TECHNOLOGY-BASED RESOURCES IN METAL FORMING

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Abstract — *As a result of global competition, the training of engineers planning and supervising the design and execution of metal forming and manufacturing operations becomes increasingly important. In addition to conventional training techniques such as seminars, conferences and classroom lectures, CDs, Internet-based interactives, and multi-media technology facilitate learning from a distance. Process modeling, where a metal forming operation is simulated in the computer, offers unique opportunities for interactive distance learning for understanding the relationships between the process variables in metal forming operations. "What if" situations posed with a simulation offer a virtual manufacturing environment that allows learners to examine how different parameters affect the forming process and the manufactured product. Thus, process modeling and multi-media techniques together delivered via the WWW, offer a very powerful method for distance learning and continuous education. This paper summarizes the courses on metal forming technology, jointly under development by Greenfield Coalition and the ERC/NSM of The Ohio State University.*

Index Terms — *distance learning, metal forming, simulations, and technology.*

IMPETUS

Theoretical Foundation

Continuous improvements in metal forming technology and the application of recently generated research and development results require manufacturing engineering students as well as engineering professionals to continuously update their knowledge and skills in new methodologies, machinery and process technology. Employers are demanding that engineers be prepared to solve problems faced in their manufacturing facilities efficiently and anticipate issues before they become obstacles. They must be familiar with a number of methodologies for handling each possible issue so that delays and inefficiencies do not overwhelm their companies. Global competition has made these challenges particularly significant in the United States, because there are only a few universities that include metal forming in their regular offering of courses. Educational materials covering both bulk and sheet metal forming are limited and rarely are they found in one concise source.

Practical Knowledge and Application

In addition to academic preparation, there is also a strong need for professional education and life long learning in metal forming. During the last decade, the importance of life long learning has increased considerably as technology is changing rapidly and global competition requires the industrial workforce to have access to the most advanced knowledge base. It is unclear whether the traditional learning techniques are capable of satisfying new demands imposed on manufacturing engineers today. Personal demands of engineers often prevent enrollment in "traditional" class settings. Furthermore, nearby universities with metal forming expertise may not be available.

The following observations, which apply specifically to metal forming, illustrate the situation:

- Time compression and rapidly changing knowledge-base in production engineering (for example in Information Technology, Internet, process simulation, novel and complex machine tools, advanced electronics, etc.) offer challenges in learning as well as opportunities for those who increase their knowledge in these rapidly changing areas.
- Requirements for instant or just-in-time knowledge, i.e. what is needed, when and where.
- Technology is changing so rapidly that paper books, for example, may become obsolete in a very short time. Thus, electronic books and online resources that can be easily updated may replace some of the publications dealing with new and rapidly changing technologies.
- Distance learning, including online courses and e-learning are now offered by universities, trade associations and private companies.
- Online courses allow quick updates, virtual processing, interactivity with students, videos, simulations and animations that books and chalkboards cannot provide effectively, if at all.

Thus, the knowledge level of the practicing metal forming engineers needs to be continuously upgraded and engineers new to this field need to be trained quickly.

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THE GREENFIELD COALITION APPROACH

The Greenfield Coalition (GC), located at the Focus: HOPE Center for Advanced Technologies (CAT), a tier one supplier to the automotive industry, offers three manufacturing engineering degrees that blend real world situations with traditional academic studies to create an environment rich with learning experiences. At GC, candidates enrolled in one of the degree programs have the opportunity to apply concepts, skills, and techniques learned in the classroom to problems on the shop floor on a daily basis. As a result, they are able to make more connections between their own prior knowledge and experiences and the new information. The significance of learning certain topics becomes more intuitive to the learners as a result of using it in a natural context – the manufacturing facility. They are better able to understand the relevance of concepts to experiences in the real world. Furthermore, problem situations are not simplified as they often are in textbooks. In this natural environment, all of the variables impacting outcomes are authentic and complex. By learning in this authentic context, the transition from information acquired in the classroom to application in the workforce can be simplified.

Because the background of a candidate is significantly different than that of an engineering student enrolled in a tradition four-year university program, GC has chosen to exploit that variation from the norm by adopting a reality-based approach to teaching and learning. This approach, practiced by GC, addresses all of these issues:

- incorporating authentic situations within the learning context,
- developing problem-solving skills of engineering students and novice practicing engineers,
- preparing graduates for real manufacturing problems in the area of metal forming,
- integrating theory with practice,
- encouraging active learning, and
- promoting teamwork and collaborative activities.

