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Finite Elemental Analysis of Rolling Process Using AFDEX: A Methodology

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***Abstract:* --- Rolling process is one of the most widely used metal forming process. The use of simulation software to predict rolling force and energy parameters is growing day by day. AFDEX software is one such effective tool for the rolling simulation. 3D modelling, automatic re-meshing and user friendly interface are some of the attractive features of this software. This paper covers in detail the methodology of modelling, simulating and interpreting the results in AFDEX software. An example illustrating the effectiveness of AFDEX software to solve rolling problem and obtain results like Von Mises stress, effective stress, effective strain, hydrostatic pressure, shear stress, Vickers'shardnessetc. is discussed.**

***Keywords:*------ Rolling, AFDEX, Simulation, Modelling**

I. INTRODUCTION

Rolling process is one of the most critical metal forming processes. Materials are exposed to rolling process during a major portion of their lifespan. Almost 40-60% of rolling takes place by flat rolling. Many researchers optimised parameters such as rollingspeed, rolling diameter, lubrication, temperature, coefficient of friction etc. to improve quality and quantity of the rolling process [1, 9]. To stay competitive in market manufacturer developed new low cost products and new technologies in mills to improve quality [2]. FEM method and numerical simulations have been proved to be a very effective tool for prediction of rolling force and energy parameters in rolling process. Most of rolling simulation studies has been carried out using ABAQUS. A new manufacturing simulation package AFDEX has been gaining importance in finite element analysis of forming operations [5]. 3D model is required for accurate prediction of data since 2D model does not indicate if any damage is present [6]. This software allows for 3D modelled rolling simulations.

Simulation techniques are applied using the AFDEX (Advisor as friend for Forging Design Experts) software. It is a FEM (Finite Element Analysis) package based on the langrangian mathematical approach. It can predict different parameters of Rolling/ forming process such as Hydrostatic pressure, Von Mises stress shear stress, effective stress, effective strain rate etc [3]. Many researchers have carried out their work using AFDEX software for simulating various components like rocker arm, stud bolt etc [3, 4, 5, 7, 8]. In this paper detailed methodology for simulating rolling process using AFDEX software package is highlighted. Some examples with results are also discussed .Fig 1 shows the methodology for AFDEX.

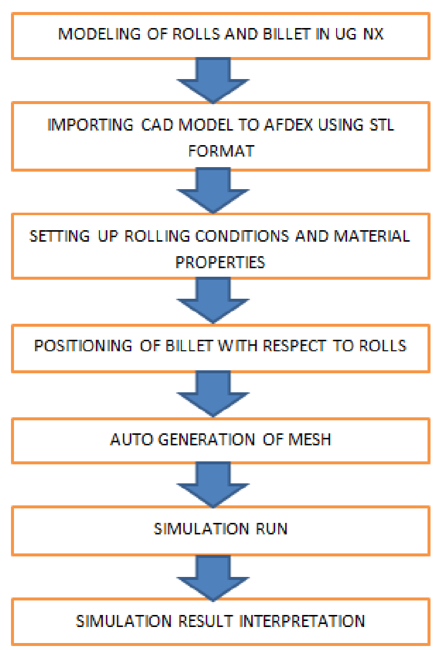

Fig 1 AFDEX methodology

II. MODELLING

The rolling modelling consist mainly three components: upper roll, lower roll and billet. In this study, roll and billet modelling is done using CAD package UG NX

9. It will be easy to give rolling axis for the rollers if modelling is done using UG NX 9.Usually modelling is done on XY plane since it is easy to simulate in AFDEX software Package.

Rolling modelling is split into three parts

1. Roll modelling
2. Billet modelling
3. Assembly

1.1. Roll modelling:

As shown in figure 2 the modelling is done on XY plane. First the upper roller is designed and then it is mirrored for the lower roller. For modelling, the separation distance between two rolls is set according to the final thickness of the billet. The width of roll is set greater than or equal to width of the billet and it is depends on the desired width of final rolled product. Figure 2 shows the roller model with diameter 100mm.

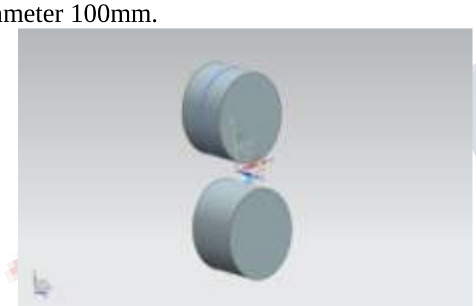

Fig 2 Roll model (100mm)

1.2. *Billet modelling*:

Billet can be of any shape like square, circular, parabolic etc. Figure 3 shows the billet modelling done using UG NX 9. This billet has square cross section of 40×40mm and 100mm in length.

