Design Graphics Team Project
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Reverse Engineering a Toy Nerf Gun

Nerf Rebelle

Audrey Pick - *Team Leader*
17295
(audreygpick@gmail.com)

Owen Mann
17350
(owen.mann@utexas.edu)

Keri Christian
17350
(keri.em.christian@gmail.com)

Justin Campbell
17350
(campbelljustin989@gmail.com)

Brenna Hurley
17295
(hurleybren@gmail.com)

Lab Instructor: Mark Chiarello

We chose to do a finite element analysis on the shaft of the Nerf gun. The shaft of the gun is pulled down in order to store potential energy in the vacuum spring, and we chose to do the analysis on this part because during normal use it will be put under considerable amounts of linear stress. We investigated whether the rod portion of the shaft would stretch significantly or break, and whether the arms at the base of the shaft would be pulled off when subjected to a reasonable load. We chose ABS plastic for the shaft's material because it is a common type of hard, commercial plastic, and we believe it is likely what the actual shaft is made out of. In the finite element analysis we restrained the flat, top face of the shaft because the face is securely fixed to the shaft head when the gun is assembled. We applied the load to the arms of the shaft because that is the part which is pulled in order to cock the gun. We chose what loads to subject the shaft to by examining the strengths of children who would likely play with the toy.

We selected three age groups (ages 2-5, 6-10, and 11-15) from research conducted by the University of Nottingham (*Child Strength Report*), and approximated the mean outward force an individual in each could apply to a cylindrical bar. We chose to subject the shaft to loads of 75 N, 200 N, and 300N, corresponding to each age group. Referencing the static nodal stress diagram for the loading condition below, it can be shown that the bulk of the stress is transferred through the mass of the cylindrical body of the shaft (depicted in teal in the figure). This is reasonable considering that the cross-sectional area of the cylindrical portion of the shaft is less than that of the handles, so there is a smaller area with which to transfer the load. Since the color of this portion of the shaft is approximately uniform, it can also be concluded that the stress is transferred uniformly from the location where the handles of the shaft mate with the cylindrical body, down through the restraint face of the shaft.

The minimum values of static nodal stress in the shaft are located around the outermost portion of the shaft handle, yet these values vary depending on the pull force. The stress is approximately 4.477e+04 N/m^2 for 75N of pull, 1.194e+05 N/m^2 for 200N of pull, and roughly 1.791e+05 N/m^2 for 300N of pull (**Figures 1-3**). Shifting gears now to examine the strain diagram, it is first noted that the characteristics bear very close resemblance to the stress diagram in that the nodal strain is distributed much in the same way as the nodal stress. Namely, the strain values reach a (uniform) maximum in the cylindrical body of the shaft and a minimum along the outermost portions of the shaft handles for each pull force. In fact, the strain values reach a minimum of 1.712e-05 for a pull force of 75N, 4.566e-05 for a pull force of 200N, and 6.849e-05 for a pull force of 300N (**Figures 4-6**). Referring to the static displacement diagram now for the 75N case, it can be concluded that the displacement decreases from a maximum value of 7.002e-02 mm at the outer portion of the shaft handles to a minimum value of 1.000e-30 mm at the fixed end. In a similar fashion, for the 200N loading case, the displacement decreases from a max value of approximately 1.8673e-01 mm at the outermost portion of the shaft handles down to a minimum value of 1.000e-30 mm at the fixed restraint. Lastly, for the case in which the pull is 300N, we notice that the displacement ranges from 2.801e-01 mm at the outer edges of the shaft handles to 1.000e-30 mm at the fixed end (**Figures 7-9**). In conclusion, this simulated displacement profile adheres to the expected conditions. Namely, the shaft handles are expected to displace slightly in the direction of the applied force as they are only fixed at one end, and the opposite end of the shaft is not expected to displace at all as it is restrained vertically. In the cases of all three loads the stress and strain that the shaft is under is acceptable, as is the displacement of the arms.

