Web-based Visualization of Forging Operation by Using Virtual Reality Technique

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ABSTRACT

This paper presented a virtual manufacturing simulation system by using Virtual Reality Modeling Language (VRML) and Finite Element Method(FEM). The system is to simulate forging operation. Stress distributions and deformation profiles as well as the operation of forging machine can be simulated and visualized in the web. Since the forging machine, user interface, and specimen were modeled by using Java and VRML, the forging machine and analysis results were browsed and integrated on the web that is interfaced to users through EAI to show the whole forging simulation. The developed system realized the working environment virtually so that education and experiment of forging process could be performed effectively even on the PC.

keyword: FEM, Virtual Reality, VRML, Forging Process, Virtual Manufacturing

Introduction

Since the early 1990, the concept of VR(Virtual Reality) has been applied extensively to Manufacturing. The new type of manufacturing technology has been applied to development of Virtual Prototyping in the field of Design and Virtual Manufacturing in the field of Manufacturing. VM(Virtual Manufacturing) is defined to be an integrated, synthetic manufacturing environment to obtain optimization of product design, production, and management by realizing the all physical factors used in factory, such as machines, equipments, and supplementary tools, on computer. Recently, with rapid improvement on network performance, a great number of researches on development of web-based virtual machine have been under way. However, most of them put their effort on only representing the machine or the process itself due to the critical speed limit for data process and transmission &reception. In other words, few researches for forging process that requires enormous data created from numerous analysis and complexities among specific process variables and plastic flows have been conducted. However, it is essential to integrate between design &production system and simulation system to reduce the time from product conception to market and production cost and to expedite mutual understanding between product designer and simulation expert.

The objective of the work presented here, web-based visualization of forging process using virtual reality, is to develop the integrated simulation system which shows kinematics and structural analysis by integrating two results of researches, one is creating production process in virtual environment, and the other is converting the analysis results obtained from FEM solver to virtual environment. Therefore, following researches need to be developed;

① Development of data processing
is to develop the program to convert an ASCII file that contains information about the deformed product from a commercial FEA solver to VRML file format to visualize the data in virtual environment. This is to be implemented to remove the difference of shapes between virtual prototype and real product by importing each data to VR program.

② Creating Virtual Factory
is to create and implement the geometric models of all the machines on the production line in a virtual world. This is to provide the user with familiar environment for him to use in realism with ease.

③ Development of Integrated Simulation System
is to provide integrated system to combine the analysis tool with VR technology. This is for engineer on the production line to obtain deformed shape after analysis and to be able to modify with ease.

The work presented here has been proceeded under the first year plan of three years, and, as the result of ① and ② above, we have developed web-based forging simulation system for user on the WEB to operate or instruct the Forging press in realism. In this system, users can not only perform the forging process by operating the virtual press, but also view the deformed shape of product and the stress distribution in workpiece. Eventually, this system will include the integration system through which engineer can perform Finite Element Analysis and evaluate analysis results in the web.

TECHNIQUES NEEDED TO DESIGN VIRTUAL FORGING OPERATION

VRML: Virtual Reality Modeling Language(VRML 2.0) is a scene description language that can be used to describe 3D models of objects and scenes with the capabilities of interactive operation. These models can be viewed using a web browser with a plug-in for VRML 2.0. The capabilities of navigation and viewpoints are built into VRML and, thus can be used as a graphical display engine. VRML inherently supports an event driven model, with allows routing of the field values inside the nodes to other values thus changing the scene. The WRL(VRML file extension) file itself is a plain text file based on the ISO/IEC UTF-8(Unicode) encoding. (ASCII is a subset of UTF-8). In addition, most of Computer-aided design packages and commercial analysis tools offer functionality to export the model designed or analysis results to WRL file format. To communicate with the real world, a programming language is needed to ling VRML with the real world. For this purpose, Java is used. This requires that the VRML browser supports the Java-VRML interface. The two existing interfaces are the Script Authoring Interface(SAI) and the External Authoring Interface(EAI). We use both SAI and EAI to link Java and VRML

.

