Agenda

- Problem introduction
- Proposed remedies
- Analysis
- Analytical results
- Conclusion
Introduction

- Navy testing at China Lake with a Phalanx CIWS system with an M61A1 gun designed and built by General Dynamics Armament and Technology Products (GDATP) experienced stops and slowdowns believed to be caused by the ammunition, Mk244 Enhanced Lethality Cartridge (ELC)
- Raytheon (system prime) and US Navy asked GDATP to determine the root cause and recommend fixes to eliminate or reduce the case neck denting
- Case neck dents, when severe enough can cause problems with the performance of the ammunition handling system
20mm Case Neck Denting

- Dents occur as the fired case is trapped between the feeder unload sprocket and the guide bar just after handoff from the gun bolt.
- Root cause is a lack of control influenced by round dynamics.

When these two forces acting on the case neck oppose each other, denting of the case neck occurs.

Dented occurring during handoff.
Ammunition Variations

- Ammunition characteristics
  - ELC round has significant difference in cg location compared to Mk149 round
- The case is the same for all types (M103)
- Potential exists that ELC case handoff adversely influenced due to dynamics of a full round on opposite side of guide bar
- ELC ammunition has a much greater impulse than Mk149 (≈25%)
CIWS Gun and Feeder Geometry

- Gun bolt
- Nose guide bar
- Case
- Feed sprocket
- Unload sprocket

View - Forward looking Aft
Lessons learned

- Lessons learned on other systems identified improvements
  - Reduce clearance between the guide bars (nose & base) and the gun rotor such that guide bar deflection under loading is reduced
  - Extend the tips of the unload sprocket to gain control of the round earlier during handoff from the gun bolt
  - Modify the nose guide bar contour on the unload side to delay impact of the case on the guide bar
Proposed Fixes

Nose guide bar contour changes

Moved 0.05 closer to gun rotor OD

Nose unload sprocket contour change

Material removed at this corner

Material added
Analysis

- Identifying the potential benefit of these proposed remedies for dented brass was desired to reduce testing.
- Previous analytical work (2001) on F/A-22 dented brass issues had shown that over 9 man-months were required to analyze the case handoff in ADAMS® (a dynamic analysis program).
- Advances in technology enable more models and surfaces to be imported and used in the analysis resulting in fewer man-months required.
- Analysis was completed in ≈ 5 man-weeks.
- Over seven different simulations were run with different combinations of ammunition and proposed fixes.
Dynamic Analysis Results

- ADAMS® showed an identifiable improvement in round handoff due to the changes on the nose guide bar and marginal improvement with a modified unload sprocket.
- A comparison between the original handoff and the modified handoff shows less case bumping around and lower forces acting on the case neck.
- The decision was made to go forward and modify the guide bar and unload sprocket for testing at our range facility.
Dynamic Analysis Results Comparison

- Old configuration
- Notice case base lead
- Very late nose sprocket contact
- Large amount of case free fall
- Large contact forces generated during nose guide surf contact
- High force locking case into gun bolt

- Recommended configuration
- Lower nose guide contact forces
- Better drive angles on nose sprocket
- Earlier sprocket contact
- Less case angle in sprocket
- Less case base lead
- No gun bolt lockup force

Note - Mk 244 shown
Test Results

- The instrumented gun system showed a small change in the behavior of the case due to the altered guide bar (initial contact between the case and the guide bar was slightly later, a good thing)
- When the modified case nose sprocket was included, the timing difference disappeared (initial contact time went back to original point, a bad thing)
Test Results

Mk 244 - 1 Skip 8 - Nose Guide Bar

Feed

Unload

Rotor Position, 60 Degree cycles (degrees)
Conclusion

- Dynamic analysis of round/case handoffs is a valuable design tool.
- Developments in the ADAMS® tool have dramatically reduced the time required to analyze complex handoffs.
- Future system designs will be able to use this analysis tool to optimize the dynamic effects during round/case handoff.