AFDEX Newsletter Q2 / 2018

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1. AFDEX_V18R01 Release

1.1 Features in the latest version

AFDEX_V18R01 was released on 1st of April. Initially aimed for February, it was postponed to include the latest features. This latest version has been improved to reflect the requirements of users in the past which mainly consists of improved calculation speed, stability of elastoplastic analysis function, improvement of die structural analysis function, improvement of assembled die structural analysis and heat transfer analysis function, improvements in the prediction of metallurgical properties and improvements in solving computationally expensive problems.

Major improvements are shown in Table 1.1. Much of the contents of Table 1.1 are consistent with those contained in 2018 Q1.

Table 1.1 New functions or improvements of AFDEX_V18

	Functions or improvements
2D and 3D	-Simulation considering die elastic deformation with shrink fit considered -Repetitive simulation between specific steps -Simulation considering elastic deformation of press -Analysis of heat transfer among assembled dies -Structural analysis of assembled dies -Control of penetration of material into the gap between dies -Calculation of shortest distance between nodal points and dies -Improved computational speed -Improvement of node separation algorithm -Improved Brozzo damage model -Function of contact exclusion during structural analysis of assembled dies -Prediction of hardness based on experimental formula -Improved heat transfer analysis function -Improved frictional conditions as a function of temperature, pressure and strain -Improved heat transfer coefficients as a function of temperature and pressure -Local mesh density control -Function of treating the nodes which penetrate into the material -Initializing state variables for the first solution step -Improved initialization of material at each stage -Increased number of available dies in one stage -Function of limited temperature increments per step -Improved coupled flow analysis with damage -Treatment of rigid-body motion of material and die -Forced remeshing before new or continuing run -Material removal function -Improved Freudenthal damage model -Microstructural evolution prediction function -Heat treatment analysis function
2D	-Boolean operation -Process design optimization using HyperStudy -Improved determination of the final stroke when non-standard dies are employed -Improved mesh density control of dies -Die geometry defined by a connection of die points -Improved description of dies -Improved convergence characteristics of multi-body function
3D	-Improved computational speed -Improved function of pusher in open-die forging including rigid body condition -Improved algorithm of step size and contact for open-die forging -Improved mandrel control for swaging, radial forging, and open-die forging -Improved algorithm for separating contact node -Improved temperature analysis during dwelling/transfer -Addition of stroke control based on distance when axisymmetric die is used in 3D -Improved rotating die function -Improved non-isothermal analysis of a screw/hammer forging process -Hydrostatic forming function -Air trapping treatment -Improved pusher for open-die forging -Improved initialization of state variables -Composite material treatment -Improved function of ring rolling simulation -Evolving function of a rotating die -Specialized remeshing for ring rolling simulation -Compensation of volumetric change due to remeshing -Element wise compensation scheme for volume change -Back pressing function of manipulator and pusher -Exact positioning of periodically moving die -Practical 3D point tracking -Improved open-die forging function -Multi-body analysis without remeshing (Manual) -Larger scale problem solver -3D quantification of grain flow (metal flow lines)

1.2 Updated features during Q1/Q2 - 2018

Improvements or plans for the latest version during Q1 and Q2 of 2018 are shown in the following table. Pre-processing functions are not currently supported for some of these functions.

Table 1.2 Plan of adding new functions or conducting improvements for AFDEX_V18

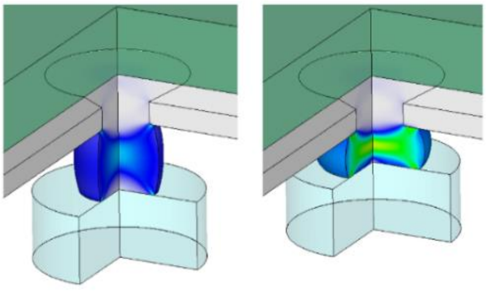
	New functions or improvements
2D or 3D	-Function for skin element generation -Function for calculating flow stress depending on compressive or tensile strain -Quantification of grain flows -Two-step motion of die (Loading and unloading) -Sophisticated material models -Microstructural evolution prediction -Heat treatment and carburization simulation -Local heating of material -Improved structural analysis of assembled dies -Improved complete simulation -3D local remeshing -Material shearing analysis function -Improved hammer forging function -Improved skin mesh system -3D multi-body metal forming simulation function -Strength/hardness prediction function -New material models to describe dynamic RCX -2D induction heating simulation -3D optimal process design

