



## Case Study #11 Preventing Toe Crushing by Creating Lighter and Stronger Toe Caps through Virtual Manufacturing and Virtual Testing

### Summary

In a collaborative project with MindMesh Inc. and Virtual Forming Inc., we developed virtual testing methods to improve toe cap designs, (Fig. 1), for safety shoes. Toe caps are used in safety shoes by multiple industries so the toes of workers are not crushed during operations with heavy equipment. As part of this project, we formed toe caps that were lighter which met safety regulations.

#### Challenges:

- Qualify a lighter and robust toe cap for the safety shoe
- Meet ASTM testing standards

#### Results:

- Developed virtual manufacturing and testing methods to design and qualify the toe cap
- Virtual testing helped optimize product performance



Fig. 1: Steel toe cap (Image courtesy of Sharpe Safety Supply Inc.)

### About the Client:

This client, Virtual Forming Inc., specializes in sheet metal forming simulation and has years of hands-on die trial experience, giving them a deep understanding of the processes necessary to accurately simulate metals. The end client is a specialty metal forming company who produces intricate metal formed products. They also push the envelope in manufacturing lighter and more efficient toe caps for the safety shoes industry.

### Challenge:

The American Section of the International Association for Testing and Materials (ASTM) is an international organization that publishes standards for a variety of materials, services, and products. ASTM has specified standards for qualifying safety shoes. The standard specifies that a safety shoe, (toe cap) should be able to absorb a maximum impact of 102 Joules. The standard also specifies that both static and dynamic tests are required to qualify these shoes. We developed a virtual testing method to evaluate the performance of the toe caps for several different designs and materials. The challenge therefore, was to virtually design and test a lighter and more efficient toe cap while staying in accordance with the ASTM standards.

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## How Did We Help?

Toe caps are typically made by a stamping process through manufacturing. However, when new toe caps are made or are redesigned, production time needs to be reduced. To do this, we developed a virtual manufacturing and virtual testing process combined to efficiently develop a new product according to strict ASTM standards. The toe caps were taken to our virtual testing process where a set weight to provide a stamping inflection and an impact test to provide the 102 Joules rating was performed.

The toe caps initial CAD designs were put into simulations so that a flat piece of metal was formed into the toe cap shape. We predicted the thickness variation and stress and strain in these toe caps. Designs were optimized to ensure that the parts could be manufactured. Once the simulated manufacturing process was completed, the material underwent work hardening. There were certain areas that were lower thickness and certain areas that were thickened. We had higher strains in some areas so it was important to carry these work hardening effects into the virtual testing process to qualify the toe cap. We mapped the resulting stresses and strains and thickness variation from the stamping into structural analysis process for virtual testing. Once these results were mapped, we followed the ASTM standards for stamping and dynamic tests and performed the qualification tests to ensure the product would work efficiently.

## Results:

By performing virtual testing of toe caps, this is what was achieved:

- We virtually formed the toe cap through metal forming operations
- We mapped the stresses and strains in a structural analysis
- We conducted virtual testing of the toe caps in accordance with ASTM standards
- We validated material behavior when they were subjected to dynamic and static loads

## Value to Client:

- We ensured that toe caps will work consistently under operating conditions
- We provided more reliability for toe caps undergoing dynamic and static loads
- Optimized design of toe caps (Fig. )
- The end client was able to implement better manufacturing techniques

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MindMesh Inc. • (713) 489-7798 • [connect@mindmeshinc.com](mailto:connect@mindmeshinc.com)

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