AFDEX Newsletter
Q4 / 2020
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1. AFDEX_V20R02

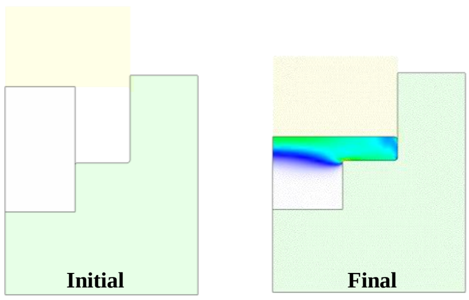
We have released a new version of AFDEX_V20R01 with minor bug fixes on July 31, 2020. The newest version for Altair APA users was already updated. The next release, AFDEX_V20R02 will be made on December 14. The upcoming updates include: high-cycle fatigue life prediction of dies, precise prediction of microstructure, improved shearing or blanking analysis, reduction of the run time, new function of predicting instability of materials in plastic deformation, etc. Some more details are given below.

2. AFDEX_V20 New Features and Improvements

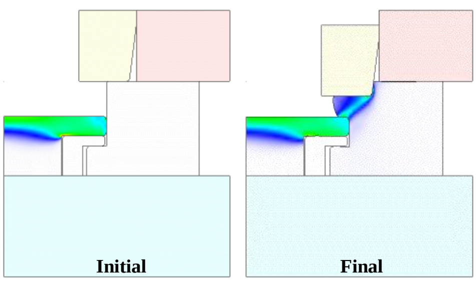
2.1 Stage-by-stage Simulation of Multi-body Problems

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 and workpieces changes during the analysis of multi-stage metal forming process, it is required to conduct S-b-S analysis by the user intervention.

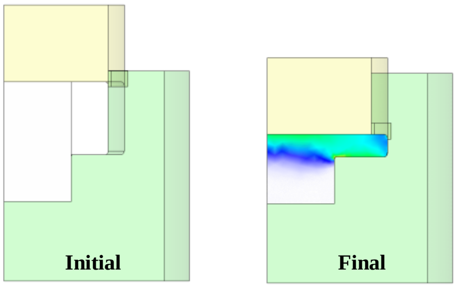
S-b-S analysis of multi-body metal forming process has not been provided in the previous versions including AFDEX_V20R01. This new feature is available in the upcoming version, and we will start beta testing for users interested in using this feature from this December. Figures 2.1 and 2.2 illustrate 2D and 3D simulation results showing the feature conceptually. 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.



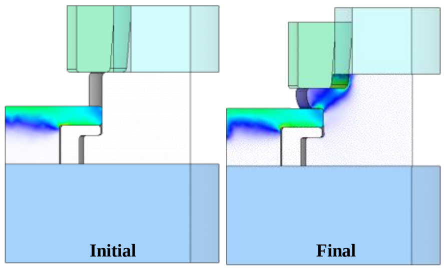
(a) First run, Single-body process



(b) Second run, 3-body process
Figure. 2.1 2D, S-b-S analysis



(a) First run, single-body process



(b) Second run, 3-body process
Figure 2.2 3D, S-b-S analysis

2.2 Tool-life Prediction of Dies

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. It is well known that the stability and the accuracy of the die structural analyses are very important for making meaningful die fatigue life predictions.

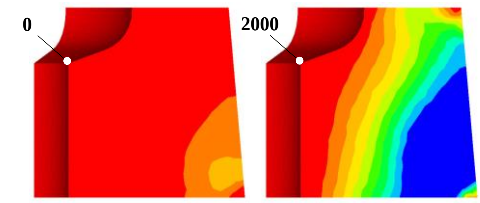
In general, fatigue fracture can be classified into low cycle fatigue fracture (LCF fracture) and high cycle fatigue fracture (HCF fracture), based on the classification criterion of 1000 repetitions of applied loads. A cold forging die experiences HCF fracture, while a hot forging die except some cases that can be explained with HCF fracture is mostly related to LCF fracture. The stress analysis provides crucial information for HCF fracture, while the theory of LCF fracture is developed in terms of the accumulation of damage based on the stress-strain relationship. Thus, strain energy in hysteresis stress-strain curve obtained under cyclic loading and the following damage can cause the fatigue fracture.

Literature on HCF fracture focuses on the structural engineering, which is nothing more than references, and it is difficult to be applied to metal forming field in terms of its purpose. Also, 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. For example, Goodman relation is generally used in the range of the positive mean stress (arithmetic mean of the maximum stress and the minimum stress), which is much conservative than Gerber method in the range. Because the structural engineering considering the fatigue life is the basis of the plastic deformation, the accurate prediction is more important than the conservative prediction.

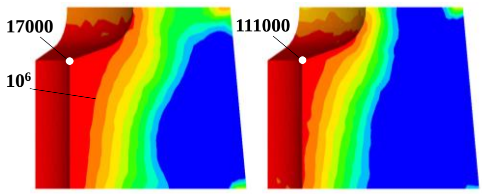
In other words, it requires to set dies to experience the fatigue fracture in a predictable manner in the metal forming. Therefore, the die fatigue life prediction in metal forming can be characterized as its accuracy with emphasis on the number near 100,000 cycles. Also, unlike the normal structures, preload is usually applied to the cold forging die, leading to move the point of (reference mean stress, amplitude) from the initial stress point on the left side of reference mean stress axis towards the first quadrant along the line inclined by 45° with the reference mean stress axis during the loading process. A purposely improved scheme of predicting the fatigue life of the metal forming dies was thus prepared for the new version of AFDEX.

