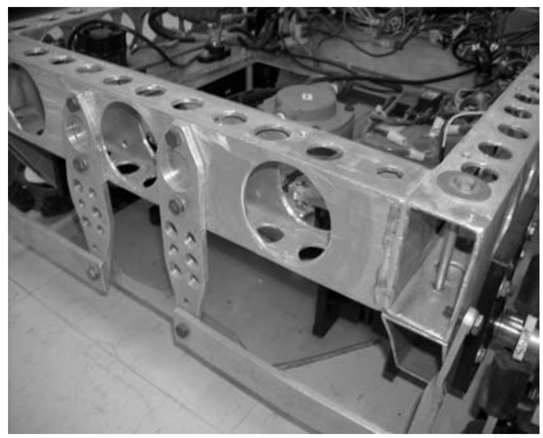
Enhanced Weight Reduction

Executive Summary

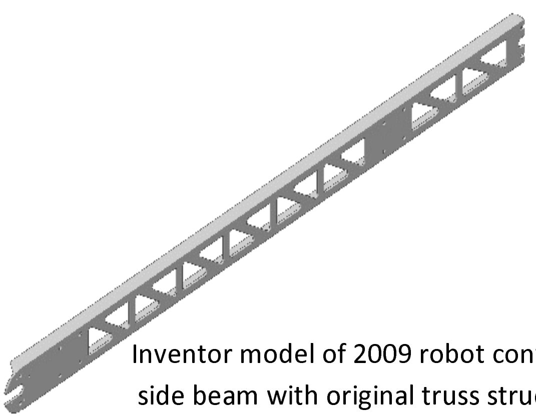
Weight reduction is an important robot design goal. A typical approach is to drill holes to reduce weight. Strength-to-weight ratio can be improved by moving to triangular shaped holes. These designs can be enhanced by computer modeling of structures, forces and stresses, and then verified by actual testing. We used an aluminum C-channel beam, integral to our 2009 robot. We designed an improved beam using Autodesk Inventor and MD-Solids, fabricated and tested both to determine an actual failure point compared to computer models. We concluded lighter structures can be designed with safety margins given approximate forces and computer modeling.

Background

In the past, we've used round holes in our robots for weight reduction. With the 2009 robot, we stepped up to a triangular truss structure with rounded corners or fillets. This 2009 design structure was designed quickly with a general rule of keeping at least ½ inch of material in all areas. Design time was limited, as were our skills in the Inventor Stress Analysis application. This design did hold up after numerous aggressive collisions with other robots and field elements. Other robot components were damaged, but the original conveyor trusses held up. However, we continued to battle overall weight issues and had to remove spare speed controllers before competition to meet weight.

