AFDEX Newsletter Q2 / 2020
MFRC
www.afdex.com, mfrc@afdex.com
Tel: +82-55-755-7529, Fax: +82-55-761-7529

1. AFDEX_V20R01

AFDEX_V20R01 will be released in the middle of June, with a delay of about two months from our initial plan. This is because we are working on the program structure so that flexible expansion of new functions and quick response to user requests can be facilitated. We apologize for the delay and will work towards the quick release of AFDEX with recently updated new functions.

The following features are newly updated in AFDEX_V20R01. They not only involve new functions such as treatment of inclined spring-attached die using new binder die; analysis of a process in which force is exerted on the material in the identified direction by die; analysis of prestressing process of cold forging die assembly by press; analysis of non-isotropic material and continuing run of multi-body forming process in stage-by-stage way but also involve some improved functions such as elasto-thermoviscoplastic analysis of cold forging process; treatment of self-contact of material; 3D air trapping analysis; analysis of forging process using actual detailed die assembly; plate forging process; ring rolling analysis and completely automatic analysis of complicated open-die forging process.

In addition, the convenience will be much enhanced with advanced pre- and post-processing capabilities.

2. Some examples of new or advanced functions of AFDEX_V20

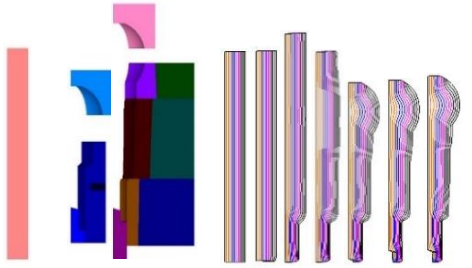
2.1 Effect of temperature and material model in cold forging process

In general, the effects of temperature have been neglected in the cold forging of steel. One of the major reasons for using the simulation technology for forging process design was that the predicted deformed shape, which is influenced by incompressibility, is closer enough to reality, to be used as a process design.

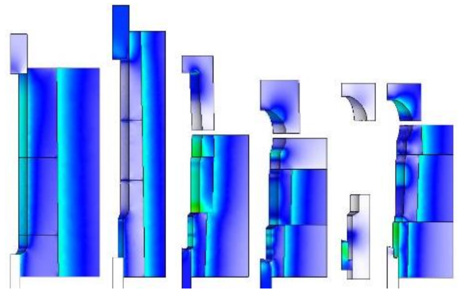
Recently, it is highly required for the strict management and the maintenance of equipment and dies due to the smartification of manufacturing processes. Thus the simulation technology is developing at a rapid pace to fulfill the demand for the prediction of forming load and lifespan of a tool. In the automatic multi-stage cold forging process with high speed and continuous manufacturing, the effects of temperature must be considered. Simulation of cold forging process with heat transfer is inevitable particularly in cold forging of high-strength material which is exposed to forming load limit and frequent die fracture.

Here, one of the analysis results is introduced, which demonstrates the effects of temperature and material model on analysis result. The analysis is executed for ball-stud manufacturing process using flow stress of SUS304 obtained from a compression test at below 500℃. Figure 2.1 depicts the predictions obtained with temperature and die elastic deformation effects considered, and Table 2.1 provides a comparison between the maximum forming load and the maximum effective stress on the die at 5th and 6th stages obtained under different conditions.

As seen in Table 2.1, the forming load and die stress of Case 1 at the 5th stage which neglects temperature effect are greater by 105% and 62%, respectively than the Case 3 reflecting the temperature effect. However, the change in the forming load and the maximum effective stress resulting from consideration of elastic deformation of a material is negligible so that it does not show a reasonable tendency. From the theoretical viewpoint, considering the fact that forming load increases as some constraints are imposed artificially on the material, which involve temperature, die elastic deformation and elastic deformation of material, the predictions with lower forming load or lower die stress are closer to the reality. However, the comparison of the metal flow lines appears to follow almost the same by inspection.



(a) Initial material, process design (5th and 6th stage, respectively) and analysis of metal flow lines



(b) Effective stress distribution in dies (Case 3)

Figure 2.1 Process design and prediction of metal flow lines

SUS304 is a high strength material, and its flow stress, dependent on temperature, decreases enormously even at below the intermediate temperature. For this material, it is reasonable to consider checking the temperature dependence of the flow stress when determining whether the forging can be done.

Table 2.1 Prediction results depending on different material and die modeling

Case	Max. forming load [kN]		Max. effective stress [MPa]	
	Stg. 5	Stg. 6	Stg. 5	Stage 6
1	187.0	866	3240	2430
2	95.7	611	1870	1980
3	91.3	597	2000	1940

Case 1: Isothermal, rigid die; Case 2: Non-isothermal, elastic die; Case 3: Non-isothermal, rigid die

2.2 Treatment of inclined spring attached die

The binder die in AFDEX exerting a force on material plays a role of pushing a plate or sheet material in the normal direction. It is verified that the binder die is effective in solving massive numerical problems occurring from applied load. More recently, the usage of an improved feature of a binder die has started. This tool exerts on the material in the forming direction while the displacement or velocity component normal to the forming direction is constrained. It was applied to the lower die working at 5th stage as shown in the Figure 2.1.