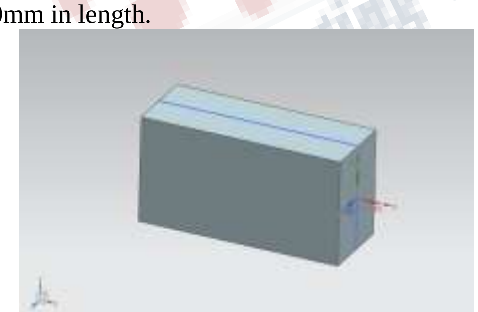

Fig 3 billet modelling

1.3. Assembly:

Once the roll and billet modelling is done the next step is to assemble them. Figure 4 shows assembled model of roll and billet. First the rolls are kept at origin position and then billet is assembled to it.

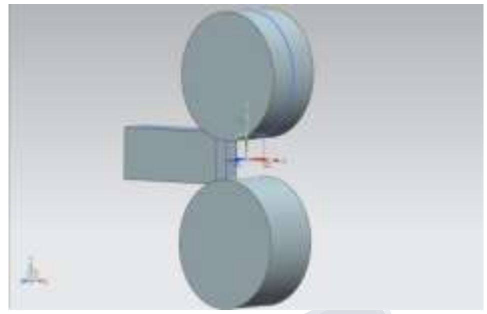

Fig 4 Rolling Assembly with 100mm diameter rolls

III. IMPORTING CAD MODEL TO STL:

Once the assembly of the roller and billet is completed using CAD package,the models need to be converted into STL format and then imported into the manufacturing simulation software AFDEX. . STL stands for Standard Triangulation Language.

IV. SETTING UP ROLLING CONDITIONS:

The rotation of rolls causes the billet to go through roll gap and obtain desired thickness. Various inputs have to be given before starting the simulation. Following are process parameters that are to be given while setting up rolling conditions.

- Type of rolling
- Type of simulation
- System of units
- Type of analysis
- Deformation
- Billet material
- Lubrication used
- Friction
- Material temperature
- Forming control
- Press data (velocity)
- Rotation axis

V. POSITIONING OF BILLET WITH RESPECT TO ROLLS:

The main positioning is done in CAD package itself as it is difficult doing in AFDEX package. But the positioning is ensured once before simulating the process. Figure 5 shows the position of the billet with respect to rolls in AFDEX software. In this stage the position of the billet, rolling axis and rolling direction is ensured. The material has to move from –X to +X and it will only occur if theupper roller is rotating anticlockwise and lower roller is rotating in clockwise direction.

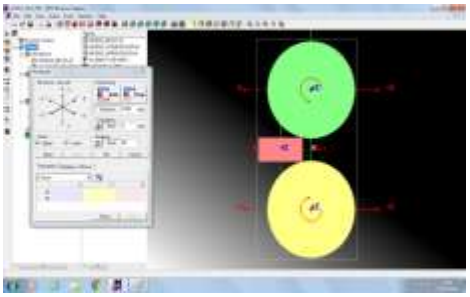

Fig 5 Positioning window in AFDEX

VI. MESHING

Meshing, the most important part of the Finite Element Analysis refers to the decomposition of the body such as strip into sub-domains or elements. The quality of body's mesh can have a large impact on overall quality of the model. The purpose of an element is to represent not only the geometry of a body, but also its stiffness. The choice of element type and number can influence how well body's geometry is represented. The workpiece material slab is usually divided into tetrahedral elements. The simulation package AFDEX has ability to re-mesh the workpiece as it deforms. AFDEX provides user defined number of elements or the automatic generation of the mesh. The quality of a mesh can be determined by running models with varying meshing size and measuring the effect of variablessuch as stress at specific location. As the size of element decrease the number of elements increase and is known as mesh convergence. The minimum numbers of elements that give the required convergence are used in the final models because additional elements would not significantly contribute to the accuracy of the model.