One strategy for impacting change is to seek cooperative relationships with industry and academic partners in order to develop resources in manufacturing that are useful to the greater manufacturing engineering education community.

Along with GC, the Engineering Research Center (ERC) for Net Shape Manufacturing (NSM) at The Ohio State University (OSU) recognized the need for the development of metal forming courses that will be offered to engineering students and practicing engineers interested in metal forming technology. By creating a partnership between GC and OSU, the approach and knowledge base are brought together to capitalize on the strengths of both institutions.

TECHNOLOGY-BASED RESOURCE DEVELOPMENT

Organization and Format

The metal forming modules are organized into two courses, one basic and one advanced in Forming Technologies. These courses are prerequisites for other applied courses and designed primarily for candidates enrolled in either the Bachelor of Manufacturing Engineering or the Bachelor of Manufacturing Engineering Technology degree program. These courses consist of ten modules, arranged based on the appropriate sequence and complexity of topics. The first six modules represent the technology aspect of metal forming while the last four modules represent the design and analysis aspects, as follows:

1. Introduction to Metal Forming
2. Deformation Behavior of Metals
3. Bulk Forming Processes and Technology
4. Bulk Forming Equipment, Tooling & Lubrication
5. Sheet Metal Forming Processes and Technology
6. Sheet Metal Forming, Equipment, Tooling & Lubrication
7. Metal Forming – Fundamentals and Analysis
8. Friction, Lubrication and Heat Transfer
9. Design and Analysis of Bulk Forming Processes
10. Design and Analysis of Sheet Forming Processes

These courses and modules are characterized by three learning streams:

- facilitated classroom activities and discussions, including calculation demonstrations, team problem-solving sessions, roleplays, feedback, and brainstorming;
- experiential assignments, where credit is granted for actual shop floor tasks, projects, process improvement initiatives and case studies; and,
- online interactivities, such as videos, process animations, process simulations, and case studies.

Courses offered through the ERC for NSM at The OSU, primarily developed for practicing engineers, focus on specific technologies that include:

- Cold and warm forging without flash,
- Hot forging with flash,
- Sheet metal forming – applications, and
- Tube hydro-forming.

At the ERC for NSM at The OSU, the online and CD-based information, interactivities, and calculators fulfill a need for just-in-time training for both students and practicing engineers in industry. Specific areas of metal forming are covered as they relate to an engineer's current job and environment, or the environment they will face upon completion of the degree program.

Transferability

Great design consideration was given to making certain that activities were independent of one another. By doing so, the same learning objects can be used for both GC and the ERC for NSM at The OSU. Likewise, the transfer of learning resources to other faculty teaching a variety of courses is easy. It is possible to use only the activities applicable to any given situation, whether in a class on metal forming, tool design, machining or manufacturing processes without jeopardizing the integrity of the activity.

For example, a series of tensile test animations were created originally for use in the courses on metal forming at GC and the ERC for NSM at The OSU. However, these animations are also used in a course on tool design and construction, when material properties are discussed.

Technology Application

The decision to develop a set of technology-enhanced materials in metal forming was made for several reasons:

- making distance learning possible,
- using multimedia to incorporate advanced visualizations that textbooks cannot accommodate,
- reducing expenses by being able to update one web version of courseware rather than continually creating new cd-roms of learning materials, and
- allowing learner-controlled pace.

In all of these courses, substantial consideration was given to the use of videos and to the development of animations and process simulations. By doing so, learners without access to manufacturing environments can learn within a contextual framework. By inputting the parameters, it is possible for students to gain an understanding of the impact of process conditions and obtain different results from the simulation. This capability is used in all the courses developed by this partnership.

For example, a series of tensile test animations were created to examine materials with different formabilities. Students review the tensile test animations (see Figure 1) for different materials and observe how certain material parameters affect the total elongation or formability. This capability can also be formulated so the student, after observing the animations, must determine which major material parameter affects the formability (tensile strength) or tensile elongation of a given material. In the GC environment, the learner then responds to critical thinking questions, such as "As the strain-hardening value increases, what happens to the test specimen?"

Simulations and videos are used throughout the courses to demonstrate a variety of metal forming processes. Following a reading about springback, learners can view the phenomenon (see Figure 2). Similarly, after discussion and reading about several processes, students can visually observe the impact of variables as well as compare the significant differences among them. Figure 3 illustrates one such simulation that depicts a bending process and many of the variables involved.

