Model 710 Firing Pin Head Finite Element Analysis
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OBJECTIVE
The purpose of this analysis is to evaluate the distribution of stress through the cam surface of a firing pin head developed for the Remington Model 710 rifle.

CONCLUSIONS
An ANSYS model was used to predict stress distribution in the firing pin head resulting from bolt-opening forces. Two areas of high stress were predicted. Along the 0.004-inch wide contact surface between the firing pin head and the bolt body, stress was predicted to be around 120,000 psi, below the 190,000 psi yield strength of the material. At small patches at the ends of this surface, however, predicted stress rose well over 200,000 psi. It is likely that a small degree of plastic deformation will occur at these patches, widening the contact area until the stress is spread out below the material's yield strength.

Another location of significant stress occurred on the edge of the lateral constraint applied on the firing pin head by the bolt plug. Stress along the edge was predicted by the ANSYS analysis to be around 30,000 psi, with a peak of 53,000 psi occurring in a small area at the end of the patch.

THEORY
The loading conditions at the firing pin head were calculated as follows:

The bolt body cam surface is a helix with 2.18 inches of rise per turn. The angle of a surface on the helix is given by

$$\theta = \tan^{-1}\frac{2.18}{\pi \cdot d}$$

where d is the diameter of the location on the helix. Using d values of 0.498 and 0.695, the inner and outer diameters of the bolt body, resulted in slopes of 55 and 45 degrees, respectively. The average, a slope of 50 degrees, was used to calculate forces.

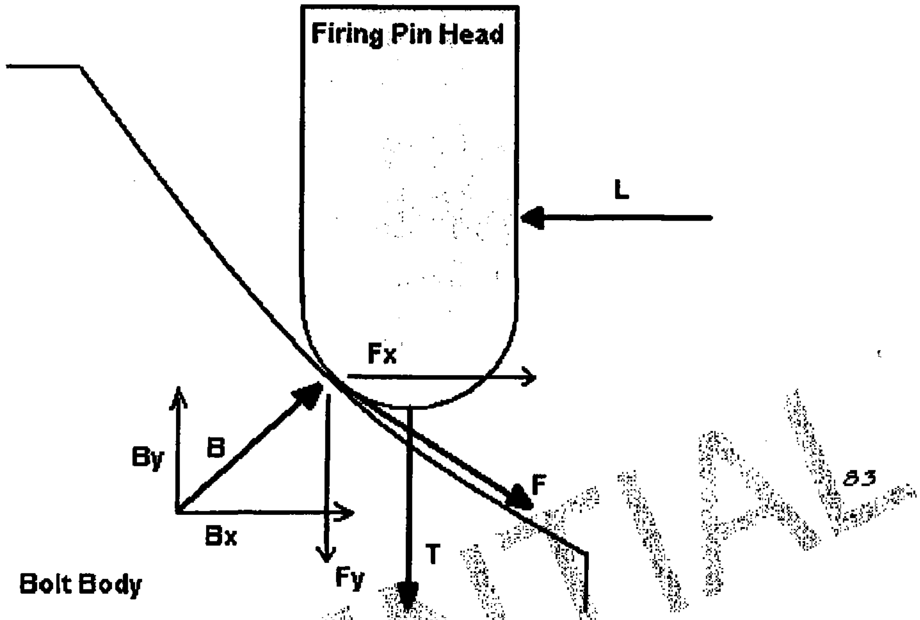

Figure 1. Diagram of stresses.

Figure 1 depicts the stress situation in the firing pin head. B represents the normal force applied to the firing pin head by the bolt body. F is the frictional force applied to the firing pin head by the bolt body. T represents the force applied to the firing pin head by the firing pin spring. L is the lateral force applied by the bolt plug on the firing pin head. F is related to B by

$$F = \mu \cdot B$$

where μ represents the coefficient of friction between the two surfaces. *Mark's Engineering Handbook* gives μ values for steel-on-steel contact of 0.4 to 0.01, depending on lubrication. 0.4, the value for dry contact, was used.

