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**The Effect of Transient Loading Discretization on a
Rotating Disk Using Lawrence Livermore National
Laboratories' Dyna 3-D**

by Morris S. Berman

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1. Introduction

The Sense and Destroy Armor (SADARM) submunition was recently modeled extensively by the Composites and Lightweight Structures Branch. Several highly detailed Lawrence Livermore National Laboratories' (LLNL) Dyna 3-D/Paradyn models of the electronic module assembly (EMA) were constructed. The output of several of these models contained unexplained oscillations.

The EMA, a very complex model with multiple materials and multiple contact elements, was suggested to investigate the cause of the oscillations using a highly simplified model loaded in a similar fashion.

2. Model Description

The EMA is a cylindrical puck ~5 1/4 inches in diameter and 1 1/4 in high. It is hollow and has several electronic assemblies inside of it. The electronic assemblies are all potted. In this investigation, a homogeneous metal puck of the same external dimensions is modeled (Figure 1).

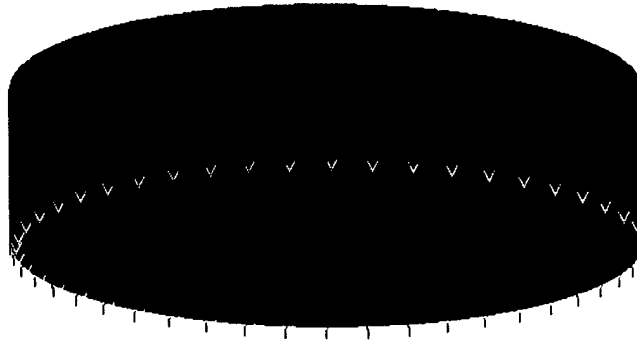


Figure 1. Disk model (control configuration).

The disk is modeled as aluminum LLNL Dyna material type 4 (thermoelastic plastic). The plastic features of the material are not utilized. Hence, the yield stress is set to zero, and the material behaves in a linear elastic fashion. The material properties used are given in Table 1.

Table 1. Material properties.

Property	Value	Units
Young's modulus	10×10^6	psi
Poisson's ratio	0.33	—
Density	0.100	lb/in ³

3. Effect of Loading Function Time Resolution

The disk is loaded with a prescribed linear velocity and a prescribed rotational velocity. The load is applied to the ring of nodes around the perimeter of the base (as indicated by the "V" in Figure 1). The initially applied loads are shown in Figure 2.

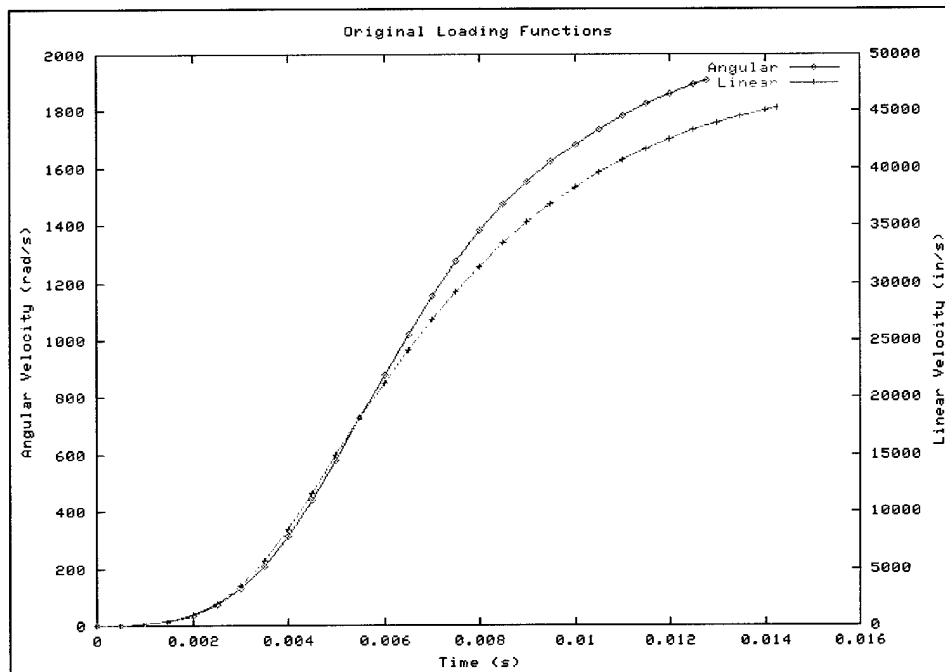


Figure 2. Original loading functions.