Another method for incorporating real world experiences into the learning environment is through the use of case studies. By analyzing real problems faced by manufacturing and forming corporations, the learner actually assumes the responsibility of an engineer and investigates the case to develop some resolution. It is not a simplified story problem used for students to apply one or two concepts just learned in class. Rather, learners are expected to define the scope of the problem, determine how to approach seeking alternatives, decide how to share responsibilities among team members, gather appropriate resources and trial and error. Figure 4 illustrates the specifications given to the learner. Using the resources provided and the WWW, it is

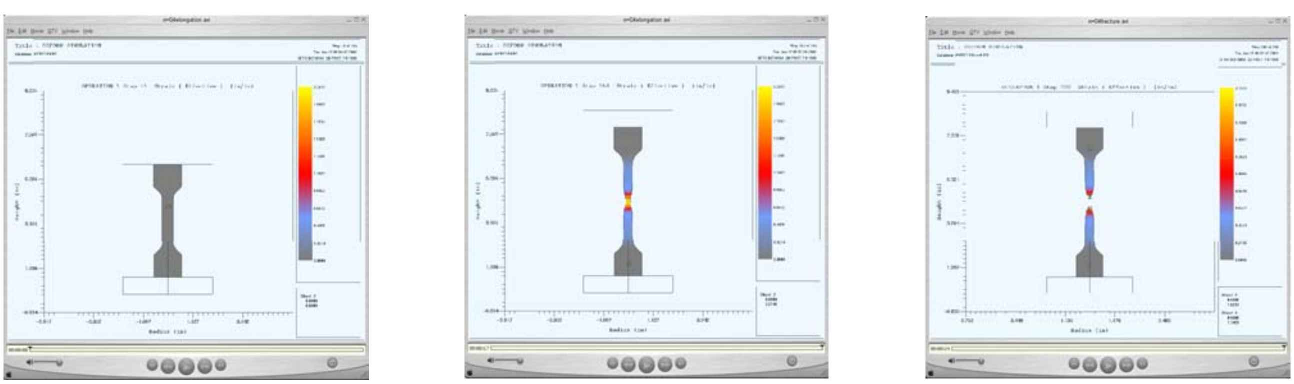

FIGURE 1.
TENSILE TEST SIMULATION

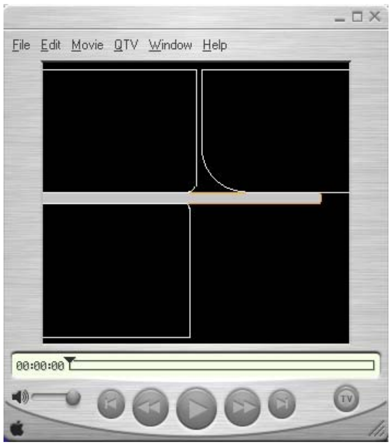

FIGURE 2.
ANIMATION OF SPRINGBACK PHENOMENA

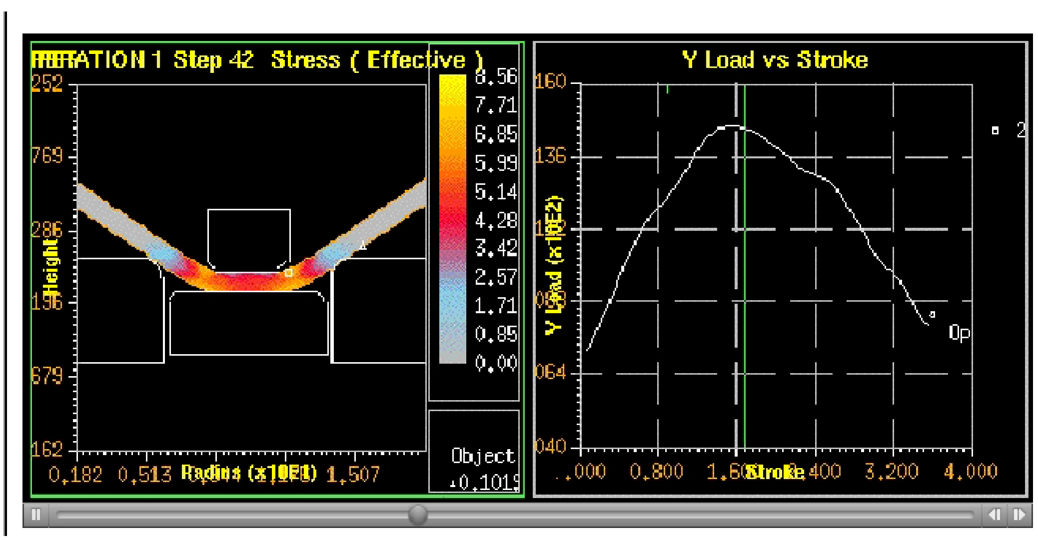

FIGURE 3.
U-DIE BENDING SIMULATION

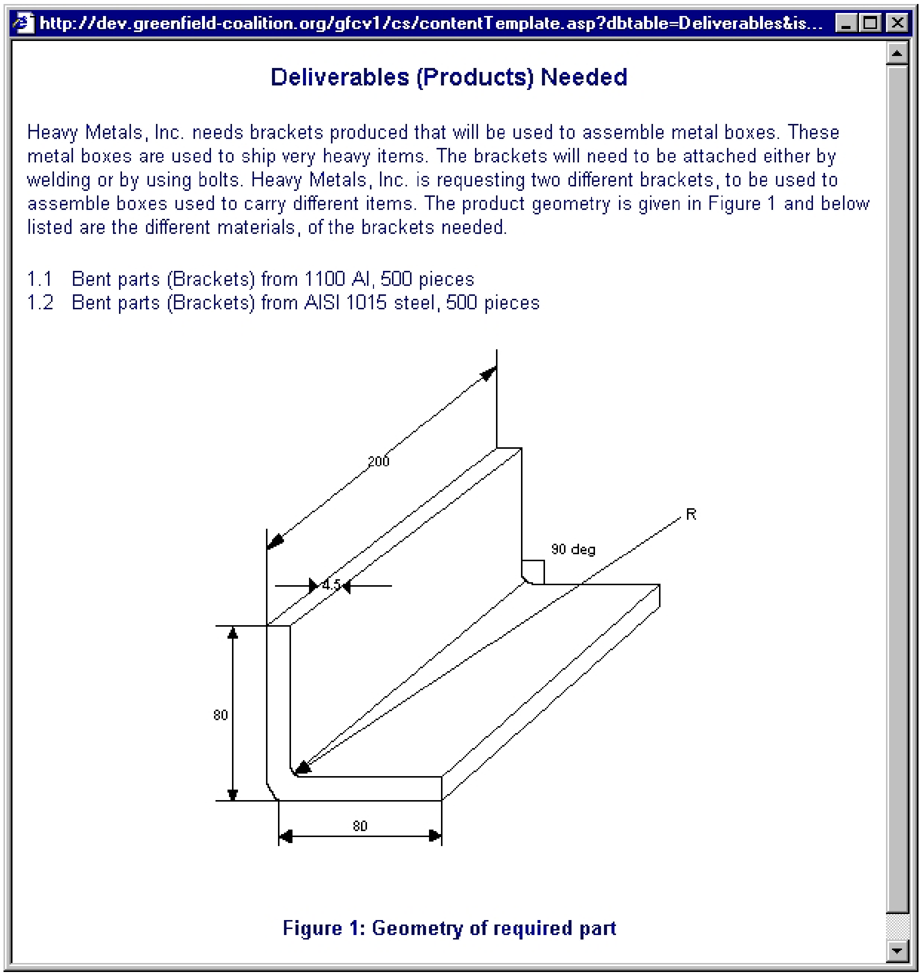

FIGURE 4.
PART SPECIFICATION FOR A SHEET METAL FORMING CASE

possible to identify appropriate processes, machinery, lubricants, costs and other critical determinants to produce the desired part. This method for immersing students in real manufacturing situations gives them a safe environment to problem solve, make mistakes and learn a variety of techniques for addressing issues.

OUTCOMES AND BENEFITS

Concise coursepacks, electronic presentations (Powerpoint), still images and photographs, process simulations and animations demonstrate the physical phenomena associated with metal forming operations. These materials support the delivery of metal forming instruction in the classroom, over the WWW, on CD and on the job. Thus, the courses can be used for both instructor-facilitated as well as learner-controlled environments, synchronous and asynchronous. They are useful in a variety of contexts and can be readily accessed online.

Additionally, the ERC for NSM at The OSU has made a commitment to review other course materials and revise them based upon a reality-based, blended learning approach.

Because of the adaptability and accessibility of these materials, it is possible to deliver training when and where it is needed. Industry professionals are enabled to be more productive by learning about current trends and new technologies without leaving their home and/or office.

Engineering graduates are better prepared to contribute to problem resolution on the job because they gain practical experience during their academic studies. The result for companies is an increase in productivity and a sharpening of their competitive edge.

Lastly, by utilizing technology, updating materials can be faster. This reduces the lag time between the inception of new technologies and appropriate training materials to engineers, students and industries that need them.

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