The vertical components of the forces in Figure 1 were added and set to zero, resulting in

$$T + Fy - By = 0$$

The y components of B and F are given by

$$Fy = F\cos 50° = B\mu\cos 50°$$

and

$$By = B\sin 40°$$

resulting in

$$T + B\mu\cos 50° - B\sin 40° = 0$$

From the spring specifications, T is 20 lbs. The above equation may be solved for B as

$$B = \frac{20}{\sin 40° - 0.4\cos 50°} = 51.86 \text{ pounds}$$

Friction may be solved for from B:

$$F = \mu \cdot B = 0.4 \cdot 51.86 = 20.74 \text{ pounds}$$

Roark's Formulas for Stress & Strain gives the following equation for width of a contact patch in the interface between a cylinder and flat plate if both materials have a Poisson's ratio of 0.3 and share the same modulus of elasticity:

$$b = 2.15\sqrt{p\frac{K_D}{E}}$$

where b is the contact patch width, p is the force over the length of the cylinder, K_D is the diameter of the cylinder, and E is the modulus of elasticity for the the plate and cylinder. Entering the appropriate values for the firing pin head to bolt body interface gives

$$b = 2.15\sqrt{\frac{51.86}{0.0798}\frac{0.170}{30\times 10^6}} = 4.13\times 10^{-3}\text{ inches}$$

PROCEDURE

The analysis was conducted on a CADDS 5 model of the firing pin head developed for the Remington Model 710. The CADDS model was simplified by the removal of all fillets not in the area of the cam surface. Faces on the model were split to provide a location to apply the side constraints and cam surface pressure. The model was brought into ANSYS. It was meshed with 10-node tetrahedral elements using the ANSYS Smartmesh tool with a coarseness level of six. The areas of the protrusion on which the cam surface acted were refined with ANSYS's Meshtool and a refinement level of one. The meshed model may be seen in Figure 2.

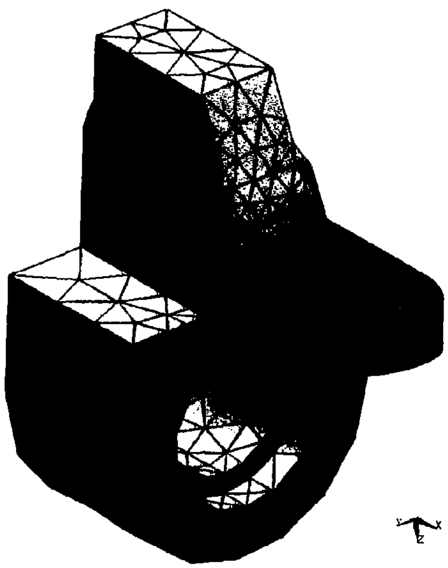

Figure 2. Meshed model of firing pin head.

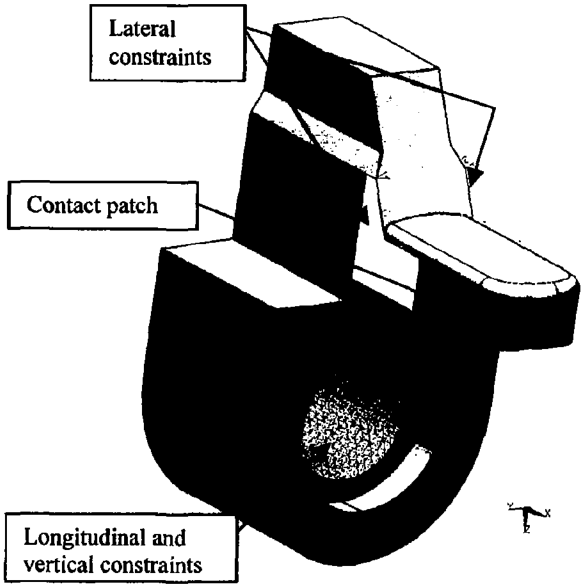

Figure 3. Constraints placed on model.

The model was constrained as follows: A longitudinal displacement constraint and a vertical displacement constraint were placed on the cylindrical area where the firing pin head attached to the firing pin. The lateral position of the firing pin head was fixed by placing displacement constraints on the areas where the bolt plug cradled the cam surface protrusion of the firing pin head. The location of the displacement constraints may be seen in Figure 3.

