AFDEX Newsletter
Q2 / 2021

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Contents

1. AFDEX_V21

1.1 AFDEX_V21 release

AFDEX_V20 was last updated in December 2020, and its main functions and improvements are introduced in the newsletter Q1/2021. Also, AFDEX_V21 will be released in the second quarter of this year.

1.2 AFDEX_V21 main features

The new version of AFDEX, AFDEX_V21 contains the following new features and improvements.

1.2.1 Beta features in AFDEX_V20

The followings are new challenging functions of AFDEX_V20 which had been partially released as the functions of beta version:

- Die fatigue life prediction (Advanced ver.)
- Stage-by-stage simulation of multi-body metal forming processes (Advanced ver.)
- Rod shearing in automatic multi-stage cold forging
- Plastic deformation instability index (Advanced ver.)
- Microstructural evolution prediction using PLF flow model (Advanced ver.)
- Delamination of composite sheet/plate (Advanced ver.)
- Fast remeshing capability
- Process simulation using dies or tools for detailed process design

Most functions above were introduced in AFDEX Newsletter Q1/2021 because they were released as the functions of beta version or presented by academic papers recently published.

1.2.2 New features in AFDEX_V21

The followings are new or improved functions of AFDEX_V21:

- Roll forming analysis (Beta ver.)
- Simulation of pipe bending with flexible mandrel (Beta ver.)
- Improved gap flow control
- Improved binder die function
- Sticky die of controlling the friction
- Flexible remeshing option in terms of stage during automatic multi-stage material forming processes
- Piercing/trimming simulation using shearing simulation technique
- Calculation of multiple damages at once
- A variety of academic material models
- Brittle fracture occurring in metal forming (Beta ver.)
- Force controlled forming die (Beta ver.)
- Shrinkage fit between plastically deformable bodies
- Processing map construction (Beta ver.)
- Material identification

New functions and the improvements are explained in more detail in the following section.

2. New Features in AFDEX_V21

2.1 Gap flow control for 2D and 3D simulation

Following the increase in the case of the complete analysis considering die-structural-analysis and heat transfer analysis, the need of the direct control for gap flow between dies has been risen. The gap flow feature has been already provided in AFDEX_V19, and there has been continuous improvement in this feature. Now, in AFDEX_V21, sophisticated control is available for preventing flowing of a material into a gap by entering a clearance for each stage. Especially, in 2D, gap flow of a material gets through occasionally as shown in Figure 2.1(a). However, there was no way to control the gap flow between dies, although the clearance can be determined automatically during a simulation. By contrast, Figure 2.1(b) shows the simulation result with gap flow controlled by user, which was set 0.5mm for the clearance limit of gap flow. This feature is useful for the simulation that requires to prevent remeshing caused by flash and fluctuation of forming loads.

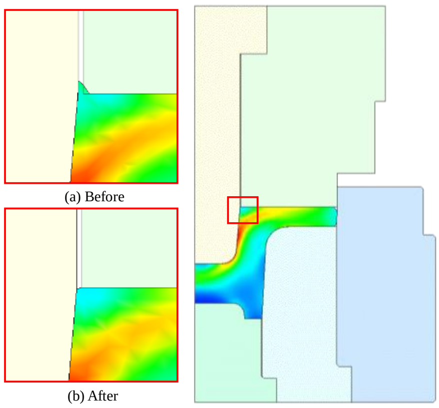


Figure 2.1 Controlling gap flow between dies

2.2 Improvement in analysis using binder

In AFDEX, the binder feature has been utilized for force prescribed die including blank holder. The implicit method algorithm implemented in AFDEX provides accurate solutions but has difficulty in imposing the given load through a die numerically. To resolve this problem, the penalty method modified specially is used in AFDEX. The penalty method stands for the method which allows penetration of a die into a workpiece considering the load imposed. Using the penalty method, it is possible that solutions that satisfies yield criterion does not exist if the high loads operate locally. This error and the inconvenience in controlling the motion of the binder are fixed in AFDEX_V21.

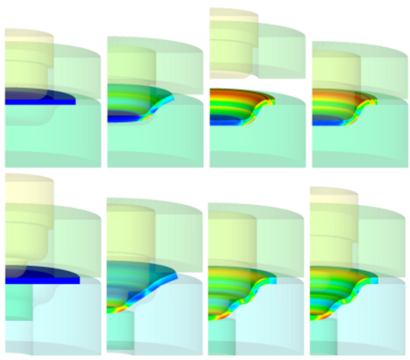


Figure 2.2 Analysis result with binder

2.3 3D moment save feature

The need of multibody analysis technology is growing rapidly. Considering this trend, the graph of moment for both workpieces and dies is available in the newest version, whereas only the graph of moment for dies has been provided in the current version.

