AFDEX Newsletter
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1. AFDEX_V20

1.1 New Features and Improvements

In June 2020, AFDEX_V20R01 with new and improved functions was released to general users. The improved numerical characteristics can be checked in AFDEX_V20R02, released in December 2020.

1.2 Main Features of AFDEX_V20

1.2.1 Precision Simulation of Cold Forging

In the cold forging industry, the forging technology of high-strength materials is improving. When determining the possibility of cold forging process depending on the analysis technology, the technological advancement is essential as follows: designing a long die life, utilizing the temperature dependence of the material flow stress during cold forging, and modeling friction phenomenon. To meet these expectations, new technologies are reflected in AFDEX V20. Figure 1.1 shows the improved program through the die structure analysis considering shrink fit.

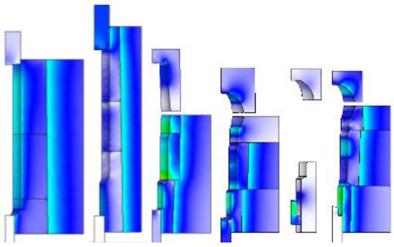


Figure 1.1 Effective stress of die insert and reinforcing ring

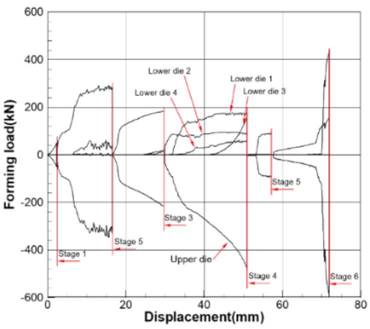


Figure 1.2 Forming load

There were also improvements in the field of die analysis technology considering elastic deformation. Figure 1.1 and 1.2 are the examples and show that the neck part diameter of the SUS 304 ball-stud forged product is predicted to be about 0.02mm larger than that of the rigid die.

Also, the friction model has been improved substantially. The state variable-dependent friction coefficient function has already been provided from AFDEX_V18, but full-scale application has been made from AFDEX_V20.

Finally, the use of elastoplastic finite element analysis has increased significantly. Figure 1.1 shows the results of the elastoplastic finite element analysis.

1.2.2 Advances in Controlling Relative Die Motions in Plate Forging

In AFDEX_V20, all the motion control needs of the users about dies for the plate forging process will be answered. In the case of the plate forging process, a relative motion between dies is comparatively complicated. This makes it difficult for designers to reflect their ideas. Now, however, the functions of the relative motion between dies and the imposing load are verified enough by examining the various practical processes. Moreover, we have constructed a system to respond proactively to users' query through the improvement of program structure. Figure 1.3 shows an example of the predictions of a plate forging process which employs the function of binder dies and dies dependent on the other dies. In the analysis of this process, the improved function of limiting relative distance between a force prescribed die and a normal die is used.

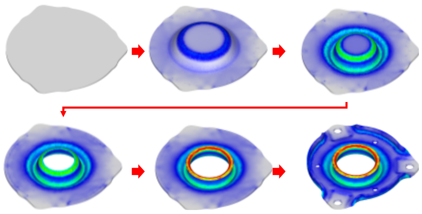


Figure 1.3 Analysis of plate forging process

1.2.3 Improvement of Identifying Potential Region of Air Trapping

In AFDEX 20, the function of dealing with air-trapping phenomena is improved. In the previous version, there are several steps to execute the analysis of air trapping for the purpose of improving computational efficiency by marking the desired region to be searched for air trapping. However, this function was not easy to use and was predominantly used by experts. Nowadays, user convenience has gained even much prominence through improvements in computational efficiency, which was a huge issue in the past. In the latest version, AFDEX users can relatively make a prediction with ease, on the air trapping phenomenon.

