Pipe Forming Simulation

Background:

The United States military utilizes a wide range of tubular product in its munition arsenal. The usage includes shells, mortars and general-purpose bomb cases.

General Dynamics Ordnance and Tactical Systems, Garland, TX, produces the steel bomb case for the Mark 84 (Mk 84) bomb, a member of the Mk 80 general-purpose bomb family. This free-fall, nonguided bomb was the most frequently employed ordnance in the Gulf War. The case is also used with JDAMS guidance systems for precision targeting.

The Mk 84 is is the most difficult of all the Mk 80 bombs to produce due to its large diameter-to-thickness ratio. The wall of the Mk 84 is only slightly thicker than that of the smaller 1,000 pound Mk 83, but the diameter of the Mk 84 is considerably larger.

Forging Process:

The production forging process of the Mk 84 bomb case consists of the following processes:

- The pipe is extruded at room temperature to start forming the nose.
- After being locally induction heated, the nose of the bomb is preformed in a contoured die.
- The finish forming occurs after a final heating cycle. The final shape on the nose is achieved at this time.

General Dynamics reported consistency problems in production with the Mk 84 bomb case. The main issues were lack of sufficient nose material, under-gauge material in the nose region and bulging of the pipe. Others included inadequate blending of external surfaces, surface cracking and excessive die wear.

Analysis:

The nominal forging process was simulated to model a 'good' bomb case. DEFORM-2D was used, since the geometry and process were axisymmetric. Multiple iterations were run to calibrate process conditions with the nominal production process.

Once the nominal process was determined, process variables such as extrusion stroke, temperature distribution and forming pressure were varied to reproduce the production problems. For example, the simulations showed that if the pipe were extruded too far at the start of the process, the exterior surface of the bomb would not be well blended at the end of forging.

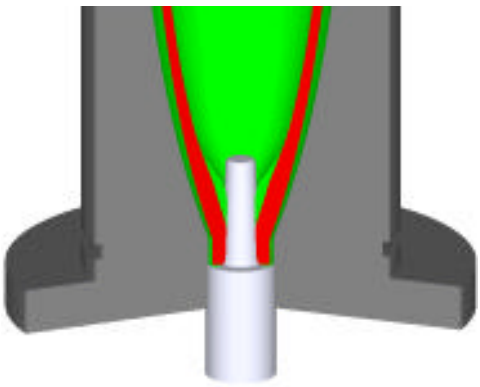

Figure 2: A cut-away shows the target geometry on the nose in green. The red image shows an unfilled nose.

Alternatively, if the pipe were not extruded far enough, a lack of nose material was observed which could lead to a bulged pipe if additional forming pressure were used to try to remedy the situation. *(over)*

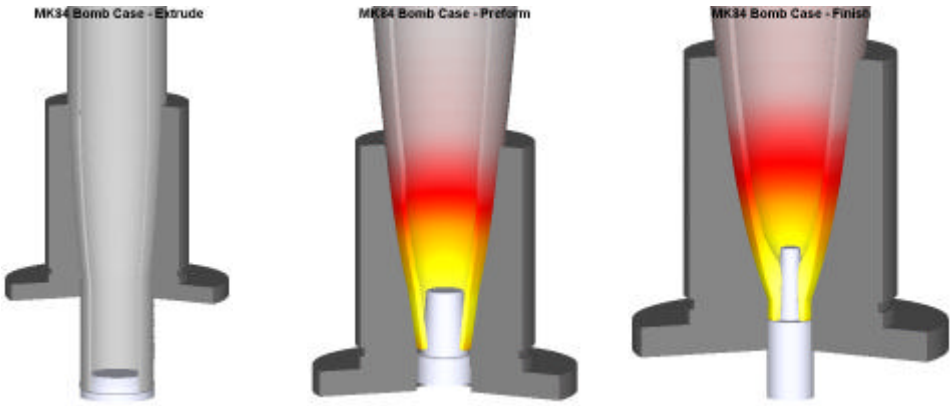

Figure 1: The forming process includes extrusion (left), preform (center) and final forming (right). Contours of temperature (yellow is hotter) show the local heating.

