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TITLE: Deflection evaluation using time-resolved radiography

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Deflection evaluation using time-resolved radiography

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ABSTRACT

Time-resolved radiography is the creation of an x-ray image for which both the start-exposure and stop-exposure times are known with respect to the event under study. The combination of image and timing are used to derive information about the event. We have applied time-resolved radiography to evaluate motions of explosive-driven events. In the particular application discussed here, our intent is to measure maximum deflections of the components involved. Exposures are made during the time just before to just after the event of interest occurs. A smear or blur of motion out to its furthest extent is recorded on the image. Comparison of the dynamic images with static images allows deflection measurements to be made.

1. TIME-RESOLVED RADIOGRAPHY

The concept of time-resolved radiography (TRR) is outlined in the following steps.

- a) The subject is continuously irradiated with x-rays to form an image on a suitably fast phosphor screen placed behind the subject. (The continuous x-ray source actually needs only to be stably on during the exposure period.)
- b) The phosphor screen is viewed by a gated camera.
- c) A trigger signal is available to indicate the start of the event.
- d) The camera gate is opened for a selected duration exposure after a selected delay following the trigger.

The basic idea is to acquire an image over a selected period of time known with respect to the event of interest.

1.1 Cineradiography and TRR

Cineradiography is a subset of TRR in that a contiguous series of images are acquired within the time frame of an event and is connoted with stop-action imaging.

Image converter cameras are commercially available which place 5 to 20 images c.. one film at rates up to 600 Mframes/sec. The camera output can also be digitized by a still video system. The highest rates available for video radiography are 2 kframes/sec at 192x240 pixel resolution or 12 kframes/sec at 64x64 pixels. Many times specialized systems are built using multiple cameras to achieve ultra-high frame rates. These multi-camera systems are limited to

the number of frames available by the number of cameras. Multiple sources, usually flash x-ray, one per camera, are used in many cases.

These cineradiography systems can be used to view a subject in motion to record sequential images for evaluation of the motion. Given a fast enough frame rate and enough total frames any moving subject can be studied by cineradiography. Therefore, each of the above described cine systems has utility in some applications. However, for our application none of these systems had the necessary combination of frame rate and total frames available for stop-action imaging over the event duration.

1.2 Integral TRR

There is another way to apply TRR. Rather than capturing multiple images spaced in time such that the motion can be followed in the temporal resolution required, some applications can use the integral of the motion in a single image to provide the necessary motion data.

The situation of measuring maximum deflection of a subject during an event is one such application of integral TRR. If an exposure is made during the entire duration of the event, the image records the path of any motion as a smear or blur. The maximum extent of the smear records the maximum extent of the motion regardless of when that maximum occurred.

Given that the requirement is measurement of maximum deflection only and not also when exactly this maximum occurred, a simple TRR system can be assembled to acquire digital integral TRR images. Integral TRR has advantages of:

- a) simple and inexpensive compared to cine systems,
- b) more flux is available to create an image -- imaging may not be possible at the frame rate needed to resolve the motion to the degree desired, and
- c) the image is in digital format immediately and can be operated on by an image processor.

2. APPLICATION OF INTEGRAL TRR TO EXPLOSIVE-DRIVEN SEPARATION

Hercules Aerospace, Magna, UT, was in need of an improved method of quantifying deflection of the parts involved in an explosive-driven separation mechanism. Strain gauges and photonic sensors were the previous methods. Neither of these methods were providing reliable data. Therefore, integral TRR was selected to complement the mechanical sensors in the most recent series of tests. This not only provided an additional deflection measurement data source but also gave a direct visual picture of the event.

A block diagram of the equipment is shown in Fig. 1. The explosive power was provided by a mild detonating fuse (MDF) threaded through the mechanism with about eleven inches (275 mm) of the fuse external. A pin switch was placed on the MDF two inches (50 mm) from the mechanism to provide the event trigger approximately 10 μ sec before the MDF burn reached the mechanism. Two gated, intensified video cameras viewed a fast decay rare earth x-ray phosphor screen. Zoom lenses were used to bring the field of view to optimal size to view the

Figure 1: Block Diagram of Setup.

event. A standard 420 kV, 4.2 kW constant potential x-ray system was used. Upon closure of the trigger switch, a signal was sent to gate the cameras open for 100 usec and 150 usec respectively. These gates were chosen from previous mechanical sensor data which indicated that the event lasted less than 100 usec. The camera video signals were input to frame grabbers to digitize the images which were then labeled and stored on a personal computer.

A total of three images were acquired by each camera for each test: pre-fire static, dynamic, and post-fire static. All images were obtained using the same x-ray technique, geometry, and timing parameters. Comparison of the static and dynamic images enabled measurement of the deflection data desired.

3. IMAGE PROCESSING

The static and dynamic images were compared using two methods. First, static and dynamic images were stored in different video memory buffers and switched rapidly on the display monitor. Second, static and dynamic images were subtracted leaving a motion image.

3.1 Display Switching

By switching the display between pre-fire static and dynamic images at a rate of about once per second, a human observer sees the total of motions which occurred within the exposure time frame. Also, switching between pre-fire and post-fire static and dynamic and post-fire static yielded qualitative data. Switching was accomplished using a PC-based hardware/software combination that allows the user to store several images in video buffers which can each be rapidly switched to active display. This video switching procedure was recorded to videotape for each test.

3.2 Subtraction

Subtraction of the pre-fire static image from the dynamic image pixel by pixel results in an image showing only the portions of the image which moved. From this subtraction image, deflections can be quantitatively measured. We used a second PC-based high resolution image processing system to do and display the subtraction images. The high resolution monitor enabled the pre-fire static, dynamic, post-fire static, and 2X magnified subtraction images to be viewed together on one display. An example is shown in Fig. 2.

The image sections lighter and darker than background are the deflection areas. The second image processor included calibrated linear and area measurement functions which we used to generate the maximum deflection data by measurement of these image sections.

4. CONCLUSION

Time-resolved radiography can be implemented in two distinct ways: cineradiographic and integral modes. Cineradiography must be used to place an event in both time and space. However, if the exact timing of an event is not

Figure 2: Example Images.

required, but the maximum extent or path of motions is the data needed then integral TRR is a simpler method of acquiring that data.

In the case of the explosive-driven separation mechanism we studied, the TRR images were able to give better quantitative data than mechanical sensors and visual qualitative data.

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