The initial loading function was defined with a point every 0.5 ms. This time spacing rendered a visually smooth curve. The response time resolution, initially set to 0.125 ms, is shown as the green curve in Figure 3. There is an obvious step in the response that occurs every 0.5 ms. This time interval corresponds exactly to the time resolution of the input function. The same run is repeated with a higher response time resolution. The results of that model are shown as the red curve in Figure 3. Even though the 0.5-ms resolution of the input curve appears visually smooth, it is obvious from the output that the model is responding to a significant transient at each point in the input function. In this model, the transient is damped out before the subsequent time step. However, the response appears as a step function instead of a smooth curve.

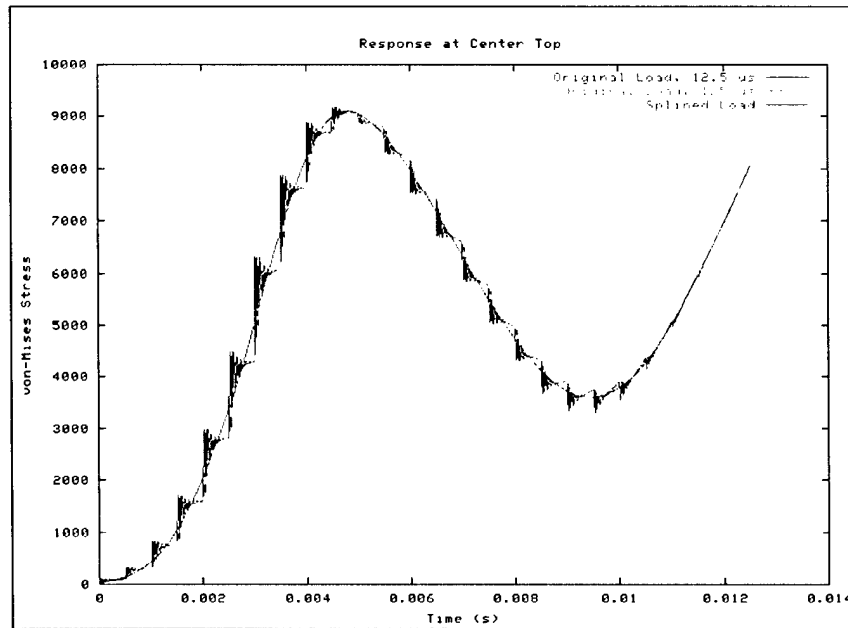


Figure 3. Response to loading function.

A new loading function was introduced to eliminate the transient. The original loading function (time resolution of 0.5 ms) was spline fit with a curve that had a time resolution of 0.010 ms. The resulting response is shown as the blue curve in Figure 3. The response to the splined loading function does not display any of the transient response that is apparent in the response from the original loading curve.

Another set of loading curves was also analyzed that linearly interpolated the original loading curves, with a time resolution of 0.010 ms. The response from the linearly interpolated curves is identical to that from the original curves. This indicates that the transients in the response are the model's response to the change in slope at the discretization points in the original curve. When additional points are added by a spline (in a smooth manner), the transients are eliminated, and the response is smooth.

4. Effect of Wedges

In order to investigate the effect of wedge-type elements on the results, an additional model was generated. The new model is shown in Figure 4. This model replaces several hexahedral elements with wedge elements. The wedge elements propagate through the entire thickness of the disk.

Responses to the splined input curves are measured at four locations on the disk. The chosen locations are on the top and bottom of the disk at the center and at the edge. This choice includes locations that are both near and far from the excitation as well as the location of the wedges.

