AFDEX Newsletter Q4 / 2019

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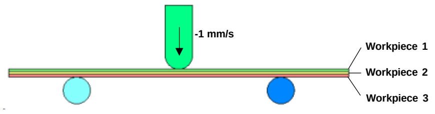
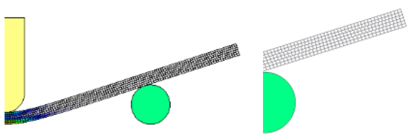
1. Summary of Improved and New Functions

1.1 No-Slip and Non-Separation Condition for Multi-Body Simulation Function

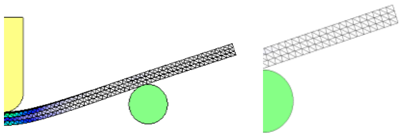
Figure 1.1 below shows an analysis results of 2D & 3D V-bending process of composite sheet under the condition of no-slip and non-separation along the interface between different materials. During the simulation, remeshing can be conducted either automatically or manually. This function has a distinct advantage over the analysis of metal forming with composite materials and can be developed in a way that analyzes for the delamination in the interface of composite sheets.



(a) Process definition



(b) 2D case



(c) 3D case

Figure 1.1 Analysis result of V-bending process of composite sheet

1.2 Direct Coupling of Material and Die

In general, indirect coupling approach is applied to simulate metal forming processes. That is, each object is solved independently and correlation, action and reaction between materials or bodies are dealt sequentially that causes some inaccuracy, which is inevitable. A direct coupling approach is beneficial to solve this problem, which solves the entire process involving material and a part of die parts at the same time without any iterations between separate problems.

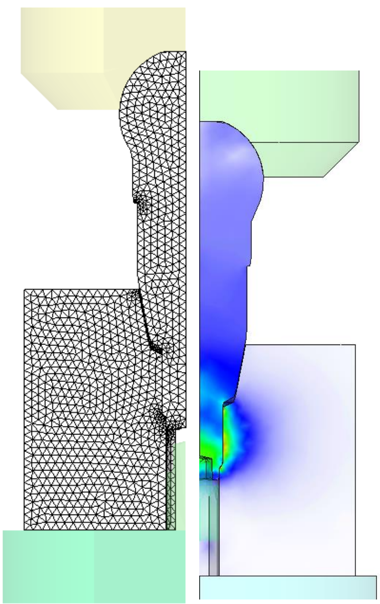


Figure 1.2 Directly coupled analysis between material and die part (Left: FE model, Right: Effective stress at the final stroke)

In the direct approach, the interface of different materials are treated by the penalty method and frictional condition can be considered.

Figure 1.2 shows a typical example of the direct coupling approach for simulating a stage of a ball-stud cold forging process. This stage is mechanically complicated because of the side die with spring and needs accurate simulation because the potential premature die fracture during backward extrusion for the hexagonal hollow end. An artificial binder die exerting force depending on its displacement is employed just below the die part. Note that the binder die exerts the exact force calculated from its displacement velocity, preload, etc.

1.3 New Function of Simulating Normal Open Die Forging Processes

The open die forging analysis in AFDEX had been focused on a complicated process such as stepped and/or hollow bar. In the previous version, manual intervention was needed in the case of changing stages. In the newest version, new feature is added, which allows to automate analysis of whole processes where motions of dies are comparatively simple as in the case of normal cogging process for long and uniform bars. The main input conditions needed for the process analysis are the range of movement allowed by manipulators located on the both sides of the material, plastic deformation limit, period, target reduction, moving position of dies, and parameters for tuning the analysis results based on the experimental results or experiences for each pass. A pass is composed of a series of the same blow by the same pairs of dies. Figure 1.3 shows the typical application example.

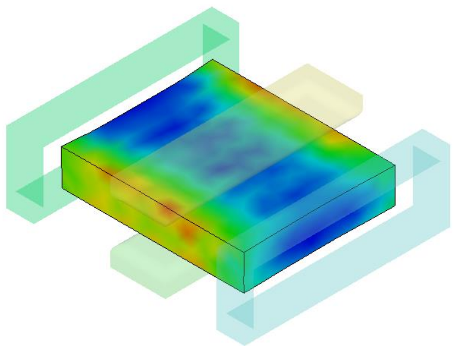


Figure 1.3 Completely automatic simulation of a standard open die forging process

1.4 Analysis Considering Cooling Channel

Sometimes, cooling of dies needs to be carried out using the cooling channel. Most metal forming processes commonly do not require the flow analysis for a coolant inside a cooling channel, which makes problems much complicated and the effectiveness is very low. Considering this reason with the factor of coolant flowing in high speed, a method is provided in practical way to take account of heat transfer between a workpiece and a coolant which is maintained at an assumed constant temperature. Figure 1.4 illustrates the analysis of cooling die using cooling channel.