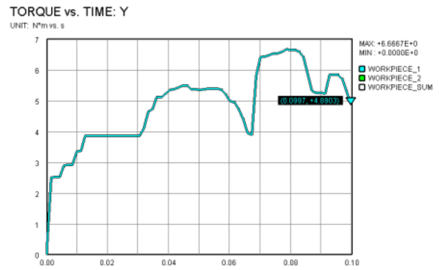
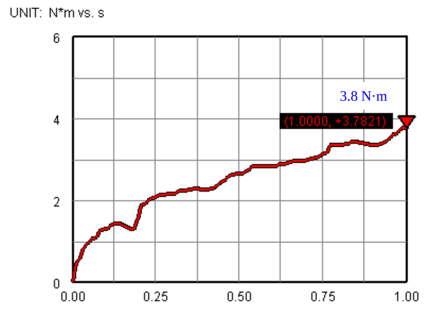


Figure 2.3 Graph of moment of a material

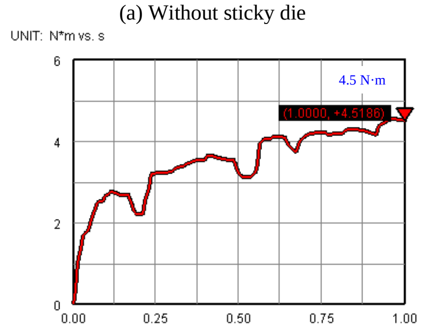
2.4 3D sticky die feature

There has been continuous improvement in calculation speed of 3D simulation in recent years, which leads to solve the large size problem with massive elements. However, increasing the number of elements cannot always be the best way for a good simulation. Metal forming simulation is inherently exposed to the limit of numbers of nodes and elements. Half edge length of finite element in 3D increases eight times the number of elements and thus the global refinement of finite element mesh system cannot satisfy the researchers who need extremely refined mesh system. This problem becomes more serious in case of multi-body simulation in metal forming. It is because the contact interface cannot be continuous in terms of slipping when the coarse surface contacts with die or material. It causes inaccuracy in dealing with friction and geometric constraint of preventing the slippage at the contact interface.

To cope with this matter, AFDEX_V21 supplies the sticky die which adjusts the contact area at the interface with coarse finite elements. When this sticky die is employed, the triangle with one or two contact nodes at the interface between material and die or material and material can experience the frictional stress.



(a) Without sticky die



(b) With sticky die

Figure 2.4 Effect of sticky die on the torque

2.5 2D and 3D remeshing for each stage

The remeshing feature can be used for each stage in AFDEX_V21, whereas it has been used for only a project in the previous versions. The newly updated feature in the latest version enables full simulation run of continuous process without pausing.

2.6 3D roll forming simulation

AFDEX_20 provides the simulation of roll forming with using rigid-plastic finite element analysis. However, one of the main focus of the roll forming simulation is springback.

Beta test version of AFDEX for roll forming process will be released in AFDEX_21.

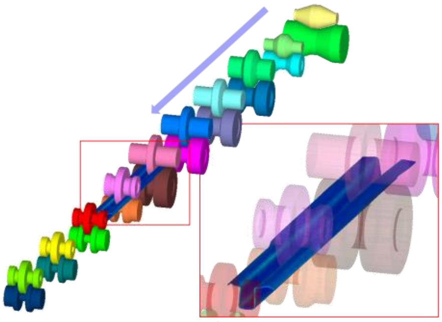


Figure 2.5 Roll forming analysis

2.7 3D shearing analysis

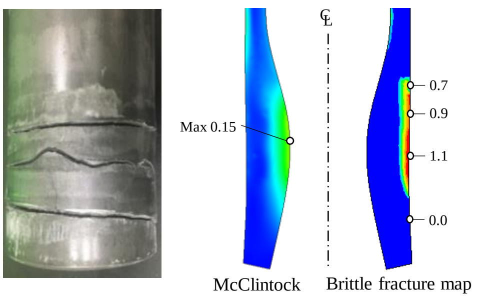
Shearing analysis is aimed to analyze the shearing process of a rod. Therefore, this feature might not operate well when it was used for the other processes including piercing and trimming in plate forging analysis. In AFDEX_V21, an improved function of shearing, piercing, trimming, etc. is given, which avoids the error mentioned above. On the contrary, the aforementioned problems could be solved using AFDEX's unique function for piercing and trimming.

2.8 Multiple damage model in a single project

Damage is one of the important factors in forming processes, and some process requires to simulate the evolution of the damage with various damage models. For the convenience of users who perform a damage simulation, AFDEX_V21 provides multiple damage calculations with various damage models during single run. Currently, at maximum three damage calculations are allowed, and its results can be checked through the post-processor. The results of damage models can be compared a lot easier by using this feature.

