Development of Visualization and Simulation Models in Materials Technology and Failures Related Courses

Sham, Man-Lung [1] ; Kim, Jang-Kyo [2] ; Zhang, Tong-Yi [3]
Lai, Rambo C L [4] and Lee, Kara K Y [5]

[1] meivan@ust.hk
[2] mejkkim@ust.hk
[3] mezhangt@ust.hk
Department of Mechanical Engineering,
The Hong Kong University of Science and Technology

[4] ctrambo@ust.hk
[5] ctkara@ust.hk
Center for Enhanced Learning and Teaching,
The Hong Kong University of Science and Technology

ABSTRACT

Rapid developments in multimedia technology allow us to innovate our teaching methods by incorporating visualization and simulation tools into conventional, textbook-oriented verbal and pictorial explanations. This project aims to provide students with an in-depth concept enabling an easy understanding of important topics within the discipline of Materials Science and Engineering. By participating in several simulation steps, students will learn the mechanical responses and fracture behavior of advanced materials when subjected to practical loading conditions in various service environments.

In this work, ten topics have been selected from two undergraduates courses where seven animations and four experimental demonstrations are produced, such as toughening mechanisms in semi-crystalline materials, crystal structures, fatigue-crack growth with plastic deformation behavior in metals, etc. Through an Internet-based platform, lecturers on the one hand can enhance their presentations by using these animations and demonstrations; on the other hand, students can freely access and review the teaching materials. The anticipated outcome of this project will be tremendously useful to all other related courses in mechanical engineering.

Keywords

Computer animations, experimental demonstration, materials science and failure

INTRODUCTION

"Tell me and I'll forget. Show me and I may remember. Involve me and I'll understand"

Scientists have found (Mandelbrot, 1983) that a comprehensive understanding of a topic may be much more easily achieved by visualizing experimental results instead of teaching the theory alone. Advances in visualization technology over the last decade have gone a long way toward realizing this Goal of Teaching. Visualization technology is now profoundly affecting the way in which knowledge and experiences are delivered (Olson, 1997). Further, visualization has its own unique advantage of making teaching materials easier understand and as a means of realistic demonstration. Research (Avila et al. 1995; Bergandine & Koka 1993) has shown that student learning capabilities and attitudes about the course were improved by including video-based teaching technologies when compared to traditional lecture-relevant visual materials such as overhead transparencies. This type of learning experience can be further enhanced if interaction is involved between the media and the learner.

Although the idea of incorporating visual aids into teaching and learning is not new in itself, it appears that the use of multimedia with the incorporation of world-wide-web techniques is increasing exponentially. Multimedia teaching is the use of more than one medium during the student learning stage to support or even replace the instructor's traditional text and verbal explanations. Hitherto, video and animation have been regarded as the most efficient means of demonstrating a particular phenomenon to students. Moreover, availability of multimedia content for the students to access through the web is highly beneficial in that students can access multimedia content at any time through the Internet before or after lectures. There is also a consensus that the web is an ideal medium for conducting visualization research and for the dissemination of its findings (Orford et al. 1998).

In order to reinforce *in-depth concepts* with easy understanding by students of the mechanical responses of advanced materials in materials-related courses such as Materials Science & Engineering and Materials Failures, ten topics have been selected from the above two undergraduate courses in from which both animations and experimental demonstrations have been selected. It is our objective to enable lecturers as well as students to take full advantage of the Internet-based platform in their teaching and learning processes.

TOPICS COVERED IN THIS WORK

Based on the textbooks of our undergraduate courses on MECH 242 Engineering Material [Callister, 2003] and MECH 301 Material Failure in Mechanical Applications [Dowling, 1998], seven computer animations and four experimental demonstrations were proposed as follows:

1. ANIMATION: Tetrahedral atomic position and octahedral atomic position in ceramic material (MECH 242)

- To explain the available sites and locations for the cations residing in the close-packed 3-dimensional anion planes, and explain how a single anion can provide one octahedral and two tetrahedral positions

2. ANIMATION: Crazing in polymers (MECH 242)
   - To explain the progress of crack development due to the coalescence of micro-voids ahead of a crack, which yields the crazing phenomenon
3. ANIMATION: Deformation in semicrystalline polymers (MECH 242)
   - To explain the mechanism of plastic deformation due to the interactions between lamellar and intervening amorphous regions under a tensile load
4. ANIMATION: Transformation toughening mechanism in ceramic materials (MECH 242)
   - To explain the toughening mechanisms in ceramic materials due to stress-induced phase transformation at a crack tip
5. ANIMATION: Crevice corrosion in metal (MECH 242)
   - To explain the crevice corrosion between two riveted sheets
6. ANIMATION: Crack tip propagation under cyclic loading (MECH 301)
   - To illustrate the plastic deformation behavior at the tip of a growing fatigue crack during a loading cycle
7. DEMONSTRATION/ANIMATION: Strengthening polymeric material by pre-tensioning (MECH 242)
   - To elucidate the strengthening mechanisms in polymeric materials due to molecular alignment/crystallization under tensile loading
8. DEMONSTRATION: Creep and Relaxation of polymers (MECH 301)
   - Experimental demonstration showing the creep and relaxation behavior of polymers with plots showing strain-versus-time and stress-versus-time
9. DEMONSTRATION: Fracture behavior under plane-stress and plane-strain conditions (MECH 301)
   - To illustrate the sample size effect on fracture toughness and to illustrate plane-stress and plane-strain conditions and the corresponding fracture behaviors. Tensile tests on aluminum plates with different thickness will be performed
10. DEMONSTRATION: Fatigue life experiment under various stress amplitudes on aluminum (MECH 301)
    - To demonstrate fatigue life and the failure behavior of aluminum under various stress amplitudes