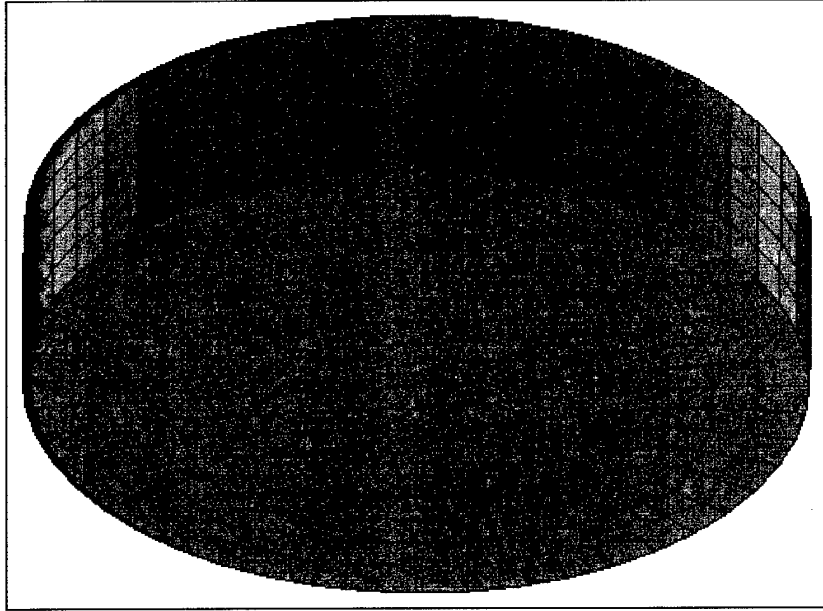


Figure 4. Disk with wedge elements.

The von-Mises stress responses are pictured in Figure 5. At the center top location, the effect of the wedges is small. However, at the center bottom, the effect of the wedges is very pronounced. Both the amplitude and the shape of the response curves are affected by the introduction of wedge-shaped elements.

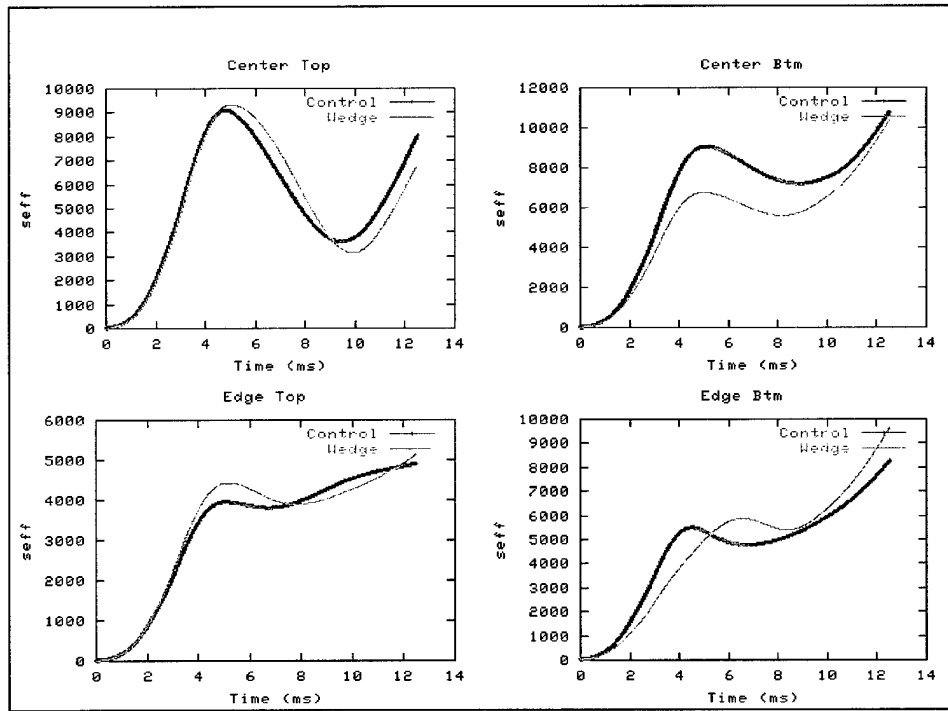


Figure 5. Response of model with wedge elements.

5. Effect of Thin Layers

An additional model was created that introduced three layers of very thin elements into the main model. That model is shown in Figure 6. The original model has five layers of elements that are each 0.254 in thick. The modified model has two layers that are 0.3 in thick, then three layers that are 0.0233 in thick, followed by two more layers 0.3 in thick.

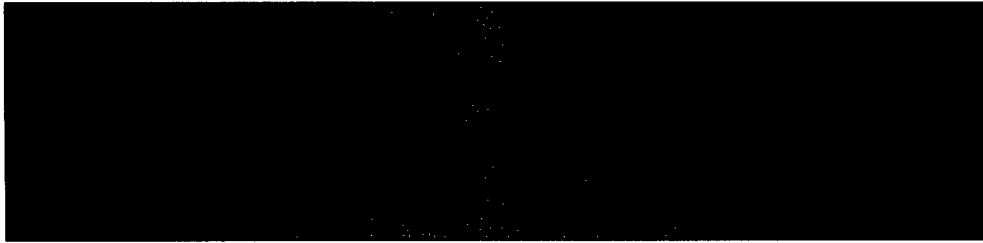


Figure 6. Model with thin layers.