2.9 Quantified brittle fracture of ductile materials

There are some cases that cannot be explained by the universal theory of ductile fracture caused by damage accumulation. Shearing analysis is one of them. For ductile materials, it is hardly possible to find fracture trace on sheared edge which is the trace of damage accumulation. A different example of brittle fracture of ductile materials was found from the cold shell nosing process. We has suggested the concept of plastic deformation induced embrittlement (Materials, Mar. 2021) to explain such fracture. The tensile strength of a material drops due to Bauschinger effect after the compressive deformation, which can result in brittle fracture depending on the material properties and level of plastic deformation. When tension is applied on the material whose yield strength became lower and embrittlement was grown, the material exhibits brittle fracture in case that the tensile stress greater than the reduced allowable tensile stress exerts. In this case, this brittle fracture occurs on the plane perpendicular to the axis of relative maximum tensile stress to the reduced allowable tensile stress. The fracture in Fig. 2.6 could not be predicted by any theory of ductile fracture while the suggested fracture model could predict the brittle fracture, as can be shown in the figure.



McClintock Brittle fracture map

Figure 2.6 Brittle fracture of forgeable materials during cold shell nosing process.

2.10 Forming instability index

The use of the forming instability index was already suggested in the previous study (Int. J. Mech. Sci., Apr. 2021). The plastic deformation instability index provides an estimate of the instability of a material affected by strain, strain rate and temperature softening during forming. The index was formulated as follows:

$$\chi = \frac{\bar{\sigma}\dot{\bar{\varepsilon}}}{C_{in}}\frac{D\bar{\sigma}}{D\bar{\varepsilon}}$$

Figure 2.7 shows the change in instability index induced by dynamic strain aging during upsetting process.

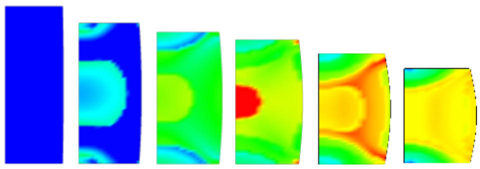
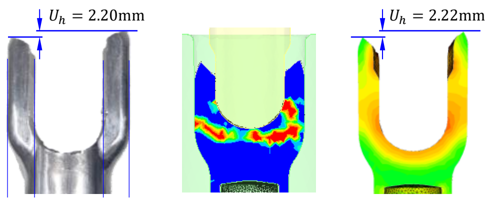


Figure 2.7 Change in instability index

Figure 2.8 shows a problem of ear height difference occurring in an aluminum yoke cold forging process, which can be predicted by FE simulation with an emphasis on the instability index. In this case, as shown in the Figure 2.8(b), the instability index shows the sign of the plastic deformation instability. In case of steel yoke forging process, such instability index cannot be calculated. The steel yoke cold forging process is stable.



(a) Experiment (b) Instability index (c) Simulation

Figure 2.8 Instability index of Aluminum cold forging for yoke

2.11 Simulation of shaft clinching with a force controlled forming die

In AFDEX_V21, elasto-plastic finite element analysis can improve the simulation of shaft clinching or rotary forming. The major concern of this simulation is the cavity between the shoulder of bearing inner race and the bent shaft because it is mechanically important in assembling and service. The research results suggest that force controlled forming die, that is, the rotary die which is same to the real process must be used for the prediction on the cavity region. Thus, the exact value of stress applied on an inner race can be obtained and predict the local plastic deformation occurring during homogenizing in the rear part of the process. Figure 2.9 shows the residual stress result predicted by the new beta features.

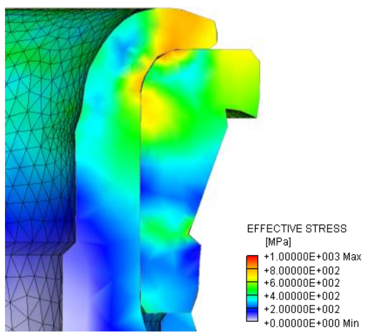


Figure 2.9 Shaft clinching simulation result

2.12 Analysis of bending with flexible mandrel

A feature for bending analysis of pipe with flexible mandrel which is one of the multi-body analysis application is added in the release version. The main point of this application is treating a mandrel as an analyzing part of material. This scheme is an application of multi-body analysis functions, implying that they can be applied to various special forming processes in a creative manner.

Figure 2.10 illustrates the result of the bending analysis of a pipe with flexible mandrel using the beta feature which will be provided in AFDEX_V21. The multi-body analysis can be applied in not only this case, but also the other process similar to it.