INTERFACE OF THE ANIMATION FRAMEWORK

The operating environment of the animations in this work is Microsoft Windows, mainly due to considerations of its popularity. The framework design of the animation interface includes a ***title heading***, the ***main display area*** in the centre showing the figures, graphs and the corresponding texts for descriptions and explanations, and the ***navigation buttons*** in the bottom as shown in Figure 1. The special feature of this framework design is that it allows students to move forward or backward in order to view the desired content. Another advantage of the present design is that the content material is presented sequentially where the descriptions specifically correspond to the figures at different stages. This allows the student to correlate their observations with the concepts visually.

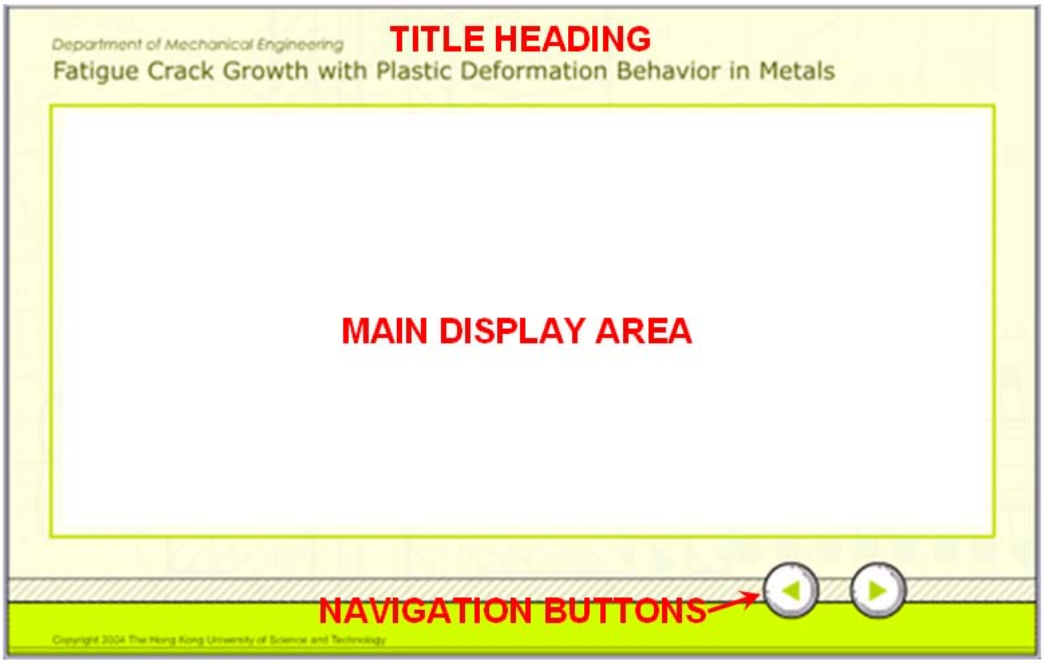

Figure 1. Interface of the computer animation framework

DEVELOPMENT OF THE ANIMATION

The development of the animation was divided into three stages: i) content organization and conceptual design; ii) storyboard development; and iii) incorporation of the idea and content into the computer animation.

In the first stage, appropriate topics and the relevant content were selected. The criteria in selecting the topics were based mainly on previous experience by the lecturers, who identified those topics which could best be elucidated with the aid of visualization tools. The concepts were schematically outlined with the corresponding descriptions, see Figure 2 (a). Details of the topics were later discussed between the content designer and the animation team. The animation team then prepared the storyboard based on the information from the content designer and the materials arising from the previous discussions, which were also used to visualize the animation process and the necessary scene transitions before fabricating the computer animation, Figure 2 (b).

Discussions among the team members were conducted again to confirm the details inside the animation. Macromedia Flash MX was employed to develop the animations under the Microsoft Windows operating platform. There are a number of advantages in using Flash for the present work, including a relatively small file size requiring less demand for data transmission through the Internet, easy integration in various Internet means such as incorporating the Flash components into a webpage if necessary in the future, or individual animation demonstration by simply using the corresponding Flash player. The animation was reviewed again before launching the usability process.