The addition of the thin layers appears to introduce an artificial discontinuity into the model. Stress waves appear to reflect off of the thin layers, thus resulting in a different response for this model than for the original model with layers of the same thickness. The two responses are shown in Figure 7. There is a very significant difference between the shape and amplitude of the response of the two models.

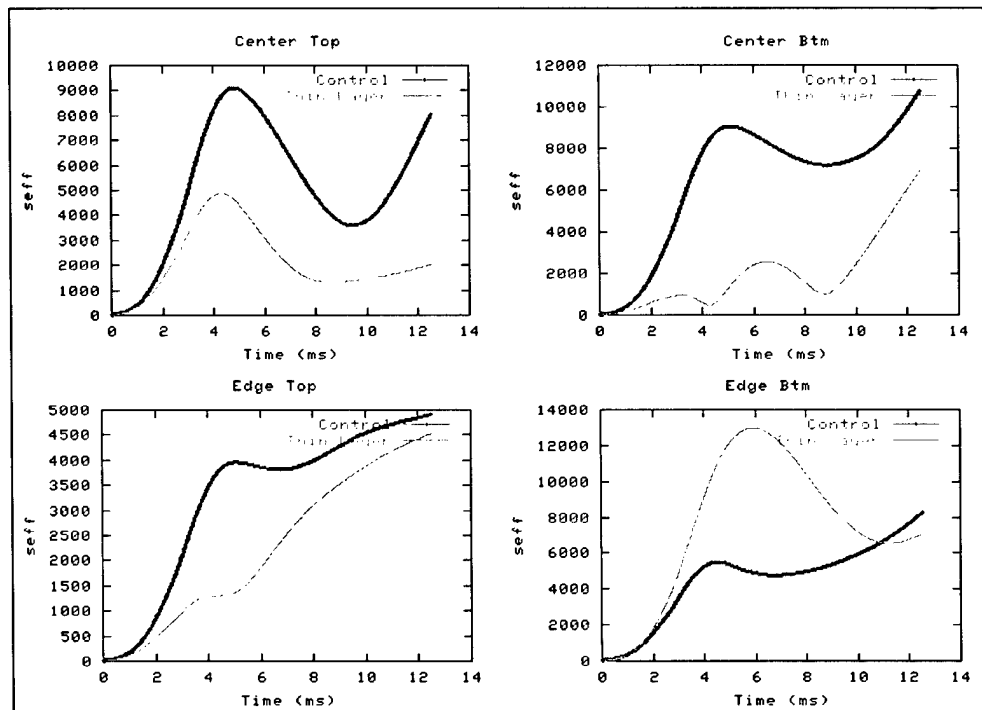


Figure 7. Response of model with thin layers.

6. Effect of Contact Surfaces

Two more models were created to investigate the effect of two different types of contact surfaces. (The contact surface is between the second and third layers of elements.) The two types of surfaces investigated are the tied and tie-break interfaces. Figure 8 indicates the location of the contact surface.

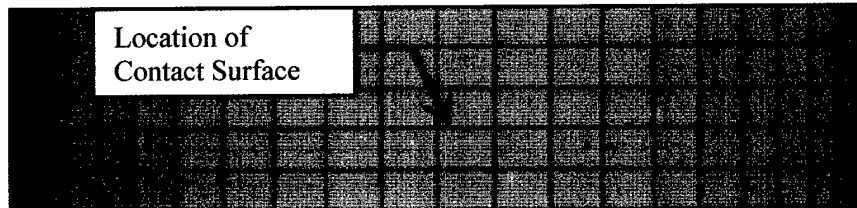


Figure 8. Model with contact surface.

The von-Mises stress responses of the models with two different types of contact surfaces are shown in Figure 9. The tied and control model exhibit identical responses. However, the tie-break interface yields a slightly different behavior than the control model. The peak stress in the interface is well below the failure threshold of the tie-break interface.