EAI: For communication between a VRML world and an external environment an interface between the two is needed. This interface is called and External Authoring Interface. This gives the functionality to extend the features of VRML by adding the power of the programming language Java. EAI allows an external program to access the nodes in a VRML scene using the existing VRML event model. In other words, we can access nodes in the different two VRML files embedded in an HTML by clicking on a button in Java applet. In this model, an eventOut of a given node can be routed to an eventIn of another node. When the eventOut generates an event, the eventIn is notified and its node processes that event. Additionally, if a script in a Script node has a reference to a given node it can send events directly to any eventIn of that node and it can read the last value sent from any of its eventOuts. For this, the applet has "methods" (user-defined functions) that are called when the specified eventOut occurs. A method is registered with an eventOut of a given node and is called when the specific eventOut event is generated. Conceptually, the External Authoring Interface allows 4 types of access into the VRML scene.

1. Accessing the functionality of the Browser Script Interface.
2. Sending events to eventIns of nodes inside the scene.
3. Reading the last value sent from eventOuts of nodes inside the scene.
4. Getting notified when events are sent from eventOuts of nodes inside the scene.

Finite Element Analysis: In the finite element analysis, a meshed model should be provided to the program. The model could be made through direct way by using the modeling procedure of the analysis program or through indirect way by using the CAD program. Generally, the models from CAD system are exported to the analysis program that usually has algorithms to interface CAD data with the inputs of the FEM program. The accuracy of the analysis depends on optimum number, size and shape of mesh. The correct material data from the material test, the dynamic information of blank and die movements, and friction factor at the contact surfaces between die and workpiece are also required for the FEM analysis of forging operation. Once the calculation is completed, the results from the analysis such as stress or temperature distributions are transferred to the post-processing routine, resulting in graphical outputs.

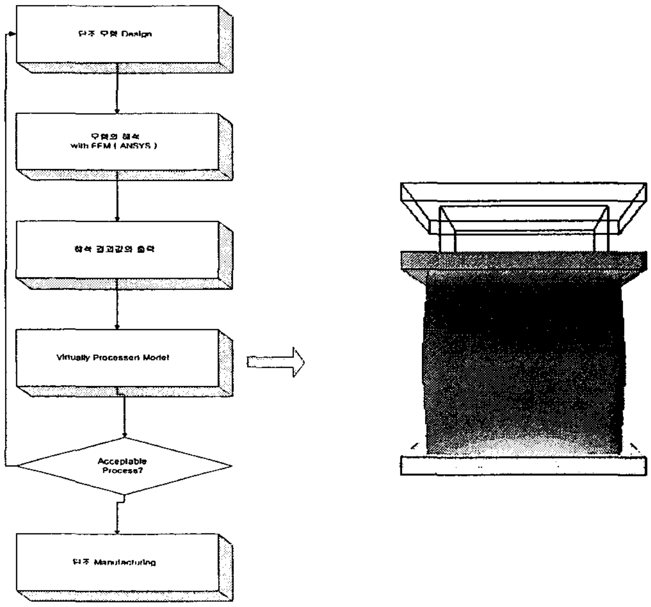

Fig 1. Finite Element Analysis Procedure

Compared to the conventional display of the analysis results, output display using virtual reality technique is more attractive and shows whole aspect of deformation during forging operation through the computer terminal. When the simulation using virtual reality is accompanied by the FEM analysis, the forging process including details of stress distribution as well as contour of deformation can be realistically presented. The user can stop the simulation temporally to see the instantaneous mechanical characteristics of forgings such as instantaneous stress distribution and thickness variation visually when he wants to know the information any time. This technique is an important technique required in the preparation stage of product design and can contribute the development of design methodology because the VR simulation with FEM analysis is the realistic display of deformation with analysis information.

MODELING OF VIRTUAL FORGING MACHINE COMPONENT

Modeling Virtual Forging Press by Using VRML: Users should be able to operate the forging press by pressing either the button on the control box built in Virtual environment or the button on the applet on the browser. Therefore, the forging press in the VRML was modeled in the tree structure shown in the Fig.2, and each node in the Fig.2 was used to get access in the Applet.

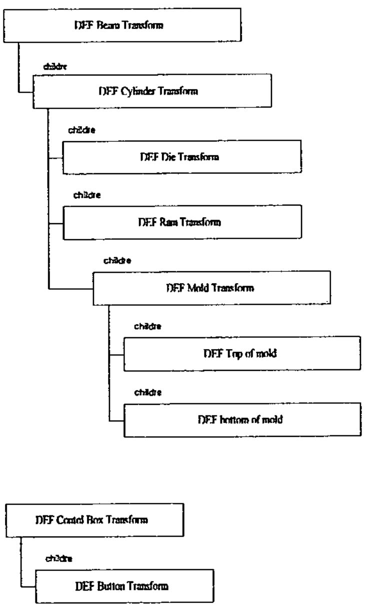

Fig 2. Tree Structure of Virtual Forging Press

Implementation of Java-EAI to Construct Web-Based Virtual Machine: External Authoring Interface (EAI) is the bridge between Java and VRML. It allows a Java applet to communicate with a VRML world embedded in the same page.