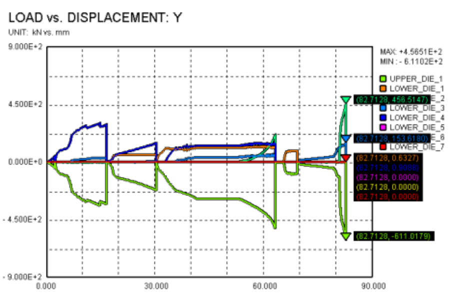


Figure 2.2 Forming load responses

Figure 2.2 illustrates the forming load response of 5th stage executed with elastoplastic finite element analysis, which verifies the proper balance of the forming load applied at 5th stage. Before contact is made between the lower die and the workpiece, the forming load becomes almost zero, because both the binder die, and the workpiece are rigid bodies moving downwards. The deformation occurs, satisfying the balance of the upper and the lower loads from where plastic deformation begins on the material. At this point, the flow of the material (expansion) will be restrained by the binder.

2.3 Advances in controlling relative die motions in plate forging

In the new version to be introduced in Q2, all of 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 are 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 2.3 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.

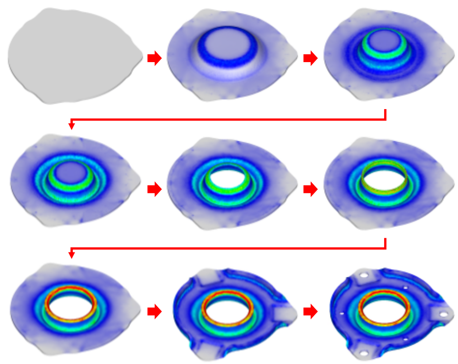


Figure 2.3 Analysis of plate forging process

2.4 Improvement of identifying potential region of air trapping

In the latest version, 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 as follows: marking the desired region to be searched for air trapping and inputting bulk modulus of elasticity of the trapped air as a function of pressure. If the pressure generated by air-trapping phenomena reaches a specified amount, this leads to leakage of air, which is the hardest part to build an accurate model. During the analysis, the compression ratio will be dropped under control when the pressure inside the space enclosed by a workpiece and dies reaches a certain fraction of the weakest pressure in the contact surface. The artificial pressure drop is aimed to deviate the potential numerical instability due to high compression ratio passively determined based on the predictions at the previous solution step. That is, the mathematical air trap model does not couple the flow analysis problem strongly with the pressure inside the enclosed air trap.

Also, it is not simple to obtain accurate relationship between the increase in pressure and the compression ratio. It can be predicted that the effects of oil and lubricant remained inside the enclosed space will grow rapidly due to the increase in pressure and the leakage of air. However, it is difficult to verify the relationship, and in fact, it is impossible to measure the pressure increasing rapidly at each point numerically. Therefore, the simulation may fail to predict the actual phenomena in the range where forming load increases rapidly. However, our experiences make us tell that the predictions just before the closure of air trap may give sufficient information about potential surface defects. It should be noted that the composition of the air trap just before its closure is not so simple and that the density increases so much rapidly.

Figure 2.4 shows the comparison between the experimental results and predictions for air trapping phenomena. It should be noted that the air trap may disappear in the predictions when additional stroke is applied from this point, as explained above. If there is no air hole, then some marks should remain because the material left involves impurities including debris, lubricant, water, or carrier.

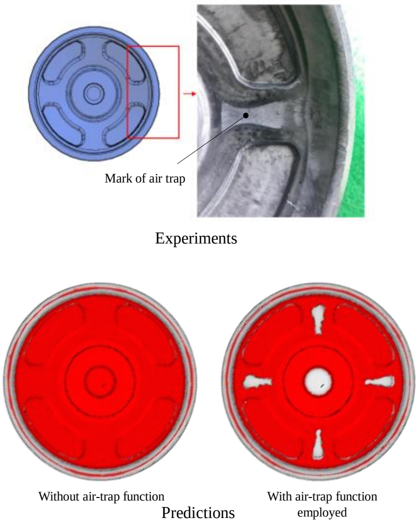


Figure 2.4 Experimental results and predictions with emphasis on air trapping phenomena

2.5 Enforced function for material self-contact

For three-dimensional analysis in any of the versions released until now, user input for 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 causes malfunction when the self-contact region is axi-symmetric.

In the latest version, only input of the index is required, which determines the activation of the function of treating self-contact. Figure 2.5 shows the application result of the new function.