Stress Diagrams for the Three Loading Cases

Figure 1 - 75N Pull

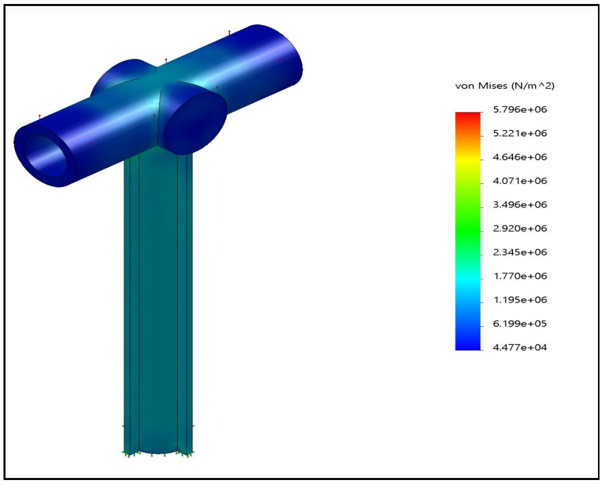


Figure 2 - 200N Pull

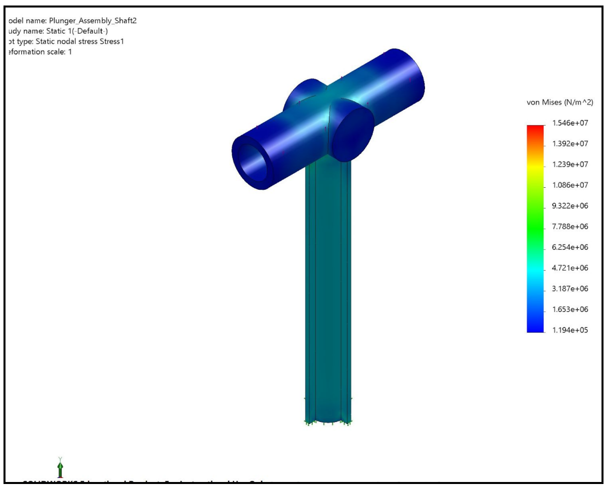
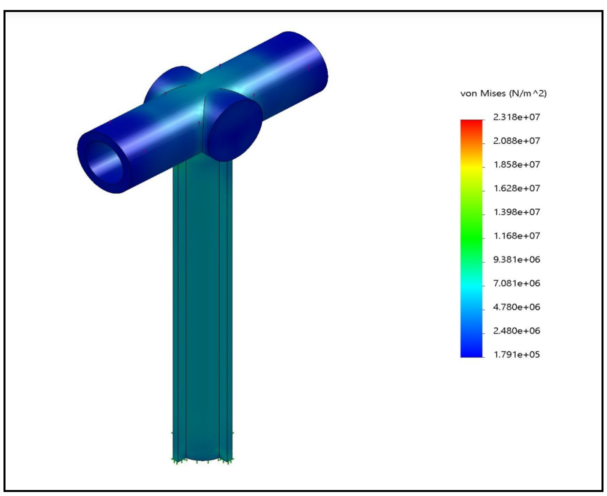