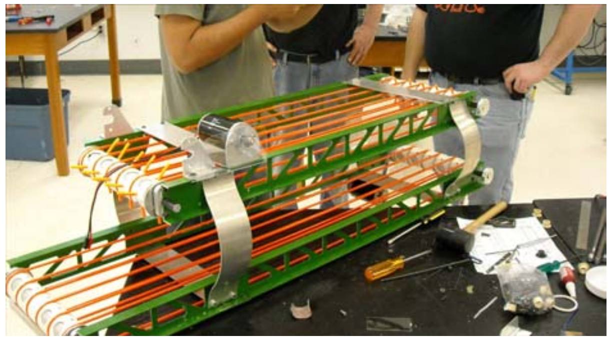


2005 robot chassis frame with round holes for weight reduction



Inventor model of 2009 robot conveyor side beam with original truss structure

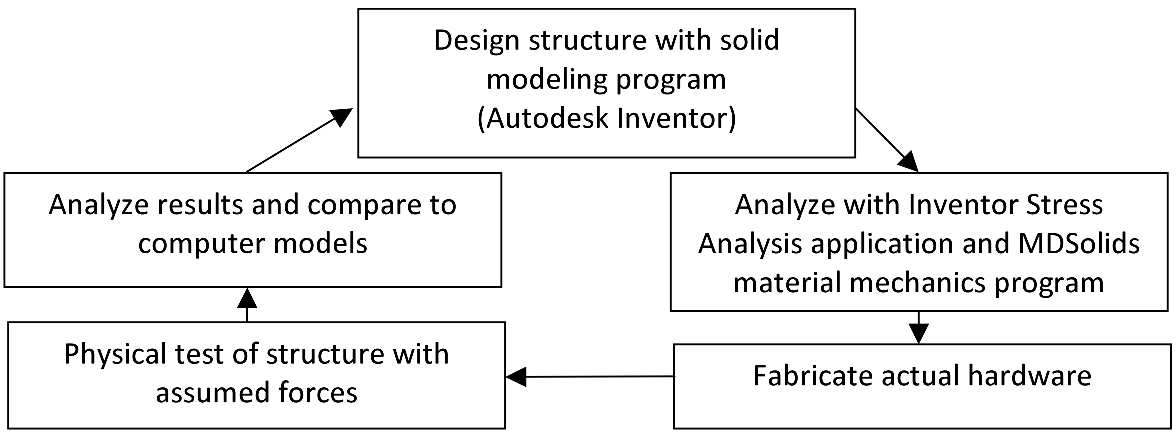
Our 2009 robot used a truss structure with triangular instead of circular holes to reduce weight. Triangle shaped holes typically have a higher strength-to-weight ratio. This lightening technique was used on a major structural component of four aluminum beams on each side of the ball-lifting conveyor. The four beams are used to stretch twelve opposing (orange urethane) conveyer belts, six on the lower rear and six on the upper front conveyors.



2009 Conveyor system with four
original aluminum truss side beams

Methods, Assumptions and Procedures

Our method for design refinement is illustrated below.



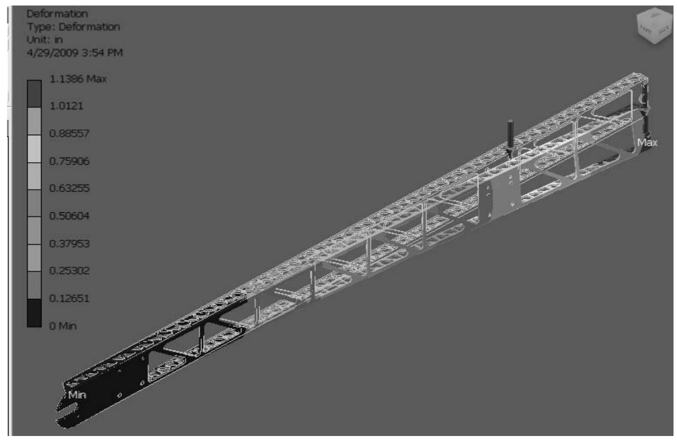
To better understand the available design tools, we went about redesigning the conveyor truss with the goal of removing another 25 percent in weight. With Autodesk Inventor we began by reducing the distance between triangle cut outs from the original 0.50 to only 0.25 inches. We also reduced the web height to 0.25 inches. This produced a weight savings of an additional 33 percent or a total of 52 percent reduction from an original solid truss. However, we did not know if there were obvious weak points or if the new design was sturdy enough.

We assumed that in a worst-case collision we would have to withstand 20 G's. We also assumed that the front conveyer assembly weighed approximately 10lbs, and is supported by the two rear conveyer trusses. Finally, we assumed the top of the conveyer is not supported because in St. Louis the bolt holding it to the upper superstructure failed. So, the force one truss had to withstand was approximately 100 lbs cantilevered from the bottom.

We used MDSolids analysis tool to calculate forces on each truss member. The analysis indicated that 75 lbs supported the far end of the cantilevered beam results in a maximum force of 889 lbs in compression on a member closest to the support point (Attachment 1). We also examined cross sectional properties for moment of inertia and predicted column buckling.

Results

We bolted and clamped the original and new lightened truss to the side of a bench and gradually added free weights. The original design held the 100 lbs without incident. We then began adding weight to the lightened truss. We measured the actual bending with 75 lbs, to be 1.25 inches. The Inventor model predicted 1.125 inches, which is quite accurate. As soon as we began adding more to reach our goal of 100 lbs, the truss immediately buckled and failed. The failure location was not at the predicted highest stress point, but right next to it. Also, the predicted column buckling suggested it should have held more than the 75 lbs. We are unsure as to why this happened, but learned to keep a larger safety factor for members under compression, which may buckle.



Inventor Stress Analysis predicted a 1.125" deformation with 75 lb load. Actual test resulted in 1.25" of deformation.

Conclusions

The new and lightened truss is indeed weaker than the original, as we expected. In the future, we can increase strength by making the inner triangles smaller where we now know the stresses are highest. MDSolids truss analysis is a good tool to determine where to expect the highest forces.

Attachment Page 1

MDSolids Truss Analysis Module