4.1 ATC Malaysia

MFRC participated in the **Altair Technology Conference (ATC) Malaysia** on **July 22, 2025**, where it presented its latest technological developments and promoted AFDEX's simulation capabilities to a global audience.

The event served as an excellent platform for MFRC to share research achievements, engage with industry professionals, and explore future collaboration opportunities.

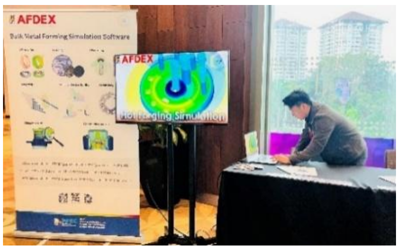


Figure 4.1 ATC Malaysia

4.2 ICFG 58th Meeting

MFRC attended the 58th ICFG (International Cold Forging Group) Meeting held in Valenciennes, France, from September 15-17, 2025, and officially became a member of this international forum.

This milestone marks a significant step in AFDEX's global journey, strengthening its presence on the international stage and showcasing its expertise in metal forming process simulation.

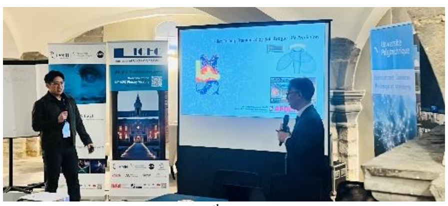


Figure 4.2 58th ICFG meeting

4.3 Workshop at Gazi (Türkiye)

MFRC conducted a metal forming workshop in collaboration with its Turkish partner Simultura Malzeme Teknolojileri and the METAT team at Gazi University.

Participants had the opportunity to explore metal forming simulations using the AFDEX software and gain hands-on experience in analyzing forming processes and material behavior.

Figure 4.3 GAZI University workshop

4.4 Workshop at METU (Türkiye)

MFRC and Simultura Malzeme Teknolojileri jointly held a Heat Treatment and Microstructure Workshop with the Metallurgical and Materials Community at METU.

Participants gained practical learning experience on heat treatment processes, microstructural evolution, and material behavior through simulations using the AFDEX software.

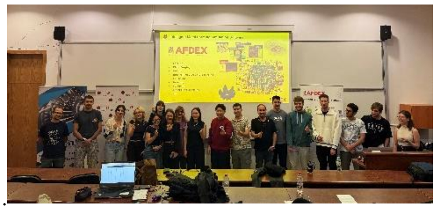


Figure 4.4 METU Workshop

4.5 Networking with Overseas Partners

Throughout the first three quarters of 2025, we have continued to strengthen collaboration with overseas partners and new customers. In particular, we have been actively providing technical support to help clients resolve issues quickly and enhance the efficiency of AFDEX utilization.

Up to Q3 2025, MFRC participated in Altair's AI+CAE technology events held across the APAC region including Indonesia, Taiwan, and Japan such as Altair Technology Day Indonesia 2025, ATC Taiwan 2025, and ATC Japan 2025.

(a) Altair Technology Day Indonesia 2025

(b) Altair Technology Conference Taiwan 2025

(c) Altair Technology Conference Japan 2025

Figure 4.5 Networking with Overseas Partners in 2025