2. Introduction of AFDEX_V18R01

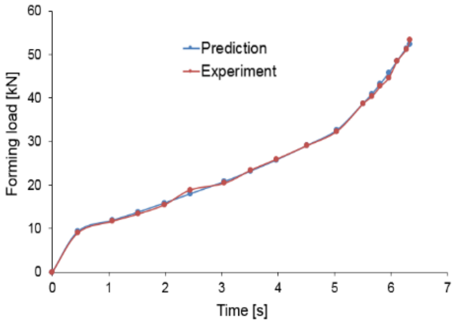
Here are some key applications from the first quarter of 2018. Some of these examples require the user to edit the input data directly. The usage of most features will be greatly improved in the next version. The new features provided in this version have already been described in the Q1-2018 newsletter and are therefore omitted here.

2.1 Elastoplastic finite element analysis of riveting process in aircrafts

The experimental results (Amarendra.A, GIT, Ph.D. thesis, 2006, experiment and ABAQUS comparison) were compared with our elastoplastic finite element analysis of the riveting process of an aircraft using 2D multi-body function. As shown in the figure, the experimental results and the analytical results closely match with each other.



(a) Deformation history

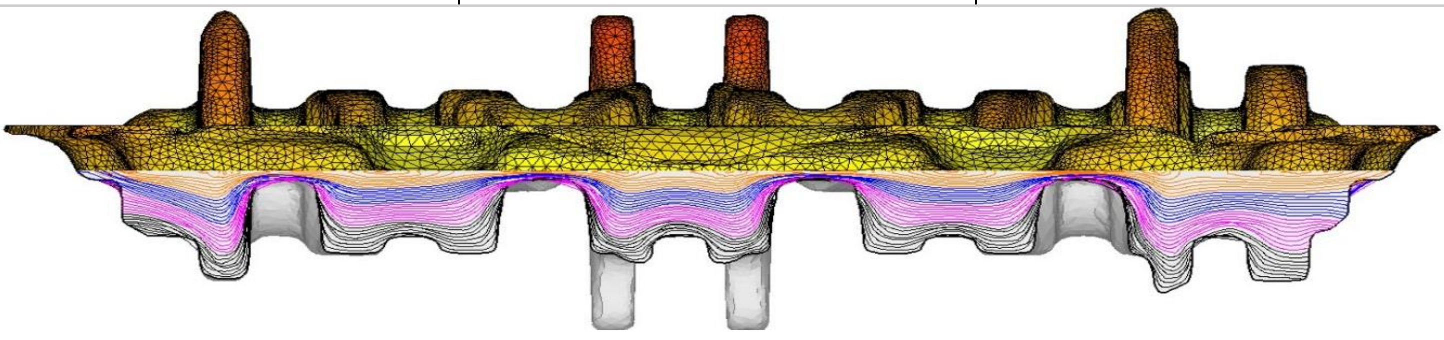


(b) Comparison of prediction and experimental results

Fig 2.1. Elastoplastic FE analysis of riveting process in aircrafts

2.2 Residual stress after self-piercing riveting

The residual stress after self-piercing riveting was predicted using two-dimensional multi-body elastoplastic finite element analysis function. In this representation, the technique of refining the mesh locally near the tip of the rivet as well remeshing was carried out.



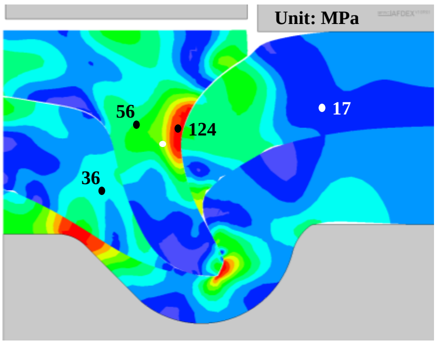


Fig 2.2 Residual stresses after self-piercing riveting

2.3 Elastoplastic analysis of aircraft fittings and tubes

A two-dimensional multi-body elastoplastic finite element analysis function was applied to a kind of necking process for connecting a high-pressure tube and a fitting of an aircraft. Residual stress due to springback and maximum separation resistance were predicted.