Figure 3 - 300N Pull



Strain Diagrams for the Three Loading Cases

Figure 4 - 75N Pull

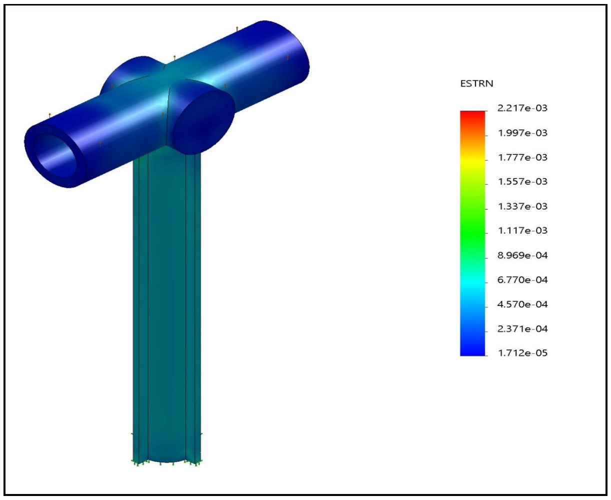


Figure 5 - 200N Pull

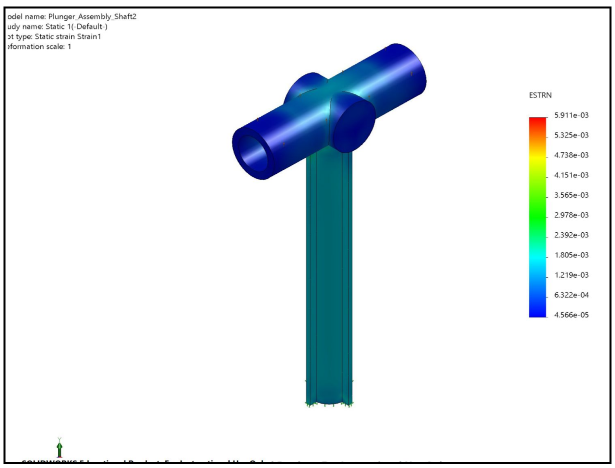
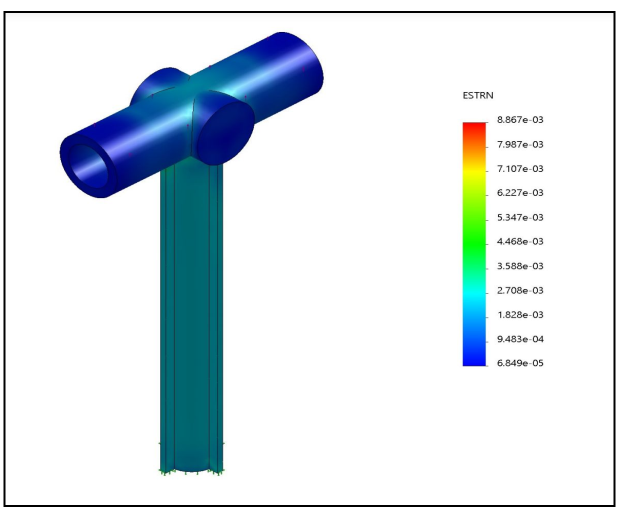


Figure 6 - 300N Pull



Displacement Diagrams for the Three Loading Cases

Figure 7 - 75N Pull

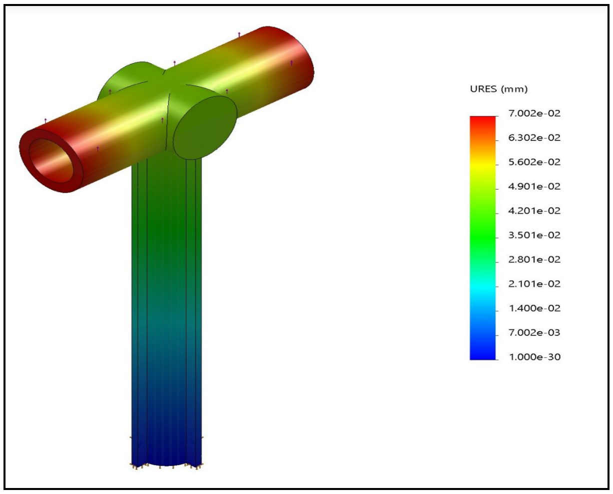


Figure 8 - 200N Pull

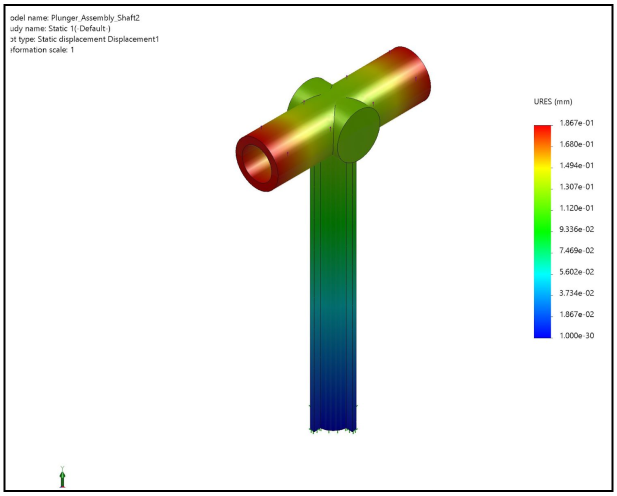
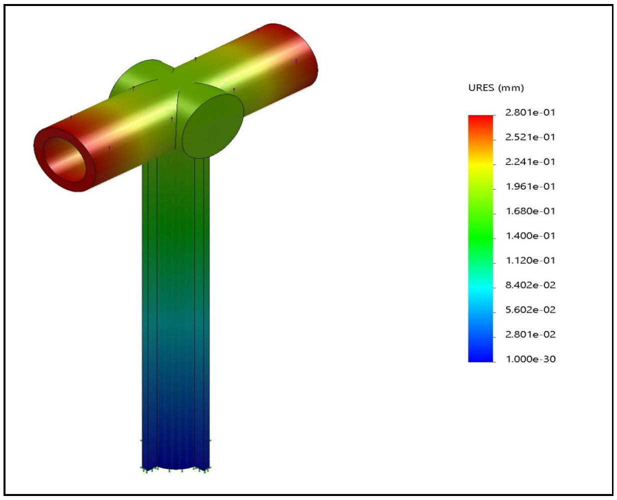


Figure 9 - 300N Pull



Works Cited

Child Strength Report by the University of Nottingham/IOE. Department of Trade and Industry DTI UK, Oct. 2000, www.humanics-es.com/strength.pdf.