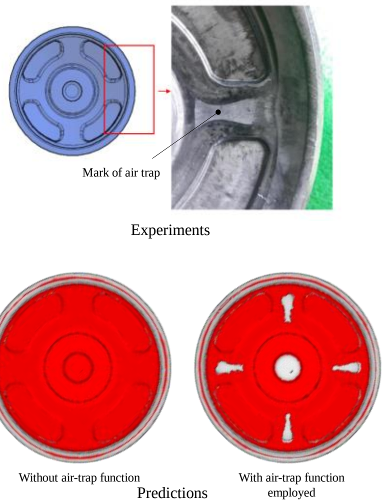


Figure 1.4 Experimental results and predictions with emphasis on air trapping phenomena

1.2.4 Improvement in Material Self-contact

For three-dimensional analysis in any of the versions released until AFDEX_V19, user input for a potential contact region had been required for the purposes of computational efficiency. This caused the problem of conducting continuing run just after checking and inputting the nodal information near the potential self-contact region. It also caused malfunction when the self-contact region is axisymmetric.

In the latest version, only input of the index is required, which determines the activation of the function of treating self-contact. Figure 1.5 shows the application result of the new function.

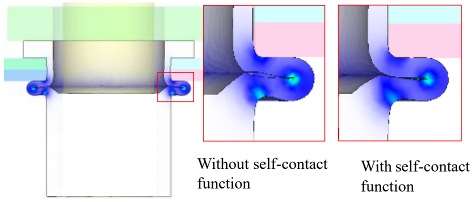


Figure 1.5 Example of self-contact of material

1.2.5 Improvement in Function of Ring Rolling Process

The major characteristics of ring rolling process are relatively fewer number of contact nodes to that of surface nodes, repetitive instantaneous contact of nodes causing directional deformation and oscillatory motion. The problem that arises from these is that it is impossible to impose the theoretical contact conditions. In other words, it is impossible to conduct an analysis considering inherent behaviors of rolling where there is a mechanical balance caused by friction.

In AFDEX_V20, the numerical stability of the original function for contacting surface was improved. In addition, a new and general function for applying force to dies or tools particularly involving guide roll in the arbitrarily intended direction can be used to prevent the oscillation of material during ring rolling just like some actual ring rolling process. Figure 1.6 compares the analysis result of ring rolling process obtained in the new version with the experiment. This result describes that the prediction is close to the actual result by reducing the amount of spread, that is, increase in ring height, which was slightly overestimated in the case without the function.

Figure 1.6 Experimental results and predictions for ring rolling process

1.2.6 Plate Forging Process

In AFDEX_V20, various analyses of the plate forging process are available due to the integration of the plate forging analysis functions. The features can be summarized in several main categories: Various kinds of relative motion between dies, force exerting die (blank holding die or tool), accurate calculation of die strokes, springback, layered FE mesh system, piercing or trimming between stages. Until now, the functions of relative motion between dies and force exerting die, etc. have been fully tested.

Figure 1.7 shows the predictions of the third stage in multi-stage plate forging. As shown in Figure 1.8, the forming load is applied continuously on die 1, while the primary die, die 2 drops 2.2mm. Then, die 1 and die 2 move together when the input value reaches the limit value. (K. K. Park et al., KSTP Spring 2020, 2020.06.25.). From Figure 1.8 that compares the analysis and experimental result, it turns out that the simulation result matches the concept design.

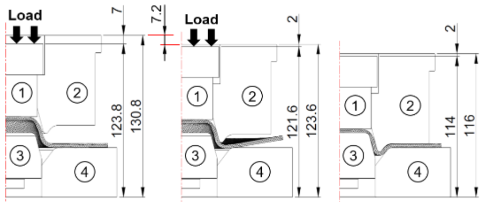


Figure 1.7 Plate forging process design

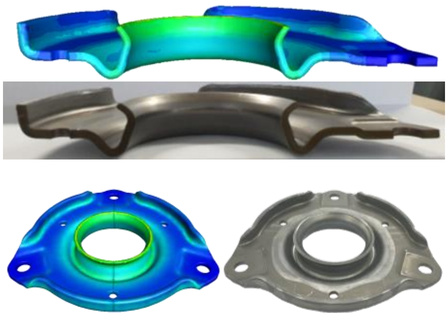


Figure 1.8 Comparison between experiments and predictions

1.2.7 Elastoplastic Analysis of Multi-body Assembly Process

One of the outstanding features of AFDEX_V20 is the analysis function of multi-body process. Especially, one of its application examples is the preload dependent on a die's press-fit. Figure 1.9 shows the effective stress distribution obtained from the press-fit of the die part. This analysis was performed using the multi-body analysis function with an elastoplastic material.