The load on the cam surface was applied in two components. The force normal to the cam surface was applied as a 158,000-psi pressure over the entire 0.0041 wide area. This represented a force of 51.86 pounds. The second component of the cam surface load was the force applied by the friction between the cam surface of the firing pin head and the bolt body. This was applied by selecting all the nodes on the 0.0041-inch wide area, rotating the node coordinate system 50 degrees and applying a force to each node in the negative y direction of the new coordinate system. The mesh had resulted in 317 nodes on the contact area, so the frictional force of 20.74 pounds was applied as a force of 0.06544 pounds per node.

After the model had been fully constrained and loaded, the analysis was solved using the ANSYS PCG solver with a tolerance of 10^{-8}.

RESULTS

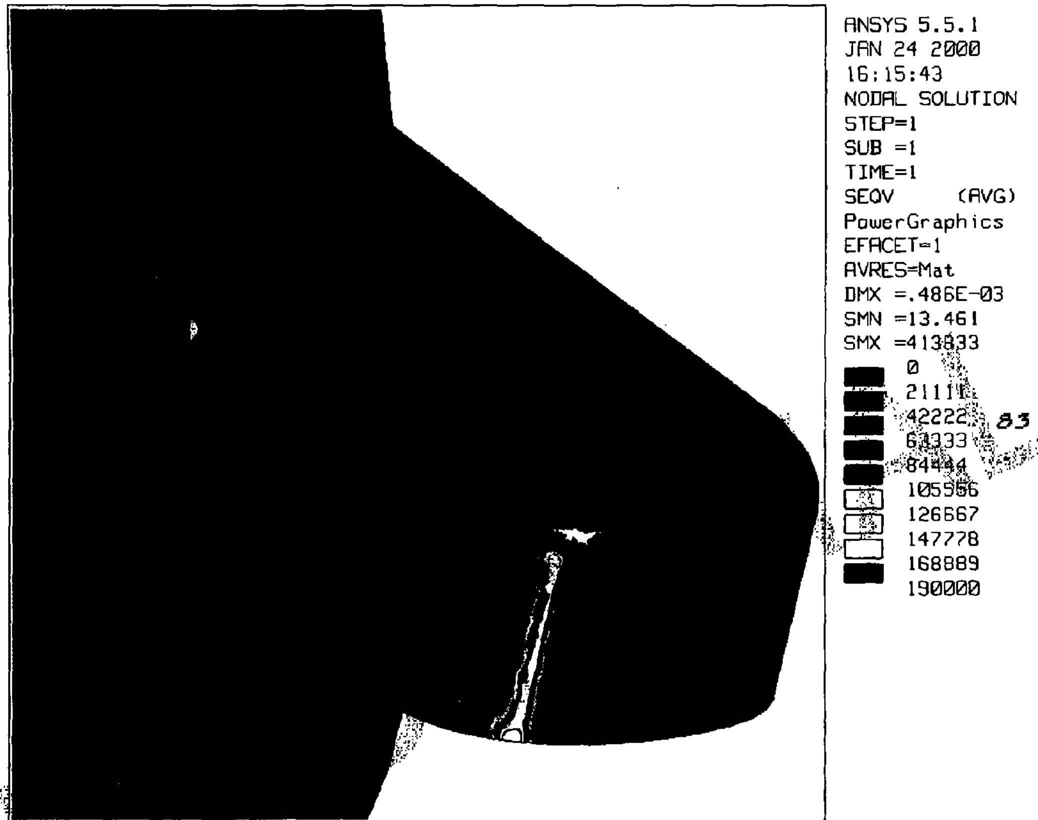

Figure 4. Stress distribution in firing pin head.

The Von Mises stress distribution predicted by the ANSYS model may be seen in Figure 4. Peak stress is concentrated in the 0.004-inch wide contact patch. Stress along the contact patch surface runs around 120,000 psi. Both the bottom and top ends of this patch contain areas, shown in gray on the above figure, where stress exceeds the 190,000 psi yield strength of the firing pin head material. One node on the bottom area returned a stress over 500,000 psi. The firing pin head may be expected to deform plastically in the regions at the ends of the contact patch. Plastic deformation in these areas will widen the contact patch area even out the stress distribution until stresses are below the yield strength of the material.