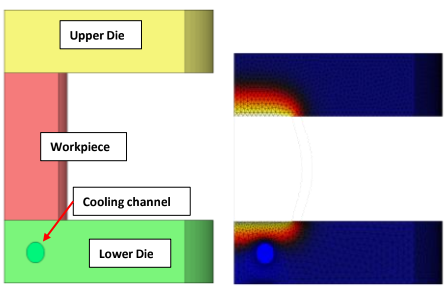
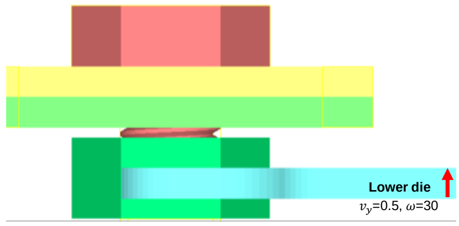


Figure 1.4 Heat transfer analysis for a die considering a cooling channel

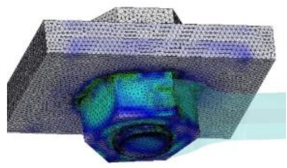
1.5 Analysis of Tightening Process of Bolted Joints

The tightening process of bolted joints is one of the representative examples of multi-body processes. The cases of relatively small slip during assembling or forming multi-bodies has been already introduced previous newsletters and related academic papers.

The tightening process of two plates with bolted joints shown in Figure 1.5 is representative of a drastic multi-body process which is characterized by its long slip along the interface, i.e, an extreme case of multi-body forming problems.



(a) Process definition

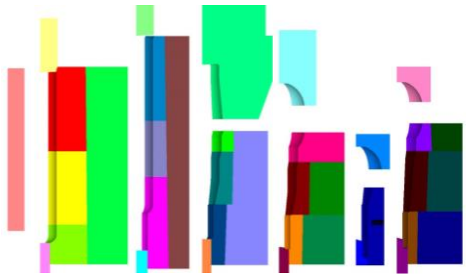


(b) Effective stress at the final stoke

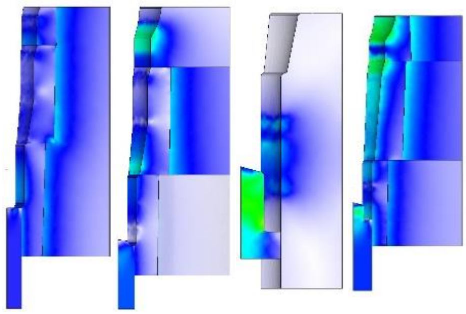
Figure 1.5 Analysis of tightening process of bolted joints

1.6 Analysis of Assembled-Die Forging Process

Recently, the analysis functions of simulating assembled-die forging processes are improved, which are inherently exposed to some numerical problems due to complicated die geometries. It is highly likely that there will be some numerical jump caused by shrink fit, singular or points or edges, i.e., geometric discontinuities between die parts and planes of symmetry. Lately, various methods have been developed to remove these problems. Figure 1.6 shows effective stress contours of die parts in a typical automatic multi-stage cold forging process.



(a) Process design



(b) Effective stress

Figure 1.6 Predictions of an automatic multi-stage cold forging process of a ball-stud

2. New Material Model for Flow Stress

2.1 At Elevated Temperature

We had been working on a research developing a flow stress model of high-temperature material considering recrystallization, and the outcome was published recently in J. Mater Res Technol.(2019, Vol. 8, p. 2710). The flow stress model has an advantage of being not only the most accurate way of expressing a complicated flow stress obtained experimentally, but also a means of increasing generality. It is applicable in expressing flow stresses for the various high-temperature situations. Even though there are too many material constants used for the model, they can be calculated easily by an optimization function. Figure 2.1 illustrates the application of the model.