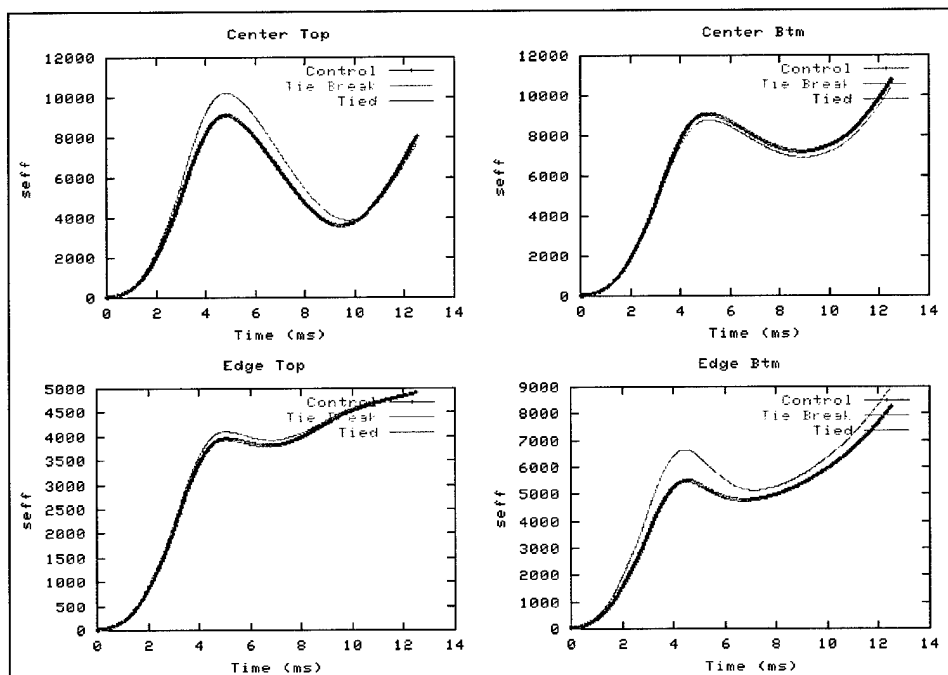


Figure 9. Response with contact surfaces.

7. Conclusions

This work was initiated to explore the source of oscillations that were found throughout SADARM modeling. The results of this report indicated that inadequate discretization of the SADARM load curves could likely have introduced oscillations into the results. If the load curves were splined and then rediscrctized to a much finer time resolution, the oscillations were eliminated for a simple disk model. As a result, an analytically smoother load curve augmented, but did not change, the original load curve.

Subsequently, other model aspects were also investigated. The use of wedge elements could significantly affect the model's response. As initially suspected, these results indicated that wedge elements should be avoided and used only where absolutely necessary.

The introduction of a sudden change in element thickness in an otherwise homogeneous model was also investigated. These elements also caused a significant deviation of the model's response from the pure homogeneous model. The thin elements appeared to create an analytical impedance mismatch in this simple structure. This mismatch led to an artificial boundary against which stress waves could reflect. The transition from one element size to another should be gradual to minimize this effect.

Lastly, two different contact surfaces were investigated—LLNL Dyna 3-D tied and tie-break contact surfaces. The use of tied surfaces had no impact on the response of the model. However, the use of tie-break surfaces resulted in small differences in response between the two models. Unless the “break” feature of the tie-break surface was necessary, the tied interface surface resulted in a more accurate computation.

8. Future Work

This report highlights conclusions that were drawn from a cursory examination of the possible causes of model oscillations. It does not quantify what constitutes a “smooth” curve for LLNL Dyna 3-D. A more thorough investigation, resulting in a set of guidelines for the “smoothness” of loading functions, would be very useful.

Similarly, a cursory examination of wedge elements, element dimension changes, and contact surfaces forms the basis of the rest of this report. Further investigations into ways to mitigate the effects of wedge elements and dimensional changes would be very useful. The cause of the response differences between the tied and tie-break contact surfaces should be investigated and should include the use of the other types of contact surfaces as well.

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Wilkerson, S.; Hopkins, D.; Gazonas, G.; Berman, M. Developing a Transient Finite Element Model to Simulate the Launch Environment of the 155-mm SADARM Projectile. *Proceedings of the 71st Shock and Vibration Symposium*, Arlington, VA, 6–9 November 2000; Shock and Vibration Analysis Center: Columbia, MD.

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