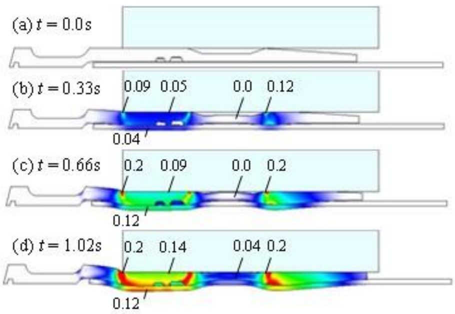


Fig 2.3. Analysis of air fitting and tightening process

2.4 Elastoplastic finite element analysis of ball-bearing contact problems

The contact and local plastic deformation analysis of the ball bearing assemblies were carried out using the three-dimensional multi-body elastoplastic finite element analysis function.

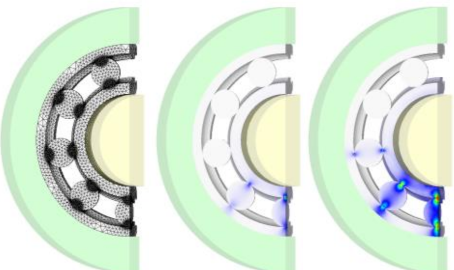


Fig 2.4. Elastoplastic structural analysis of ball bearing assembly

2.5 Elastoplastic finite element analysis of assembly process of hub bearing assembly

The assembling process of the hub bearing assembly and the rotary forging process using the three-dimensional elastoplastic finite element analysis function was carried out. The bearing was assumed to be an elastic body. Figure 2.5 shows the residual stress.

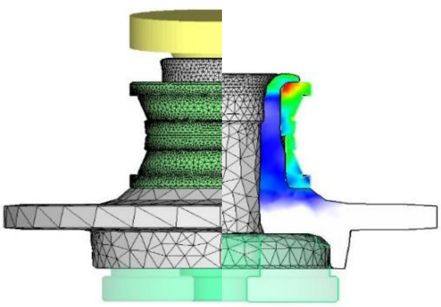


Fig 2.5. Residual stresses after the fastening process

2.6 Prediction of grain size and experimental verification of hot forged bearing components

The grain size was predicted during hot forging and the validity of the results was verified. The material constants were obtained using AFDEX's unique optimization technique for the single stage upsetting process of the three-stage process. When compared with the experimental results, it is concluded that the error is about 10%, which can be lower than the temperature dependency of the material constants.

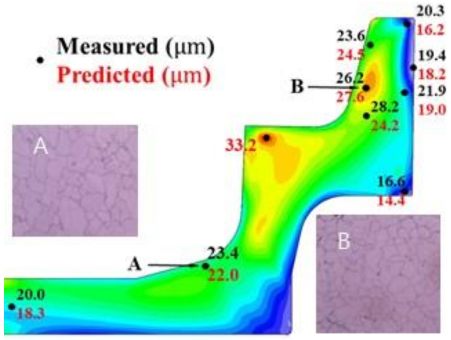


Fig 2.6. Determination of grain size

2.7 Hardness prediction of hot forged bearing parts

A phase transformation analysis was performed under the same conditions as in Section 2.6, and the fractions of different phases were calculated. The hardness and the grain size were predicted using this value. From the prediction results, we can confirm the influence of the grain size and phase fraction of the quenched material (see Fig. 2.7). Continuous efforts are being made to progress the research further in this area.

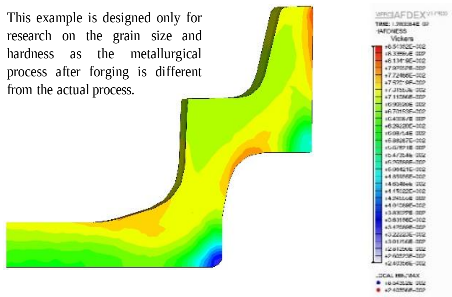
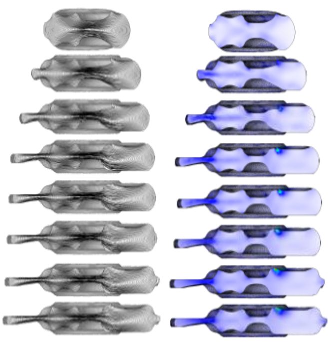