For this Forging press, EAI classes such as Browser, Node, and field classes need to be included in the vrml.external.*package.

1) reference of the Browser class
It's the representation of VRML world(Forging press in the VRML format) in the Java applet by using the static method, getBrowser.

2) reference of the Node
① reference to the nodes of the Forging press using getNode
② reference to the EventIn and EventOut fields of the node
③ the setValue and getValue methods of these eventIns and eventOuts to get info from the Forging Press and send updates to the nodes back to the Forging Press.

The applet offers the functions, such as all movement of the forging press (Down, Up, cushion Down, cushion Up, Auto, Stop) and function to make the top mold of the press transparent for users to view the forging process.

3) motion control of forging press
① declaration of variable for postion of each part of the press - EventInSFVec3f
② reference of the Node of each part
Node position = browser.getNode("Cylinder_block");// y axis of cylinder
Node position1 = browser.getNode("topunit");// y axis of the Top of die
Node position2 = browser.getNode("down");// y axis of the Bottom of die
③ EventIn for each part
translation = (EventInSFVec3f) position.getEventIn("set_translation")
translation1 = (EventInSFVec3f) position1.getEventIn("set_translation")
translation2 = (EventInSFVec3f) position2.getEventIn("set_translation")

4) Transparency of the mold
① Variable for mold transparency -
② reference of Node -
Node transparenc = browser.getNode("you");
③ EventIn for transparency
transparen = (EventInSFFloat) transparen.getEventIn("set_transparency");

5) View point

① Variable for View point -
EventInSFVec3f ,EventInSFFloat, EventInSFBool, EventInSFRotation

② Node reference for View point -
Node viewp = browser.getNode("far")

③ EventIn for changing View point
fieldview = (EventInSFFloat) viewp.getEventIn("set_fieldOfView")
jump = (EventInSFBool) viewp.getEventIn("set_jump")
orien = (EventInSFRotation) viewp.getEventIn("set_orientation")
posi = (EventInSFVec3f) viewp.getEventIn("set_position")

The updates of each EventIn can be sent to the the forging press in VRML using the setValue setValue methods

Transforming ASCII format of results from the Finite Element Analysis into the VRML format: In order to show the deformation information such as stress and deforming profiles of workpiece during virtual forging operation, finite element analysis has to be performed by using a program of the finite element method. The results with ASCII format from the finite element analysis need to be transformed into VRML format. The transformed VRML results will be included in the virtual forging machine to show the forging operation as well as the stress and deformation information in the forged specimen during the forging process.

The finite elements in the meshed model of the forging specimen are consisted of nodal points. First, each nodal point and element of the undeformed model have to be changed into VRML format. This procedure depends on the ASCII format of the output from the finite element analysis. Then, the displacement of each node created during forging operation is calculated by comparing nodal values before and after forging. Fig. 3 shows the algorithm used in this procedure. This value is divided into 20 steps and different color is allocated to each step to show the deformation process in the forging operation. Four or more nodes are connected to construct elements of the meshed model that are used to construct virtual forging machine and forged specimen. The algorithm is shown in Fig. 4.

Three cases of the finite element analysis, two upsetting and a deep drawing operations were simulated and conducted in this paper. The deep drawing simulation used four node elements and its result is shown in Fig. 5. Results from two cases of upsetting operations by using 8 node elements and 10 node elements are shown in Figs. 6 and 7. Each transforming process followed the algorithms in Figs. 3 and 4

```
String[] tmp = new String[20000];
float n[] =new float[20000];
float d_n[] = new float[20000];
float result_n[] = new float[20000];
int i=0;
String d_newLine = " ";
StringTokenizer st=new
StringTokenizer(texts2,d_newLine);
while(st.hasMoreTokens())
tmp[i]=st.nextToken();
   tmp[i]=tmp[i].trim();
   n[i]=Float.parseFloat(tmp[i]);
    i++;

String test[] = new String[20000];
 for(i=0;i<=3*3111-1;i++)
   result_n[i]=n[i]+n[3*3111+i];

 for(i=0;i<=3111*3-1;i=i+3)
  test[i]= Float.toString(result_n[i]);
  test[i+1]=Float.toString(result_n[i+1]);
  test[i+2]=Float.toString(result_n[i+2]);
  log.append(test[i]+"                    "+test[i+1]+"
"+test[i+2]+newLine);
```