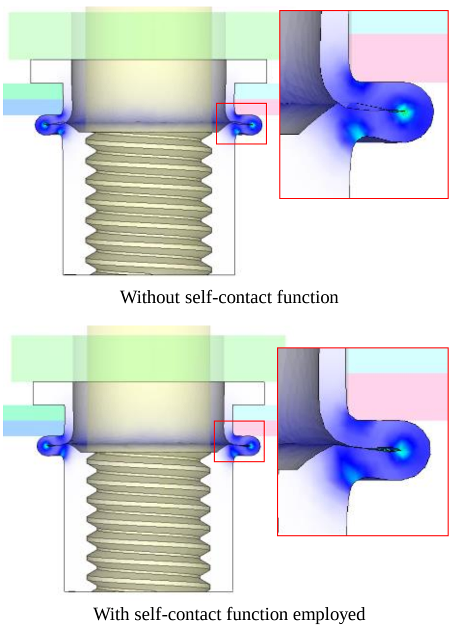


Figure 2.5 Example of self-contact of material

2.6 Improvement in function of ring rolling process

The characteristics of ring rolling involve relatively fewer number of contact nodes to that of surface nodes, repetitive instantaneous contact of nodes causing directional deformation and force imposing dies or tools.

The first characteristic make it 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 mechanical imbalance caused by existence of friction. For such cases, artificial boundary conditions must be used. For instance, if the amount of spread of material is relatively excessive in analysis results, forced friction or prevention of slip in the spread direction would rather be imposed on a part of contact region. Such functions are added in the new version so that users can easily utilize the function of imposing contact conditions.

The second characteristic prevents flexible mesh density control during remeshing or too frequent remeshing causing inaccuracy due to smoothing of surface and state variables. AFDEX has supplied special mesh density control function for torus shape to solve this problem.

Lastly, for the problems of force prescribed die or tools, several functions have been provided in AFDEX. In AFDEX_V20R01, the numerical stability of the original function for contacting surface was enhanced. 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 2.6 illustrates the analysis result of ring rolling process obtained in the new version. 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 2.6 Experimental results and predictions for ring rolling process

2.7 Enhanced analysis using detailed die design information

The function for analysis using the detailed die design information of actual process is enhanced in the new version. In most cases, FE analysis is conducted using conceptual die design for engineering which reflects only major mechanical characteristics. Of course, it is recommended that this approach be right in most cases. However, a die structural analysis can be affected a lot not only by assumption, but also by the shape of die or assembly. Therefore, analyzing technology that is intended for the entire process has been requested for various purposes.

This function requires improvement in many technical or functional things of the program. For example, it needs the function that controls the allowance of material flow towards the space between two contacting dies.

2.8 Analysis of anisotropic material

Currently, the development of the anisotropic material function is in progress. The feature of rigid-plastic analysis is prepared so far and will be released next year. The basic features are planned to be provided with 2020 edition in this October and can also be provided for the users who need it for research purpose.

2.9 Analysis of prestressing cold forging die by press

AFDEX has provided the shrink fit analysis, and it has been applied efficiently to the die structural analysis during forging where preload caused by shrink fit is considered. The original function can be employed for analyzing the process of prestressing cold forging die by press using an equivalent thermal load, which is more numerically stable. In most cases, it seems to be working fine. However, if the amount of preload or prestress is greater than common cases, the elastic or local plastic deformation of die or tool parts during preloading or prestressing can have significant influence on the distribution of the prestress in the die insert. Figure 2.7 illustrates the effective stress at the final press stroke during die prestressing. The analysis was conducted for an elastoplastic material using multi-body simulation.

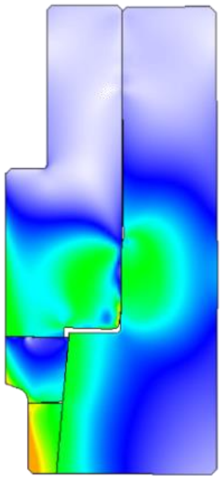


Figure 2.7 Effective stress distribution due to preload

3. Notice

3.1 Online lectures

In response to the continued evolution of the COVID-19 pandemic, Gyeongsang National University (GNU) and MFRC are shifting in-person classes to online to provide all students with video or non-contact lectures. The following subjects will be provided: mathematical background, tensile testing, statics, solid mechanics, introduction to plasticity theory, finite strain, finite element method, and all things 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. You can see here, for more details: "Menu" – "Education and conference" in www.afdex.com.

More than 20 AFDEX 2D and 3D tutorials (with narration in English) have been uploaded recently in MFRC's YouTube Channel. We hope, this would be a valuable source for AFDEX users and trainees to learn new processes and get started quickly.

3.2 Altair webinar on plate forging

Professor Dr. ManSoo Joun, in association with Altair, will present a webinar on plate forging for the global Altair users and the potential users on May 28, 2020. We will update further details and provide a registration link in the notice section of AFDEX website.

AFDEX is currently available through the Altair Partner Alliance (APA), which enables to introduce AFDEX to the global users in this field. The global users who are mostly forging customers are interested in total engineering using forging. MFRC has put an effort on the enhancement of the functions such as multi-body and optimal design to answer the user needs.