Fig 6 tetrahedral meshed workpiece in AFDEX

VII. SIMULATION RUN

The rotation of rolls cause billet to go through roll gap and obtain desired thickness. The various inputs are given before starting the simulation. . Once the simulation starts the material is auto meshed into tetrahedral meshing. The figure 7 a, b and c below shows the rolling simulation with the initial, intermediate and final stages respectively

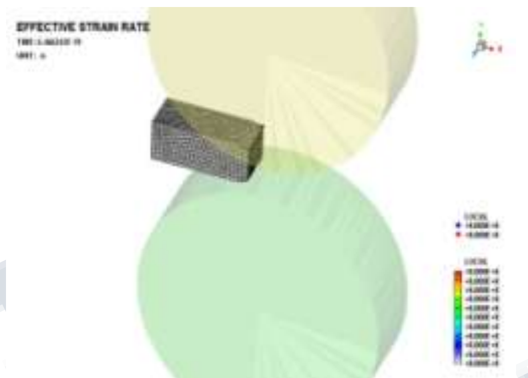

Fig 7a initial stage of simulation

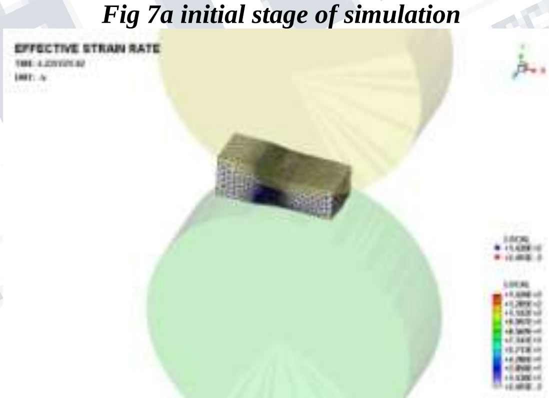

Fig 7bintermediate stage of simulation

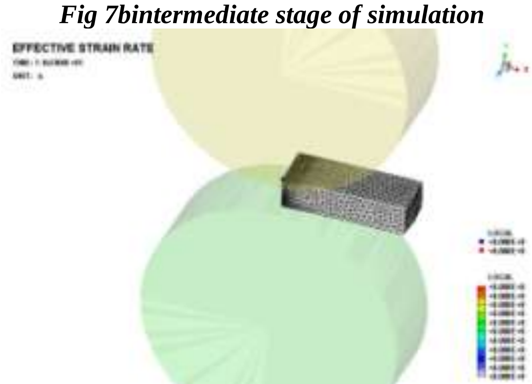

Fig 7c final stage of simulation

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7.1. Example

Following data's are to be entered for run the simulation for rolling operation with roll diameter of 100mm and billet with 40×40mm and 100mm in length, it is then reduced to 30mm in height with flash.

Type of rolling	Hot rolling
Type of simulation	3d without flash
Type of analysis	Flow analysis
Deformation	Rigid plastic
Billet material	AISI_1055
Lubrication used	Graphite+water hot (steel)
Friction	0.3
Material temperature	1000˚C

Table 1 rolling parameters used for simulation upset rolling.

2. SIMULATION RESULT INTERPRETATION:

At this stage results are interpreted as Von Mises stresses, Effective stress, Rolling load, Strain, Pressure etc. The stress distribution pattern across the billet is also obtained at this stage along with Vickers's hardness, principal stresses and strains in various directions.

2.1. EXAMPLE:

Following results shows the simulation carried out with 100mm diameter rolls to reduce square 40×40mm billet to 30mm in height.

Diameter (mm)	100
Speed (rpm)	480
Von Mises stress (MPa)	200
Effective strain	1.26

Effective stress (MPa)	211.2
Pressure (MPa)	480.5
Shear stress (MPa)	124
Hardness Vickers (kgf/mm²)	222.8

Table 2 & 3 Results

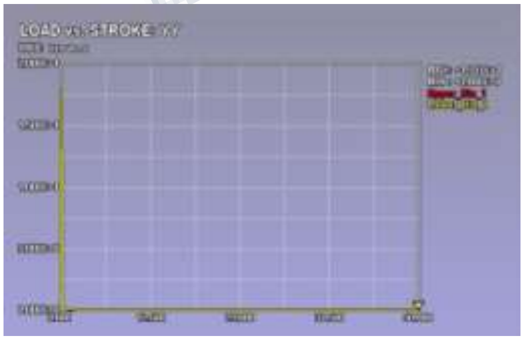

Fig 8 load in YY direction

Figure 8 shows maximum load of 17.87 tons for the rolling operation.

VIII. CONCLUSION

- The modelling of the billet and rolling mills were done successfully using UG modelling software and the steps have been discussed in detail.
- The AFDEX Software was used to simulate the rolling process and the interpretation of results has been discussed.
- An example has been to illustrate the effectiveness of AFDEX software for rolling simulation.

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