Fig 3. Convertion of Node into VRML

```
result_m[(i+3)/3]=Math.sqrt(Math.pow(n[i],2.0)+Math.po
w(n[i+1],2.0)+Math.pow(n[i+2],2.0));
result_n[(i+3)/3]=(float)result_m[(i+3)/3];


 for(i=0;i<=3110;i++)
 if(t-result_n[i]>=0)
 t=t;
 else
 t=result_n[i];

 for(i=1;i<=3110;i++)
 if(s-result_n[i]<=0)
 s=s;
 else
 s=result_n[i];
```

Fig 4. Construction of Elements in VRML

DESIGN AND IMPLEMENTATION OF VIRTUAL FORGING PROCESS

System architecture: Fig. 8 shows the architecture of the virtual forging machine system and how to operate the system. The web based virtual machine shows the whole procedure of forging operation and deforming procedure including the stress-strain information in the workpiece. By using Java-enabled web browser, users can perform the forging process simulation and evaluate the result of analysis in virtual environment. The forging process simulation can be done by operating the forging press, and the result of process containing deformed shape and stress distribution of the product can be viewed and evaluated by the users.

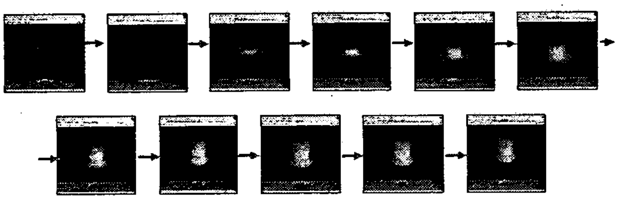

Fig 5. Deep Drawing case (4-nodes)

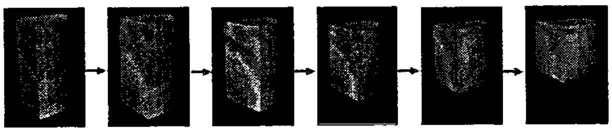

Fig 6. 8Node Upsetting Analysis

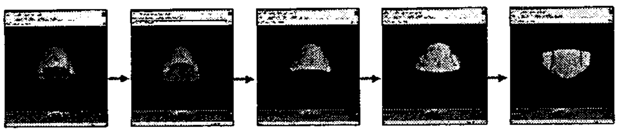

Fig 7. 10Node Upsetting Analysis

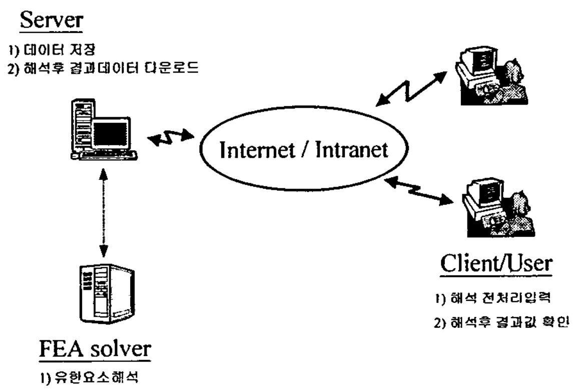

Fig 8. System Architecture

System implementation: The forging press and mold were modeled by using Pro/ENGINEER-2000i and converted to VRML format. The mold was assembled with the forging press after importing into the Cosmo Worlds 2.0 in the VRML format. The user can operate the virtual machine to control the forging press which is designed by using Java EAI(External Authoring Interface) and evaluate the deformation such as the deformed shape and stress distributions by interfacing the finite element analysis server.

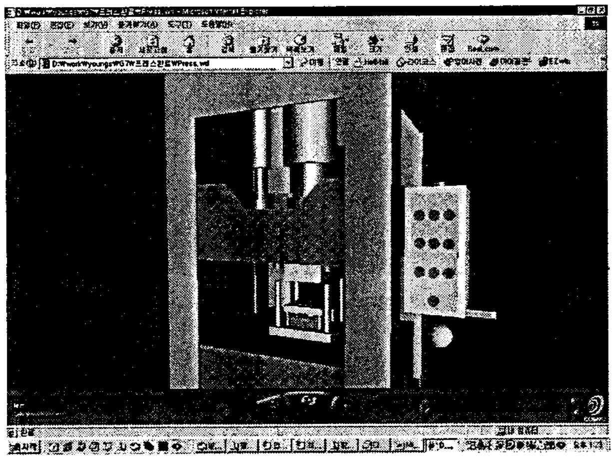

Fig 9. The Forging Press in the Web

Users can operate the forging machine by clicking the buttons on the control box(Fig. 9), and Fig. 10 shows the original shape of workpiece in the deep drawing operation. Fig. 11 shows the deep drawing operation and the top view of the die.