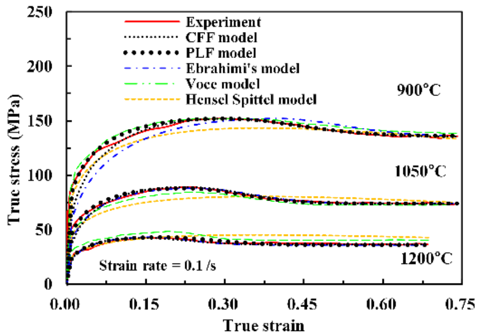


Figure 2.1 Verification of CFF and PLF model of AFDEX

2.2 At Room and Intermediate Temperatures

A considerable decrease in flow stress is caused by increase in temperature due to viscous heating during an automatic multi-stage cold forging process. It implies that temperature has a great influence on the plastic deformation and forming load of a material. Therefore, a change in flow stress which depends on a change in temperature must be considered essentially for the forging of high-strength materials. As temperature of a material increases, the velocity dependence of the flow stress inevitably increases. In order to reflect the deformation characteristics of a material at room and intermediate temperatures, the following model is proposed, which is added on the program as 'Model 29.'

$$\sigma = a_1(1+\alpha_2\varepsilon+\alpha_3\varepsilon^{a_4})^{a_5}(1+\beta_1 T)^{-\beta_2}(1+\gamma_1\dot{\varepsilon})^{\gamma_2}$$

Note that the flow stress model is developed based on experimental study on SUS304 and that it can be applied to the other materials because it is general and flexible. Figure 2.2 shows the flexibility of the proposed model. It is noteworthy that a necking occurs on the same elongation over all the flow stress curves.

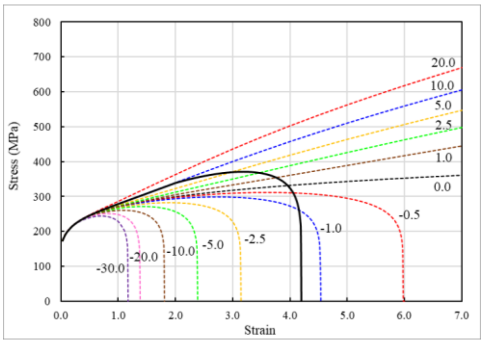


Figure 2.2 Flexibility of the proposed model

3. Recent research activities using AFDEX

Good research cases are introduced below, and they were presented in MFCAE 2019.

3.1 Crankshaft die structural analysis

Figure 3.1 illustrates the die structural analysis result during crankshaft hot forging process. The simulation result was used for prevention of fatigue-induced die crack occurring on the region where the max. principal stress is applied.

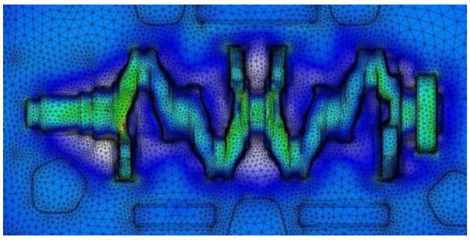


Figure 3.1 Max. principal stress distribution on die during crankshaft hot forging process

3.2 Optimal Design for 3D Die Shape

Details about the optimal design was already mentioned in Newsletter 2019 Q1. For generalization of the optimal design for 3D processes, the die shape should be parametrized. A research regarding this have been continued and will be developed gradually. This content will be published through Int. J. Auto. Tech.

Figure 3.2 shows the case of the 3D optimal design of a die shape, where the design variables include geometric dimensions of die and material. The optimal design was able to reduce 8% from the original weight of a material, and 5% from the original forming load.

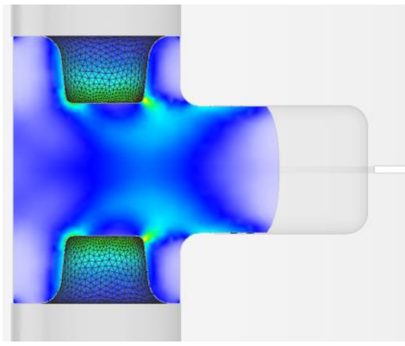


Figure 3.2 3D optimal process design

3.3 Improvement in Plate Forging Process Design

The plate forging process (forming plate using forging methods) is being applied for the purpose of omitting material removing process. When a workpiece whose thickness has changed drastically through the plate forging, is formed, the process design often ends in failure because bending occurs due to a difference in thickness. For this purpose, it is highly effective to optimize the process design using the metal forming simulation. Figure 3.3 compares the predictions of different process design tryouts by simulation.

Figure 3.3 FE predictions for finding acceptable process design

3.4 Experimental and Numerical Acquisition of Material Constants for Grain Size Prediction

Material constants that have the characteristics of a material and the proper constitutive model are essential to predict the grain size during hot forging. However, it requires high cost and expertise to obtain those material constants. AFDEX researchers have developed a method for determining the material constants at comparatively low cost (J. Mater Res Technol.(2019, Vol. 8). Figure 3.4 shows an example which is applied in real process using the material constants obtained. To get the material constants, the results of high-temperature compression test and the grain size information of the model process obtained experimentally are needed.