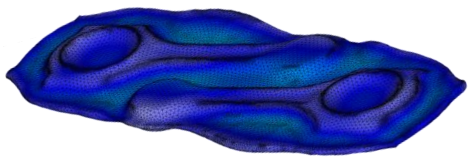
Fig 2.7. Prediction of hardness

2.8 Quantification and visualization of metal flow lines

Quantification of the flow lines is very important. Quantification techniques have been developed based on AFDEX's unique metal flow line visualization capabilities, and 2D features have already been introduced. Recently, three-dimensional functions have been added. This function allows the evaluation of the quality of the metal flow lines by a numerical value, which is effective in arriving at an optimal process design and preventing mistakes. Fig. 2.8(a) shows the decisive defect of the short-circuited lines while forging a connecting rod, which can be hardly observed from strain distribution in Fig. 2.8(b).



(a) Metal flow lines and overlapping index



(b) Effective strain distribution

Fig 2.8. Quantification of metal flow lines

2.9 Solving computationally large problems

The ability to solve large-scale problems has been improved to expand the various capabilities and analysis functions to multi-body processes in recent years. Figure 9 shows the results of the analysis of the crankshaft hot forging process and 500,000 tetrahedral elements were used. We plan to progressively improve functions for computationally expensive problems according to demand from the users.

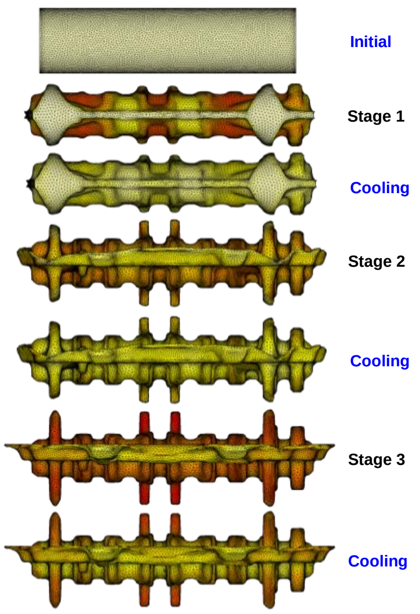


Fig 2.9. Analysis of large scale problems

2.10 Analysis of multi-stage hollow shaft swaging process

An analysis of the 5-stage hollow shaft swaging process was made. In this process, the change of the thickness is very high in the first and second stages. The position of the workpiece is controlled by the mandrel in the first and second stages and pusher controlled the workpiece motion in the third stage. Fig. 2.10 shows the final deformed workpiece and the process consisted of totally 5310 blows.

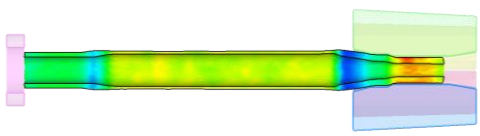


Fig 2.10. Swaging process

2.11 Analysis of precision spline forming process by oscillatory punch

We analyzed the spline forming process by the punch of the spline die on which vibration was imposed for minimizing the influence of forming load on the base material with the height of the tooth kept relatively high in the structurally weak bar material. Three-dimensional elastoplastic finite element method is used and only 1/30th of the geometry is set as the analysis domain by using two planes of symmetry. The predictions showed that the vibration has considerable influence on the forming load (increasing structural integrity below the plastic deformation region) and a little higher teeth height, implying that the strain distribution was concentrated on the tooth profile. This is because local plastic deformation is relatively high in the contact area due to vibration.

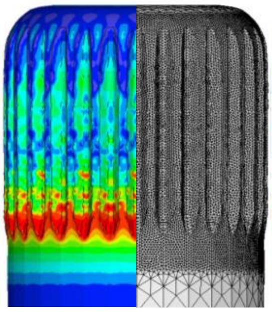


Fig 2.11. Spline forming process with vibration

3. A Study on flow stress at elevated temperatures

3.1 Basic models in AFDEX

One of the basic AFDEX flow stress models for hot materials is as follows:

$$\bar{\sigma}=C(\varepsilon,T)\dot{\bar{\varepsilon}}^{m(\varepsilon,T)} \quad (1)$$

on which material properties of AFDEX for hot/warm metal forming simulation has been based. Although this model looks simple, since C and m values are stored at the sampling temperatures and strains, the number of material constants is large, which is most effective for expressing experimental data directly. These material constants can be easily obtained using AFDEX MAT, one of the modules of AFDEX, and stored in AFDEX material DB. Figs. 3.1 and 3.2 show examples of this application. In the figures, the solid line is the experimental data by hot cylinder compression test, and the points are the material property of AFDEX. As shown in this application examples, AFDEX MAT provides almost exact flow stresses in an engineering sense.