DEVELOPMENT OF THE EXPERIMENTAL DEMONSTRATION

The preparatory work for the experimental demonstration was similar to the preparation of the animations. From the conceptual design to the final product, storyboards accompanied by demonstration narration scripts were all necessary in allowing smooth video production, as shown in Figure 3. A digitized video will be prepared for Internet access during the class so that students can review the experiments at any time.

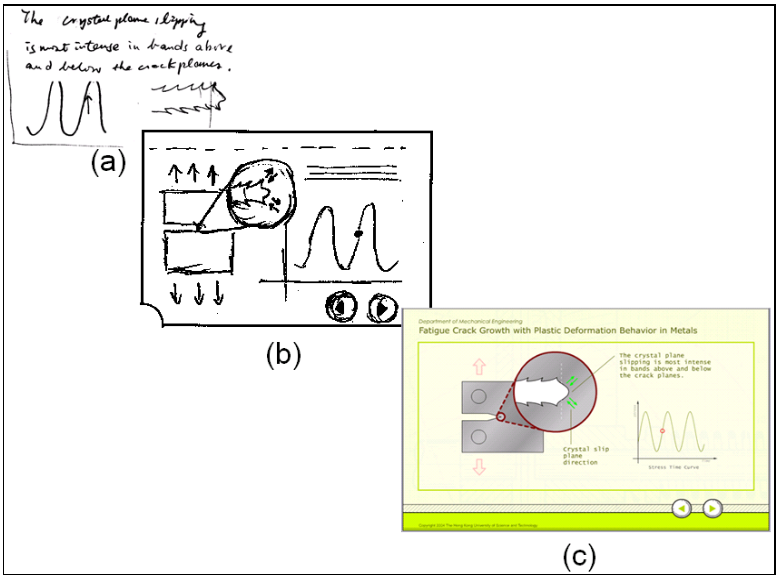

Figure 2. Development stages of the computer animations, from conceptual design (a), through the drafting of the storyboard (b), and eventually the product (c)

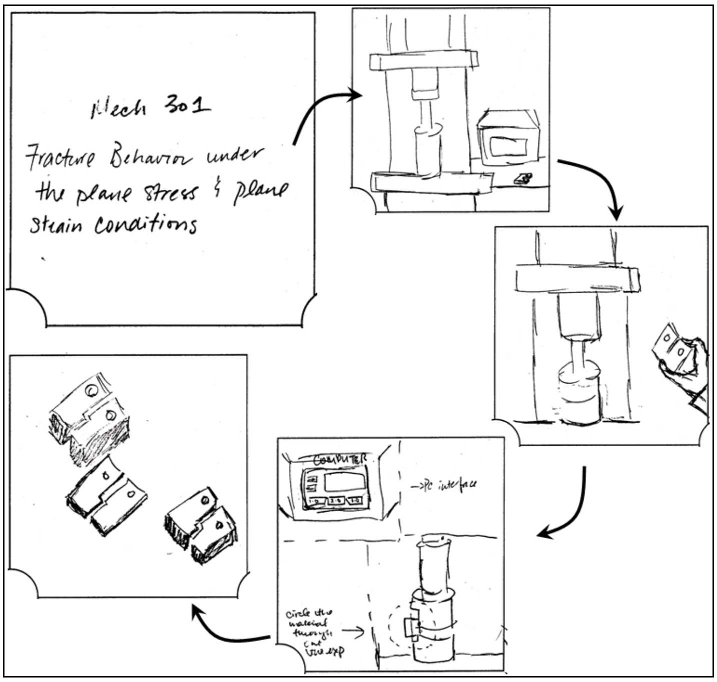

Figure 3. Storyboards for the experimental demonstration based on the narration script descriptions

SUMMARY

To conclude, the goal of this project is to enhance student participation through navigating the animation, to encourage student curiosity to learn and also to enhance the student understanding of the subjects. By making this series of computer animations and experimental demonstrations available on the Internet, it is our objective to stimulate students to learn more comprehensively and with greater reinforcement of the subject content.

REFERENCES

Avila, R A; Biner, P M; Bink M L and Dean, R S (1995). *Course materials presentation using video-based technologies: An evaluation study of college-student performance and attitudes.* Psychology in the Schools, 32 (1), pp. 38-45.

Bergandine, D and Koka, T (1993). Visualization in teaching chemistry. *Abstracts of Papers of the American Chemical Society,* 205 (1), pp.338.

Callister, W D (2003). *Materials Science and Engineering: An Introduction.* 6th Ed. Wiley.

Dowling, N.E. (1998). *Mechanical Behavior of Materials*. 2nd Ed. Prentice Hall.

Mandelbrot, B B (1983). *The fractal geometry of nature*. W.H. Freeman and Co., San Francisco.

Olson, J M (1997). Multimedia in geography, Good, Bad, ugly, or cool? *Annals of the Association of American Geographers,* 87 (4), pp. 571-578.

Orford, S; Dorling, D and Harris, R (1998). *Review of visualization in the social sciences: A state of the art survey and report.* School of Geographical Sciences, University of Bristol.