Figure 2.3 shows the effect of initial stress caused by preload on fatigue life of a die under the condition that the effect of forming load on stresses in die is fixed. Figure 2.3(a) depicts the plastic deformation occurring on the upper-left corner without applying any preload. Moreover, Figure 2.3(b), (c), and (d) show the die life when 80%, 100% and 120% of the stresses are applied on the corresponding die, respectively.

The fatigue life of dies can be predicted with various theories and can be obtained by multiplying stress induced due to forming load or thermal load by weights. More details will be provided in AFDEX training program or research papers.



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



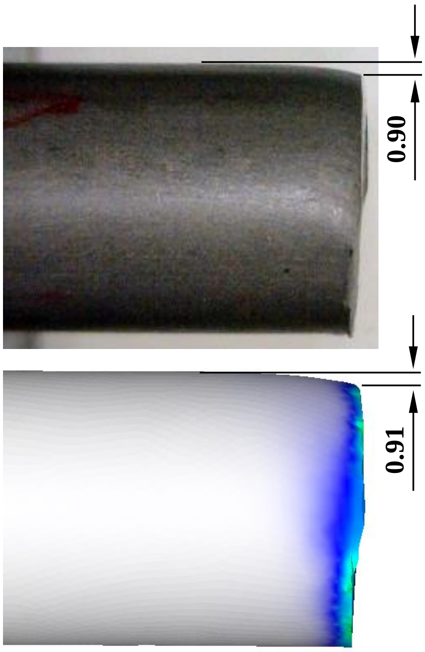
(c) 100% of preload (d) 120% of preload
Figure 2.3 Change in die fatigue life considering preload

2.3 Prediction of Rollovers at the Ends of Sheared Materials

The cold bar shearing analyses and its applications were already introduced in AFDEX newsletter Q1 2019. The previous study of the automatic multi-stage cold forging using a sheared material was intended to obtain the sheared shape of the material in the qualitative way and to evaluate sheared zone by measuring the inclination angle of a cross section.

However, 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.

A rod used for the automatic multi-stage cold forging contacts with shear knife system and is constrained by two sets of feeding rollers of a shearing machine. The distance of two nearest points contacting the two tool assemblies is quite large. Also, it is required to develop an analysis model considering elastic deformation occurring on the feeding rollers and preload acting on the rod which is caused by the feeding rollers. We thus developed an analysis model to simulate the shearing process. It needs two input constants that can be obtained easily by the experiments assisted by the predictions.



Stopper side

Figure 2.4 Comparison of predictions with experiments

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. 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 next version, and users can try this feature in the beta version.

2.4 Instability Index and Use of Processing Map of Formability Diagram

Recently, studies about dynamic strain aging (DSA) and difficult-to-form materials raise the importance of improvement in instability index and use of processing map or 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 up-down asymmetric or the softening behavior during the forming can influence the metallurgical and mechanical properties negatively.

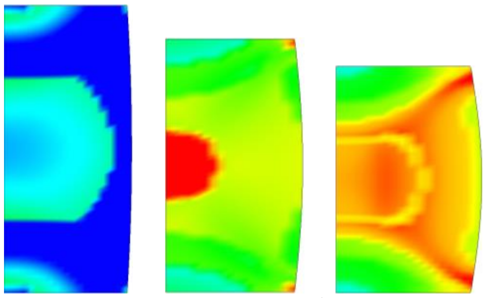
The instability index was developed to express these phenomena quantitatively, which will be provided with the feature of processing map or formability diagram in the next version.

This feature will be available through the beta version from this December. More details will be introduced soon with appropriate examples.

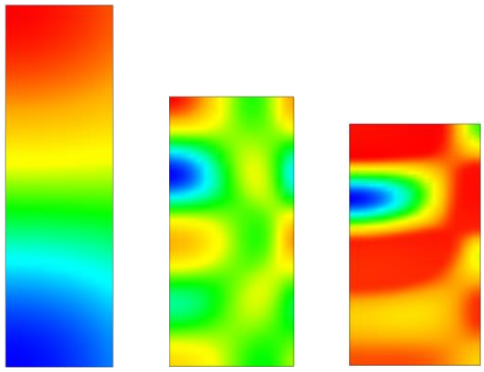
Figure 2.5 shows two typical cases of instability of two different materials in the potential working ranges of temperature and strain rate where significant softening behaviors occur.

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.



(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

2.5 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(a) 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.

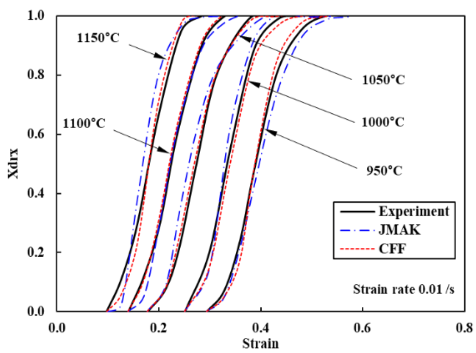


Figure 2.6 X_{DRX} kinetics curve of 0.15C-7Mn steel

2.6 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, an improved remeshing technique has helped to reduce the run time while keeping its own features of delicateness or sophistication. Accordingly, from this December, a much quicker version of AFDEX is available through the beta testing.

It is also expected that a continuous and steady improvement towards reducing computational time will be made because even minor improvements on the FEM front yield significant reductions in remeshing time, which takes up almost 60% of the total computational time.

3. Notice

3.1 AFDEX Training Schedule

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. (youtube.afdex.com)