Another location of significant stress is farther back on the protrusion of the firing pin head, at the edge of the area where lateral constraints were applied. Stress in this location runs around 30,000 psi, peaking at 53,000 psi at the top end of the edge. The same pattern and levels of stress occur on the other side of the part.

APPENDIX

This appendix contains an enlarged Figure 4, as well as other views of the stress results.

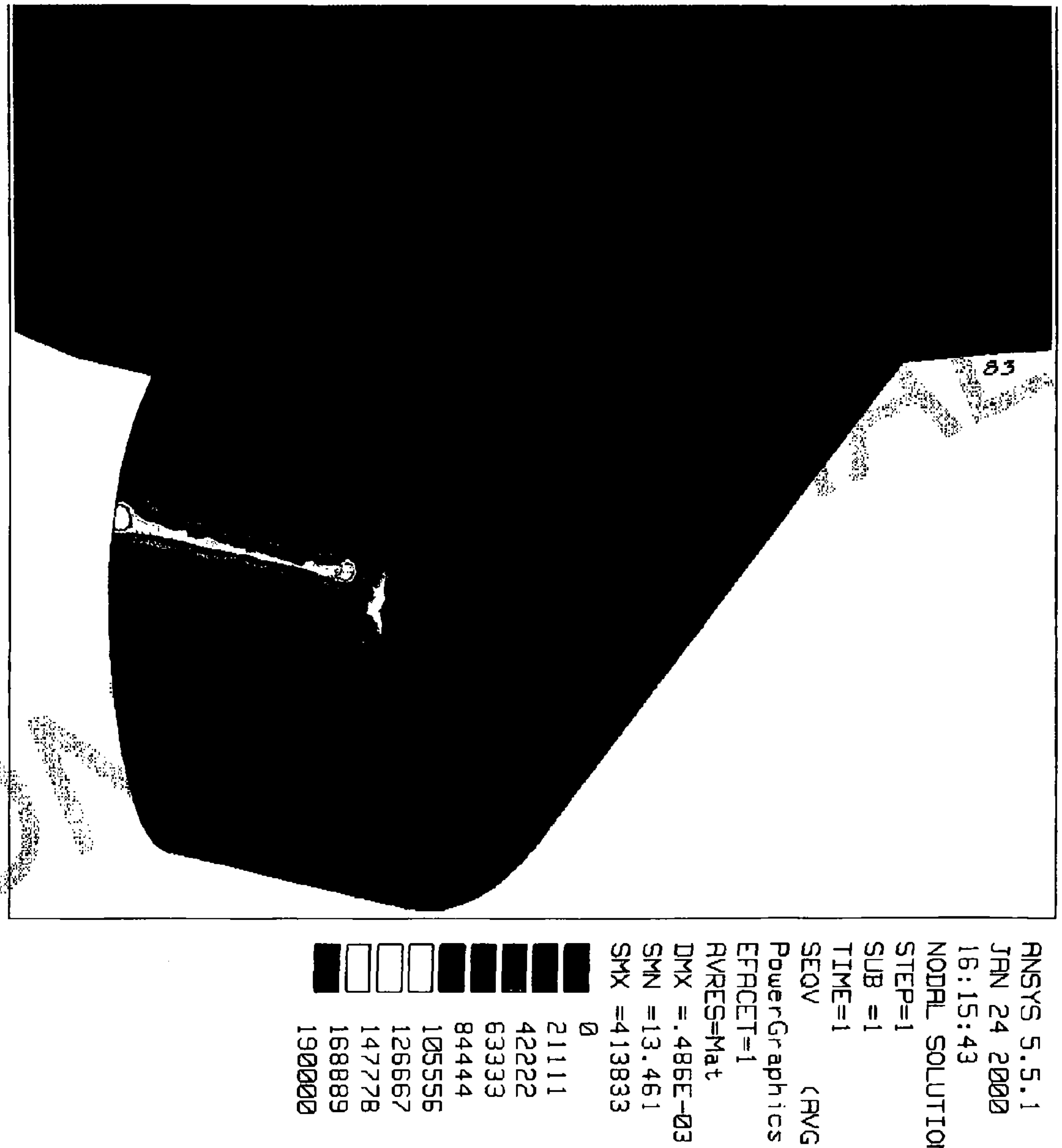

Figure 4 (enlarged). Von Mises stress distribution in firing pin head

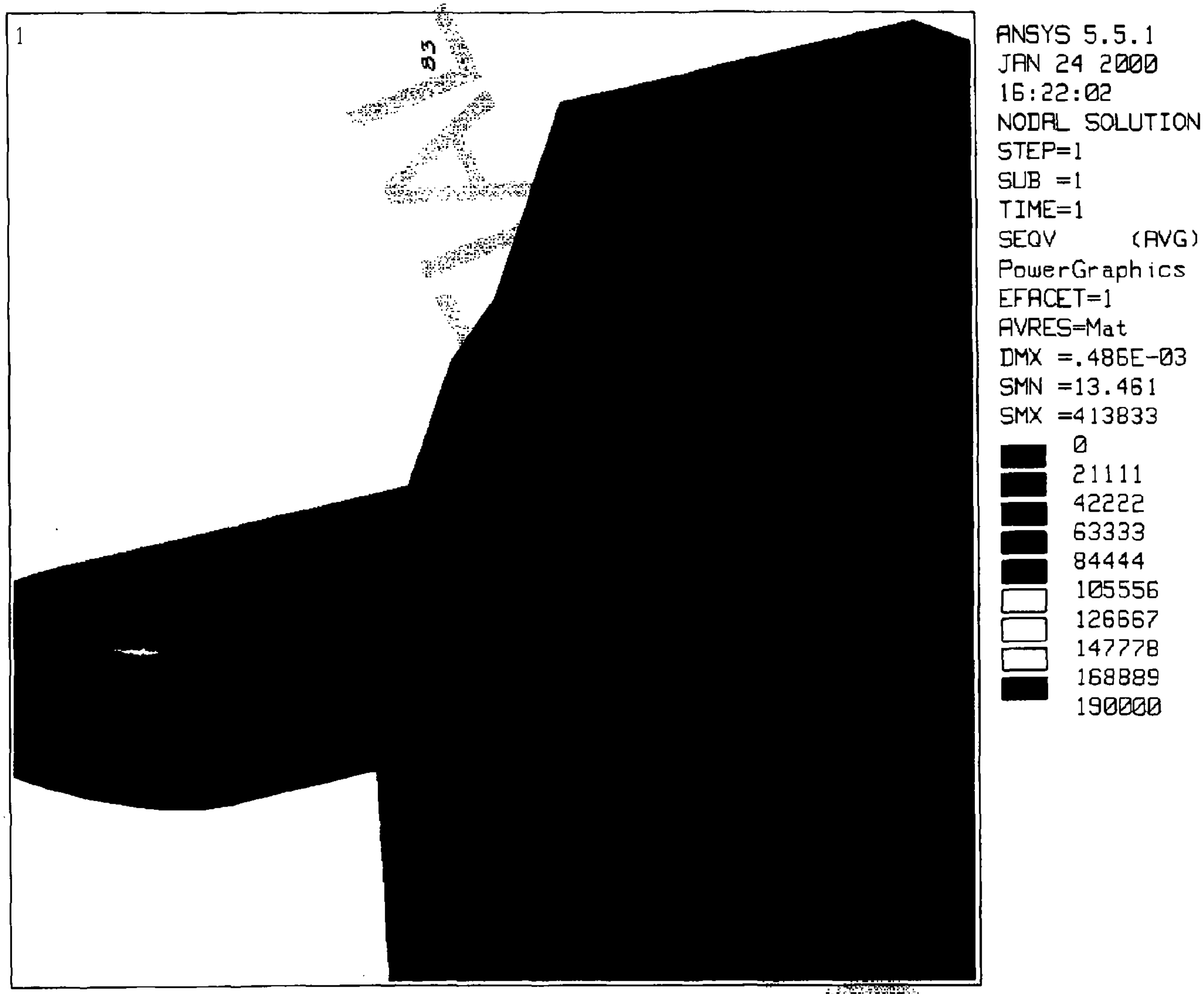

Figure 5. Von Mises stress distribution in firing pin head, other side.