Multibody analysis technology is expected to contribute greatly to the development of various assembly and fastening processes.

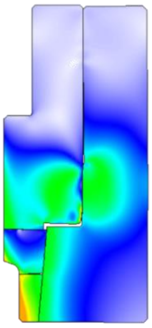


Figure 1.9 Effective stress distribution due to preload

1.2.8 Acquisition of Flow Stress Information

In AFDEX_V20, there was a breakthrough improvement in AFDEX MAT. In the *C-m* model, the accuracy of obtaining the coefficient at the sample point was improved. From AFDEX_V21, more accurate and useful extended *C-m* model programs can be used.

In AFDEX_V20, for cold forging, the utilization of the existing traditional material model was increased, and new flow stress equation models were added.

From AFDEX_V20, AFDEX_MAT provides enhanced modification control in elastoplastic analysis for converting K to $K(\varepsilon_p)$ where $K(\varepsilon_p)$ is a function of effective plastic strain. Figure 1.10 shows the tensile test result using the flow stress obtained without considering the elastic deformation. For the elastoplastic analysis, the material properties such as Young's modulus, Poisson's ratio and coefficient of thermal expansion are used in the elastic region. ($\sigma = K(\varepsilon)\varepsilon^n$)

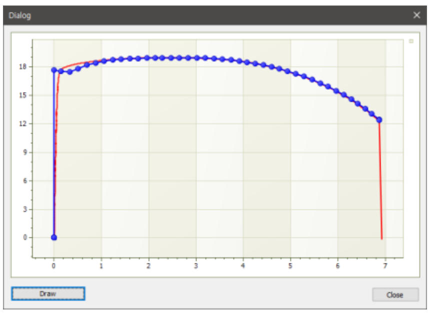


Figure 1.10 Comparison of experimental tensile test(red) and fitted flow stress(blue)

2. AFDEX_V21

2.1 New Features in AFDEX_V21

2.1.1 Die Life Prediction Function

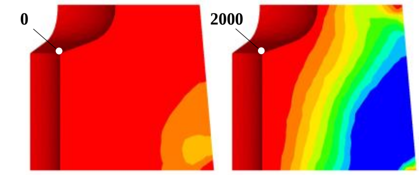
The stabilization of the die structural analysis results is of paramount importance in predicting the fatigue failure life of a die that is exponentially affected by the stress analysis results. In the recent few years, in especially AFDEX V20, the reliability in stress analysis results has been increased through tremendous improvement in die structural analysis.

Most of the research in fatigue fracture has been conducted to evaluate fatigue analysis considering structural fatigue life or to calculate the safety factor for applied loads exerted onto unloaded structures. Therefore, the conservative method has been utilized in terms of the stability.

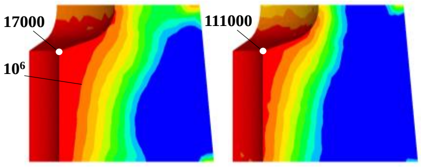
Because the fatigue life is a major factor of the plastic deformation to be considered in the structural engineering, the accurate prediction is more important than the conservative prediction.

An improved scheme of predicting the fatigue life of the metal forming dies was provided from the AFDEX_V20 beta version and will be officially distributed from AFDEX_V21.

Figure 2.1(a) depicts the plastic deformation occurring on the upper-left corner without applying any preload. Moreover, Figure 2.1 (b), (c), and (d) show the die life when 80%, 100% and 120% of the prestresses are applied on the corresponding shrink rings, respectively.



(a) Without preload (b) 80% of preload



(c) 100% of preload (d) 120% of preload

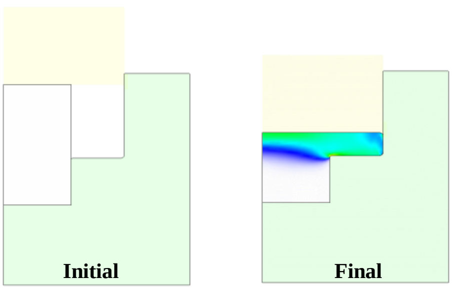
Figure 2.1 Change in fatigue life of die depending upon preload

The fatigue life of dies can be predicted with various theories and can be obtained by multiplying stress induced due to forming load or shrink fit by weights.