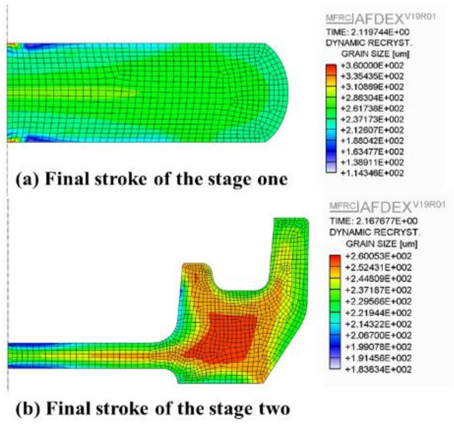


Figure 3.4 Predicted DRX grain size (μm)

4. Notices

4.1 Global ATC 2019

Altair's Global Technology Conference - GATC will be held in Detroit, USA on 10th and 11th of October 2019. The show, a major PLM technology exhibition, brings together a community of global tech leaders. MFRC will participate in GATC as an exhibitor-sponsor and introduce some latest features of AFDEX during this event.

Fig. 4.1 Conference site at Detroit, USA

4.2 JSOL CAE Forum 2019

JSOL CAE Forum 2019 will be held in Tokyo, Japan (Tokyo conference center Shinagawa) for three days from November 6 to 8. Dr. Mansoo Joun, CEO of MFRC will present the metal forming simulation technology for multibody and optimal design.

Full details about the conference:
https://www.jsol-cae.com/en/event/usersevent/2019/caeforum/

4.3 MFCAE 2019

MFCAE 2019 was held at Jinju MBC Convention from 8 to 9 August. At this event, undergraduate sessions, graduate student sessions, user sessions, developer sessions, and professional training sessions were held. Also, Dr. Mansoo Joun delivered a special lecture about the modeling technology of the metal forming process.

Figure 4.3 MFCAE 2019

4.4 GISPAM 2019

GISPAM 2019 was held at Gyeongsang National University for five weeks starting from 15th July. GISPAM is an international cooperation program, started and financially supported by the government of the State of Mexico six years ago. In this year, 30 scholarship students in the State of Mexico, 2 university students from Universiti Teknologi MARA, Malaysia, and 10 Korean undergraduate and graduate students participated.

Fig. 4.4 GISPAM 2019 after evaluation of the program

4.5 MetalForm China 2019

MFRC participated in MetalForm China 2019 exhibition held in Shanghai, China (Shanghai New International Expo Center, SNIEC) for three days from July 17 to 19, 2019. In this Expo, MFRC had collaborated with BRIMET, our agent in China.

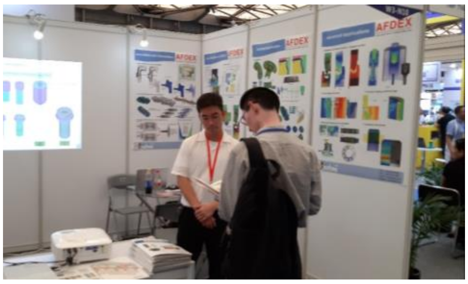


Fig. 4.5 MetalForm China 2019

4.6 China Forging Technical Committee Seminar

Dr. Mansoo Joun attended Chinese National Congress on Forging Technology held in Changchun, China from 25 to 28 of July, and presented on applied technology using metal forming simulation as an invited speaker.


Fig. 4.6 Chinese National Congress on Forging Tech.

4.7 ICAME 2019

MFRC attended the 6th International Conference on Advances in Mechanical Engineering 2019 (ICAME 2019) as a Gold Sponsor in The Kota Kinabalu, Malaysia at August 14-16, 2019. The theme for the 2019 edition of ICAME was “Engineering for Humanity”, emphasizing the role of engineering in providing technologies to fulfill the needs of modern humanity. industry experts from Malaysia, Germany, Japan and Korea discussed on various topics such as human capital development in the era of Industry 4.0, advanced manufacturing technology and simulation and design applications within the automotive industry. In conjunction with ICAME 2019, two MoUs (MARii-MFRC and UiTM-MFRC) were signed.


Fig. 4.7 After signing MOU between MARii/UiTM and MFRC

4.8 Visiting Indian Forging Companies

MFRC member visited prominent Indian forging companies in Belgaum, Nashik and Pune, during the third week of September 2019. The visit was very helpful to understand their needs and provide them innovative and efficient solutions as well as to get some new ideas for AFDEX improvement. A two-day training program was also conducted to introduce AFDEX and its world of capabilities.


Fig. 4.8 Meeting for finding some new idea to model a special shearing process