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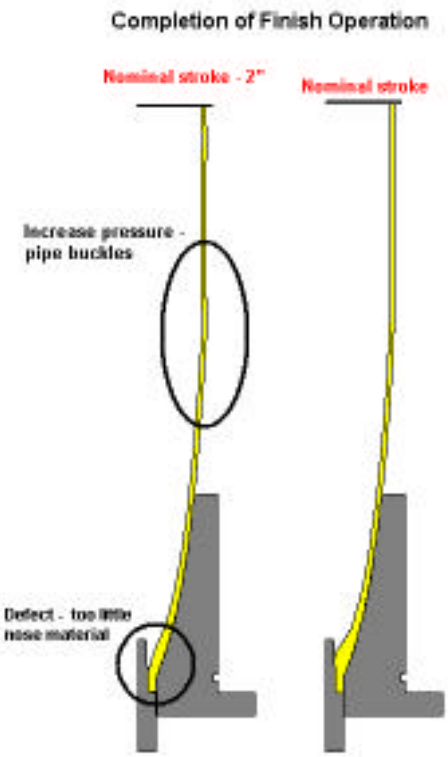

Figure 3: Simulation was used to identify the root cause of various quality problems. The left images show how a bulge is formed when the extrusion punch stroke is 2″ below nominal. The right image shows nominal extrusion stroke.

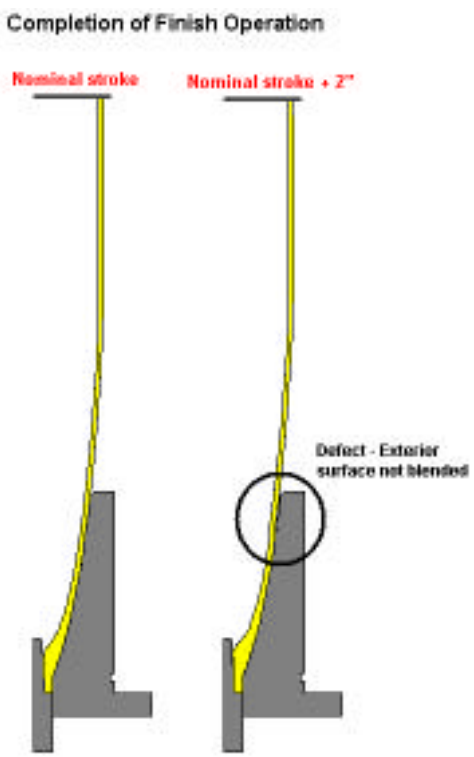

Figure 4: The right image show a blending problem when the extrusion is 2″ above nominal. The blend meets dimensional requirements at the nominal extrusion stroke, as shown on the left.

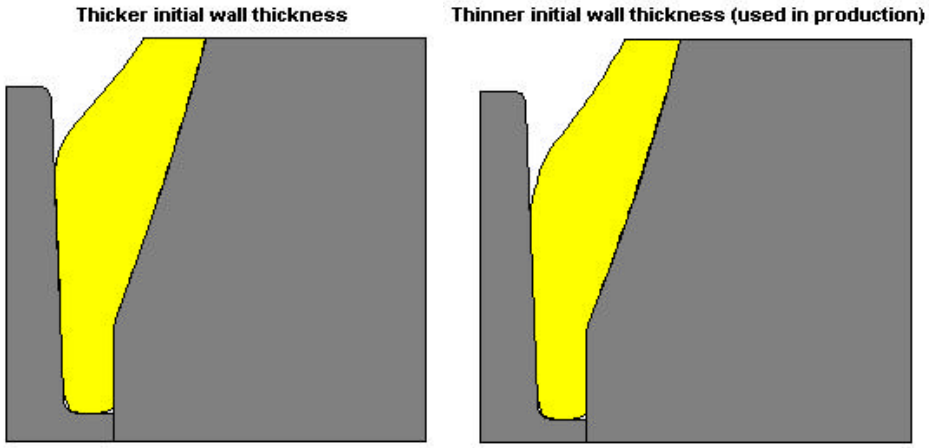

Figure 5: The thicker wall pipe (left) provided additional material in the nose end of the pipe using the improved process versus the original process (right).

(continued)

By adjusting various process parameters, the root cause of each forging problem was determined.

Design changes and process controls were proposed to reduce the scrap and rework. One change was the use of a thicker walled pipe. Simulations showed that this improved both die fill in the nose and the thickness profile through the body. The thicker pipe had greater column strength, with less tendency to bulge.

Since this study was performed, thousands of bomb cases have been produced using the thick walled pipe. General Dynamics has reported that the defect rate due to insufficient nose material de-creased by over 20%. Problems related to under-gauge material in the nose region and pipe bulging have been essentially eliminated.

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