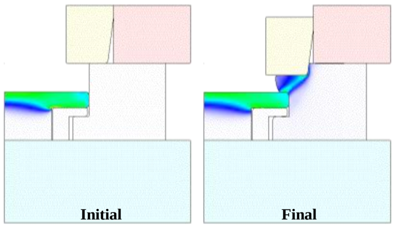
2.1.2 Stage-by-stage Simulation of Multi-body Problems

AFDEX is programmed based on minimized user intervention, automatic, and continuous simulation of multi-stage metal forming process. However, stage-by-stage (S-b-S) analysis is provided to avoid any inconvenience in cases where user intervention is inevitable. In case the number of materials changes during the analysis of multi-stage metal forming process, it is required to conduct S-b-S analysis by the user intervention.

S-b-S analysis of multi-body metal forming process was provided in the beta version of AFDEX_V20. This new feature is available in the upcoming version, AFDEX_V21. Figures 2.2 and 2.3 illustrate 2D and 3D simulation results showing the feature conceptually, respectively. A body is forged in the first stage while the second stage assembles the forging with two additional bodies or deformable materials by a forming method. In other words, the final stage is of a metal forming process of three materials.

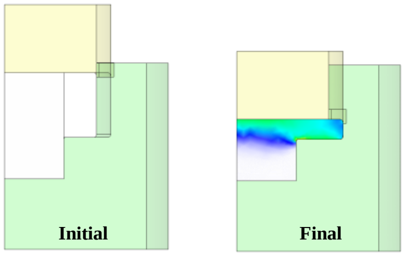


(a) First run, Single-body process

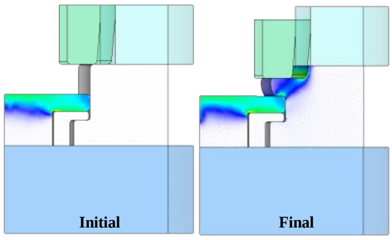


(b) Second run, 3-body process

Figure 2.2 2D, S-b-S analysis



(a) First run, single-body process



(b) Second run, 3-body process

Figure 2.3 3D, S-b-S analysis

2.1.3 Prediction of Rollovers at the Ends of Sheared Materials

A recent study raises the need to predict quantitatively the geometric features of sheared material such as rollover near the sheared surface. Therefore, the shearing analysis model was developed with the improvement in boundary conditions on the material supplying side.

Figure 2.4 shows the application of the rod shearing during the automatic multi-stage cold forging and compares the rollover depths. The simulation result (0.91mm) is consistent with an actual shear experiment result (0.90mm). It turned out that the rollover depth was considerably affected by two coefficients needed for an analysis model.

Figure 2.5 compares the experimental results and predicted results of the amount of bending at the stopper side obtained in previous studies. It was found that this amount of bending is greatly affected by the reaction between the material conveying device and the material. The new feature can be useful tool in analyzing shearing, piercing, trimming and blanking process, which can be potentially applied to consecutive forging stages especially in automatic multi-stage cold forging. It will be included in the AFDEX_V21.

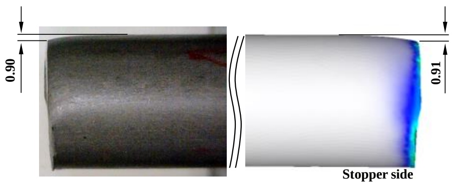


Figure 2.4 Comparison of predictions with experiments

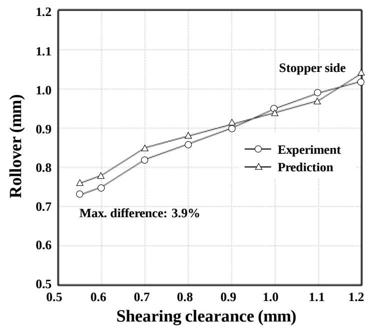
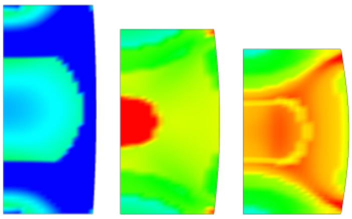