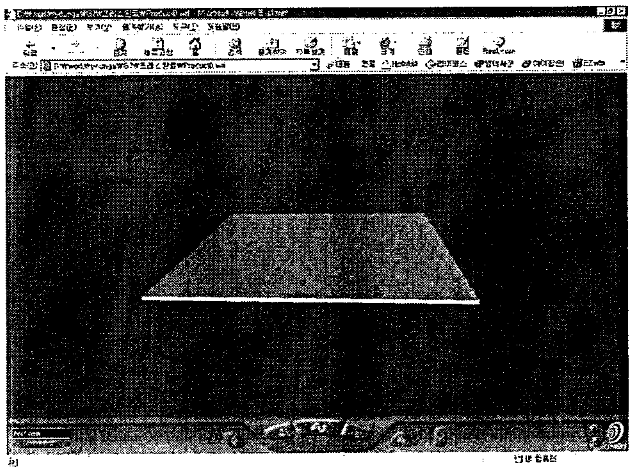

Fig 10. Original Shape of Workpiece

The original workpiece was modeled by using Pro/ENGINEER was transformed into VRML format. At the same time, the workpiece was processed in the deep drawing operation and analyzed by using finite element method program for the stress-strain information as well as deformed shapes of each step of deep drawing. Then, the ascii format of outputs from the FEM analysis was converted into VRML format and converted outputs are merged into the operation of the virtual forging machine. The user can evaluate the whole process of forging as well as stress-strain of the workpiece during deformation in the web (Fig. 5).

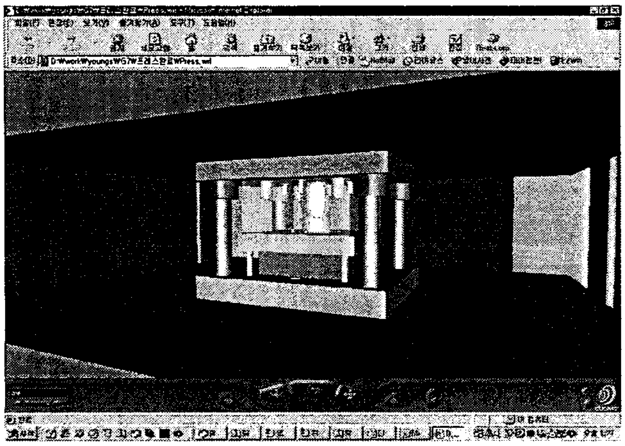

Fig 11. View of Deep Drawing Die

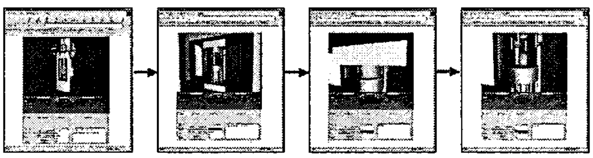

Fig 12 Visualization of Forging System

RESULT

Recently, with rapid improvement on network performance, a great number of researches on development of web-based virtual machine have been under way. However, most of them put their effort at only representing the machine or the process itself due to the critical speed limit for data process and transmission &reception. In other words, few researches for forging process that requires enormous data created from numerous analysis and complexities among specific process variables and plastic flows have been going on. However, it is essential to integrate between design &production system and simulation system to reduce the time from product conception to market and production cost and to expedite mutual understanding between product designer and simulation expert.

This paper presented a simulation technique using Virtual Reality Modeling Language (VRML) and Finite Element Method(FEM). The technique was applied to simulate forging operation. Stress distributions and deformation profiles as well as the operation of forging machine could be visualized in the web. Since the forging machine, user interface and specimen were modeled using Java and VRML, the forging machine and analysis results were browsed and integrated on the web that is interfaced to users through EAI to show the whole forging simulation. The developed system realized the working environment virtually so that education and experiment could be performed effectively even on the PC.

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