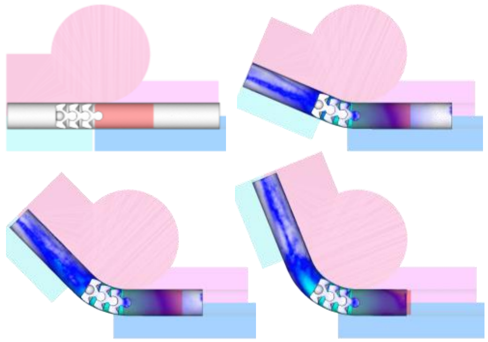


Figure 2.10 Predictions of pipe bending process with flexible mandrel

2.13 Flow stress models at room temperature

AFDEX_MAT has been used for obtaining the flow stress using MFRC's model K(ε)-n, which predicts result of tensile test exactly. AFDEX_V21 provides the new feature that can obtain the material constants with respect to various types of the flow stress model with using the tensile test data.

Especially, the flow stress predicted by AFDEX_MAT based on K(ε)-n model is highly accurate until a fracture occurs so that it can be used as a reference flow stress. Figure 2.11 is showing the evaluated flow stresses (Ludwik, Voce, Swift and Hollomon law) in terms of tensile test and compares to each other.

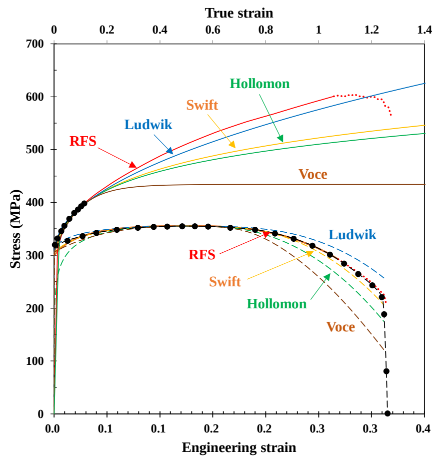


Figure 2.11 True stress-strain curves (upper) and their corresponding tensile test predictions (lower)

2.14 Flow stress at elevated temperature

A variety of numerical models express high-temperature constitutive model of a material as a state variable. AFDEX_V21 provides useful flow stress models which can be used both in academy and industries.

Figure 2.12 shows the predicted flow stress models for Magnesium alloy, AZ80. The flow stress models such as the hyperbolic sine Arrhenius equation, the modified Hensel-Spittel model and the modified Johnson-Cook model are used based on the results of R. Ebrahimi et al. study. Ebrahimi, C-m and PLF models, on the other hand, are tested by AFDEX researchers. This comparison tells us how important the flow stress model is.

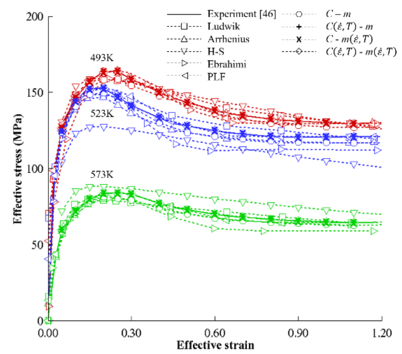


Figure 2.12 Comparison of high-temperature constitutive models for AZ80 (strain rate: 0.01/s)

2.15 Cladding extrusion process at front end

For the futuristic technology, various activities for effective usage of materials and recirculation have been being made. For example, special or expensive materials have been purposely locally clad and the heat treatment has been applied partially to the mechanical parts for improving their service life. Figure 2.13 shows the predictions of plastic deformation and effective strain occurring during cladding of the front end of an extrusion with sheet material.

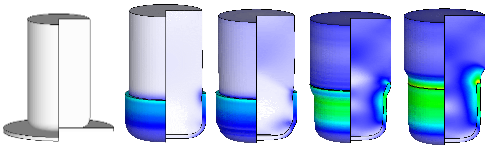


Figure 2.13 Analysis result of cladding extrusion process at a front end

3. Notice

3.1 APA webinar in Japan

MFRC will be presenting an ALTAIR Partner Alliance (APA) online webinar entitled, "Metal forming simulation using AFDEX" for Japanese users. The webinar will be held on April 20, 2021 14:00-14:30 PM JST and will be focus on the following topics: Automatic simulation of multi-stage forming process, Multi-body forming process, Fatigue life prediction of a die and optimal process design & material properties, etc.

You can find the abstract and register for the webinar here: http://web.altair.com/ja/apa-afdex-2021

3.2 APA annual webinar for AFDEX

APA annual webinar organized by ALTAIR for AFDEX will be held in the end of this June. The main themes that will be covered in this webinar are the die fatigue life prediction based on precision simulation technology and the accurate material characterization with using AFDEX_MAT. The specific date will be announced soon on AFDEX homepage (https://www.afdex.com/).