Figure 2.5 comparison of rollover test results and analysis results

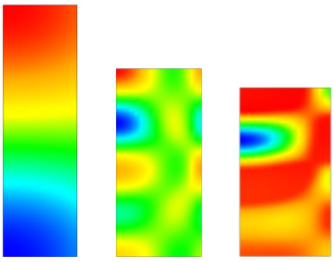
2.1.4 Instability Index and Use of Processing Map of Formability Diagram

Instability of a material causes the inhomogeneity of plastic deformation and/or decisive defects of strength of materials. For example, the final shape of the product of the upsetting process will be top-down asymmetric or the softening behavior during the forming can influence the metallurgical and mechanical properties negatively.

The instability index was developed to express these phenomena quantitatively, which will be provided with the feature of processing map or formability diagram in AFDEX_V21.



(a) The instability obtained from DSA (Coefficient of friction = 0.1)



(b) Deformation instability of Ti6Al4V in the range of warm forging (No friction)

Figure 2.5 Inhomogeneity of deformation

Figure 2.5 shows two typical cases of instability of two different materials in the potential working ranges of temperature and strain rate where significant softening behaviors occur. Figure 2.5(a) depicts the instability of deformation occurred in the range with accelerated softening behavior due to DSA, which is detected in the coil type material of S25C. Figure 2.5(b) shows the instability index related to inhomogeneity of deformation due to the continuous and strong softening during the homogeneous compression of Ti6Al4V alloy.

2.1.5 Precise Prediction of Microstructure

For the precise prediction of microstructure of a material, a microstructure prediction model obtained from the flow stress with high accuracy is required. AFDEX research team had already suggested two accurate and powerful flow stress models with the optimized fitting techniques including CFF model and PLF model (JMR&T, 2019). Recently, the microstructure prediction model using the CFF model has been developed, and it leads to decrease the error between experiments and predictions.

Figure 2.6 compares the fitting results and experiment results of X_{DRX} kinetics curve directly related to the precision of microstructure prediction result for the upsetting process. From the graph, it turns out that the fitting result obtained from CFF flow stress model is the closest to the curve of the experiment. Figure 2.7 emphasizes the accuracy.

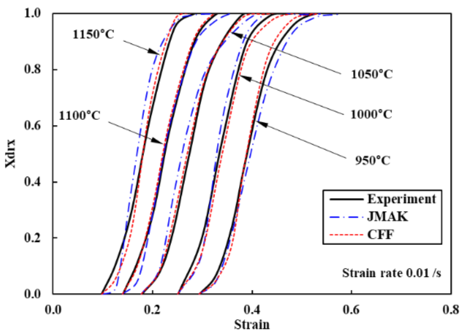
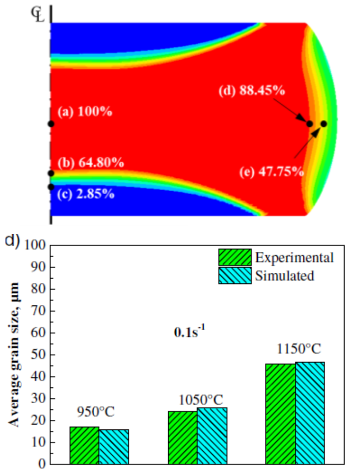


Figure 2.6 X_{DRX} kinetics curve of 0.15C-7Mn steel



(b) Predicted X_{DRX} and error analysis results

Figure 2.7 Accurate and practical approach of microstructural prediction

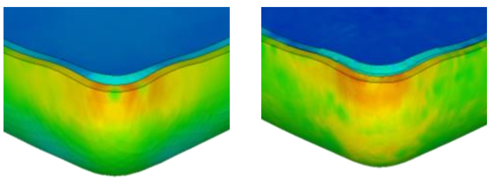
2.1.6 3D Elastoplastic Finite Element Analysis of Delamination Growth in Composite Material Plate

The application field of clad metal bonded with different materials and composite materials has been expanding to utilize the advantages of various materials such as the thermal conductivity and the brazing efficiency of copper, light weight and economy of aluminum, steel's stiffness and economy, titanium's durability and surface beauty.