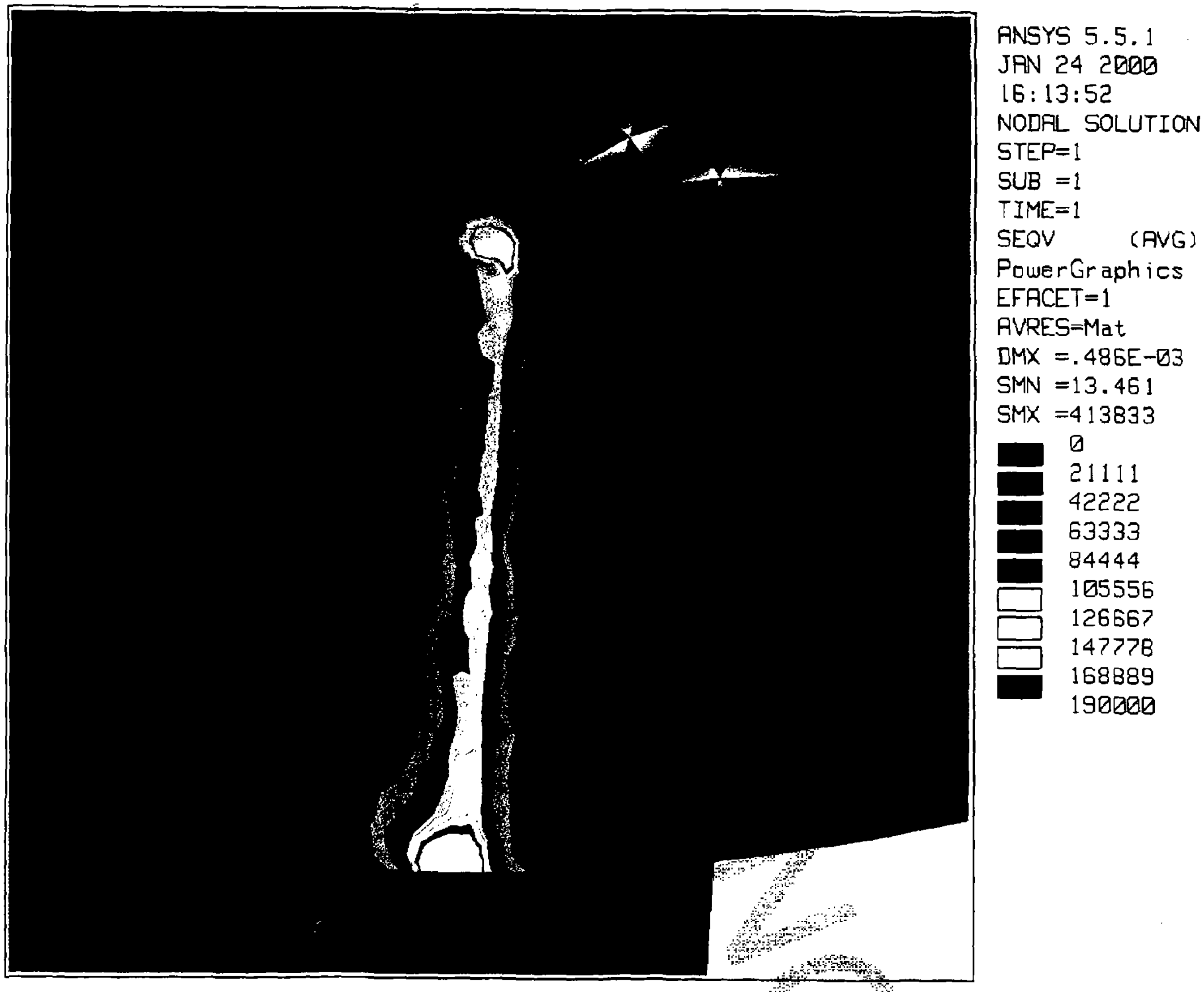

Figure 6. Von Mises stress distribution, closeup of contact patch.