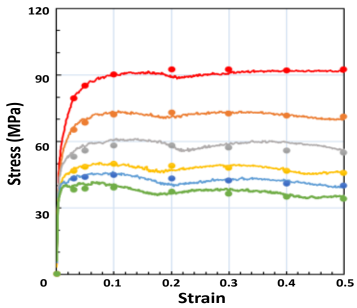


Fig 3.1. Hot flow stress of Aluminum A6082

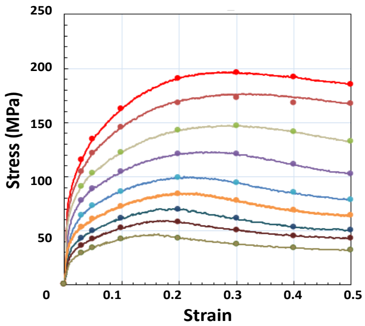


Fig 3.2. Hot flow stress of alloy steel SCM 420

3.2 Improved flow stress model

On the other hand, many researches and applications have been made on the widely used flow stress models including Voce model, Hansel-Spittel model and Johnson-Cook model. The problem is about the accuracies and generalities of these flow stress models and their applicability.

Recently, a flow stress model and a method of acquiring its associated material constants have been developed by the research team of Gyeongsang National University of Korea to improve the metallographic prediction ability. As shown in Fig. 3.3, it can be observed that the experiments (solid lines) and the new flow stress model equation (dotted line) are in excellent agreement with each other.

This result will enhance the reliability between user and developer and will be of great help to future metallurgical research and application.

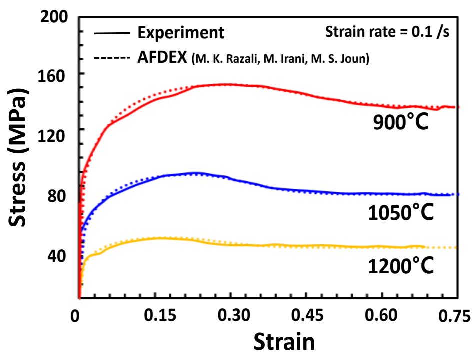


Fig 3.3. New flow stress model

4. Notice

4.1 Cooperation and communication

4.1.1 IMTEX Participation and seminars

MFRC participated in the IMTEX 2018 exhibition held in Bengaluru, India for five days from January 25 to 30, 2018. IMTEX 2018 is an international exhibition held in India and is a major event in the Indian metal forming industry. MFRC also held technical seminars and practice sessions in Bengaluru, Pune and Delhi.

Fig 4.1. IMTEX, Bengaluru

4.1.2 Hannover Messe

Hannover Messe exhibition will be held in Germany from April 23 to 27 for 5 days. MFRC will be exhibiting AFDEX at Hall 4, H48 in the industrial supply exhibition hall.

Fig 4.2. Hannover Messe, Germany

4.2 MFCAE 2018

MFCAE 2018 will be held on August 17 at the MBC Convention Center, Jinju. Users are encouraged to participate actively through oral/poster presentations to learn the simulation software as well as gain expertise. Their research activities can be presented in Korean. The location and date may be changed and will be announced to the users through our homepage and e-mail after further confirmations.

Venue	Date	City	Contents
MBC convention	Aug. 17, 2018	Jinju	-Theory and practice -Application

4.3 Introduction of professional educational courses by KSTP

Special lectures on engineering plasticity and heat treatment will be held on June 25-26 at Yonsei University in Seoul, Korea under the supervision of the Korean Society for Technology of Plasticity (KSTP). Lecturers are including Professor Joun, Man-Soo (GNU), Professor Chung, Wan-Jin (SNUT), Professor Hong Suk-Mu (KNU) and Professor Lee Kwang-Oh (PNU)).

This lecture focuses on the principles of elastic and plastic mechanics of solids, and heat treatment, and aims to establish the basis of mechanics and heat treatment for their application in bulk metal forming including forging, rolling, extrusion and drawing. It is aimed at engineers and students. The lectures will be presented in Korean language, but the contents and materials would be available in English.

Detailed information about the contents of the lectures and tuition fees can be found on the website of the KSTP. (http://www.kstp.or.kr/).