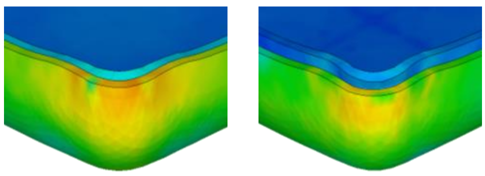
In finite element analysis, there is a need for a multi-body treatment technique for laminated materials and a treatment technique for delamination between materials when the limit conditions are exceeded. Tsai-Wu model is one of the examples for this case. This theory states that the contact surface would be broken when the sum of the ratio of the applied tensile stress and shear stress to the limit tensile stress and shear stress at the joint surface is 1 or more.

After the joint surface is broken, the velocity field in the normal direction of the contact surface of the material must be matched, and a friction condition must be imposed in the tangential direction. The friction between materials was formulated with the Coulomb friction law.

As an example of application, it was analyzed whether a three-dimensional delamination phenomenon occurred according to the bonding conditions of different materials. Figure 2.8 shows the analysis results of the composite material deep drawing process for four different bonding conditions.



(a) Perfect bond (b) 200 MPa



(c) 300 MPa (d) Simple lamination

Figure 2.8 Dissimilar material plate forging analysis

2.1.7 Reduction of Computational Time

The calculation time for the FE model of a process in need of extremely finer mesh system will be reduced by 30% to 50% in AFDEX V21. Recently, the improved remeshing technique has helped to reduce the run time while keeping its own features of delicateness or sophistication.

2.1.8 Analysis of the Use of Enhanced Detailed Process Design Information

In the new version, detailed design information of the actual process can be used and analyzed. In most cases, analysis models based on several assumptions are used for characteristic parts of the process. This is the recommended method even in a correct way in terms of engineering. However, if you are interested in the structural analysis of the die assembly, as previously seen, the analysis result is greatly affected by assumptions, but the shape and assembly of the die are also greatly affected. Therefore, analysis techniques for the entire actual process have been required, and this function requires improvement of several functional elements in the program. For example, the function to determine or control whether to allow material flow between two dies is an example. In AFDEX_V21, many improvements have been made to meet the characteristics of these problems and the creative needs of users. In AFDEX_V21, practical functions and modules that greatly improve user convenience will be provided.

2.1.9 New Interface of PRE/POST Processor

PRE/POST processor facilitates user convenience. However, the existing framework caused some hindrances to update and reflect new features on the PRE/POST processor. In order to fix this, new PRE/POST processor with new concept will be provided in AFDEX_V21. Figure 2.9 shows the interface design of the new PRE/POST processor.

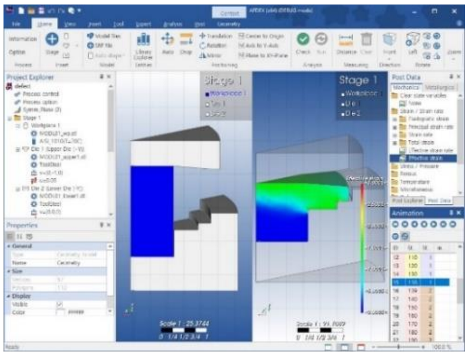


Figure 2.9 AFDEX PRE/POST V21

3. Notice

3.1 ATCx Manufacturing

MFRC will be exhibiting the latest features of AFDEX in ATCx Manufacturing, a fully virtual event in German language, scheduled to happen on January 28, 2021. The event emphasizes on innovative software solutions for manufacturing processes. We will present demo videos and latest features of AFDEX in the German language. Kindly use the link below to know more details and register for the event. https://hubs.ly/H0D9s3M0

3.2 Training Schedule in 2021

In response to the continued evolution of the COVID 19 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://youtube.afdex.com/)