Bolt Load Analysis / Robotic Arm Simulation

Engineering Methods, Inc.

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ABSTRACT

Engineering Methods Inc. is working with a world class supplier of manufacturing/material handling systems. To provide flexibility to their customers, they combine state of the art analysis with a history of reliable products. This paper shows how a kinematic analysis was performed using the existing CAD model and integrated analysis tools. The results showed excellent agreement with current experience. The geometry was modified for new customer requirements, but the results indicated the floor-anchoring configuration needed to be modified to satisfy well-established limits. The final result is a configuration that offers the end customer more flexible manufacturing systems and assured reliability.

Introduction:

Engineering Methods Inc. was founded in 1979 as an ANSYS support distributor (ASD) and design engineering firm. As one of the original ASDs, EMI was integral in the proliferation of Finite Element Analysis (FEA) for in-depth understanding of products developed throughout the world. EMI has grown to support over 200 companies in the application of Ansys technologies.

In addition to our Ansys expertise, the technical staff at EMI are experienced design engineers. All have been involved in the unique decision making process that is design engineering. All have experienced functional development when critical design decisions have to be made effectively and promptly. Many of our customers look to us for this product development expertise in addition to our engineering analysis expertise.

EMI's technical approach is derived from our experience in the engineering decision making process of product development. Thousands of decisions are required to bring a product to market. EMI's strategy is to become an integral part of this decision making process. We are expert in the application of Computer Aided Engineering tools in this decision making process.

Our unique experience is a relatively recent development. As little as a decade ago, specialized engineering "analysts" performed most FEA based engineering analysis. FEA was simply too costly to justify except for the most critical or high volume products. The rapid advance in computational efficiency lowered costs to the point where most products today are developed in conjunction with engineering analysis tools. We were involved in this transformation as design engineers using analysis tools to interactively assess product functionality.

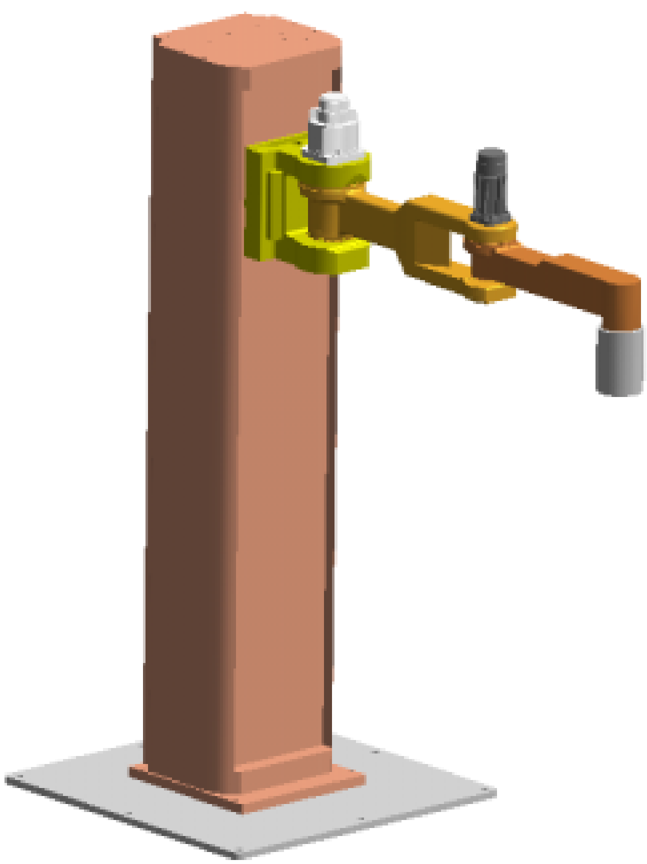
As engineering analysis becomes more cost effective, more product development decisions are being simulated in an effort to reduce product cost and to improve product quality. Tremendous cost benefits are achieved when performing analysis early in the design cycle. It is our priority to ensure that our customers use these tools effectively, and to enable our customers to simulate their products and processes early in the development process. It is through the product quality, functional, and cost improvements that Engineering Methods provides value to our customers.

One customer in particular is R.A. Jones, Inc. R.A. Jones designs and manufactures industrial automation equipment for the packaging industry. These tools are designed using the Solid Edge CAD system from Unigraphics Solutions, Inc.

Due to confidentiality, the precise numbers for the analysis have been omitted from the paper. Relative percentages have been provided as a reference.

Problem Description/Critical Issues

The tool in question was a robotic arm used in a manufacturing assembly capacity. During operation, the tool performs both linear and rotational tasks. R.A. Jones' customer was changing the assembly line configuration, which necessitated a change in the floor-mounting configuration of the existing robot. The critical issue for the customer was how would changes the mounting location and configuration of the robot arm have effect on the robot's operation? Specifically, if the configuration changed, would the robot work effectively? Would the existing floor mounting be sufficient to hold the robot in place or would the bolts fail. Failure was defined as the tensile loading at any specific bolt location exceeding 1800Newton. This would lead to stopping the production line and doing repairs. The possibility of stopping the production line would result in a cost of tens of thousands of dollars in lost production. Worse yet, failure, which could cause injury, would result in lost productions as well as legal concerns. Some sort of evaluation of the new mounting configuration needed to be performed. Physical evaluation was not a preferred mainly because this evaluation method would disrupt the current production process and result in similar costs.

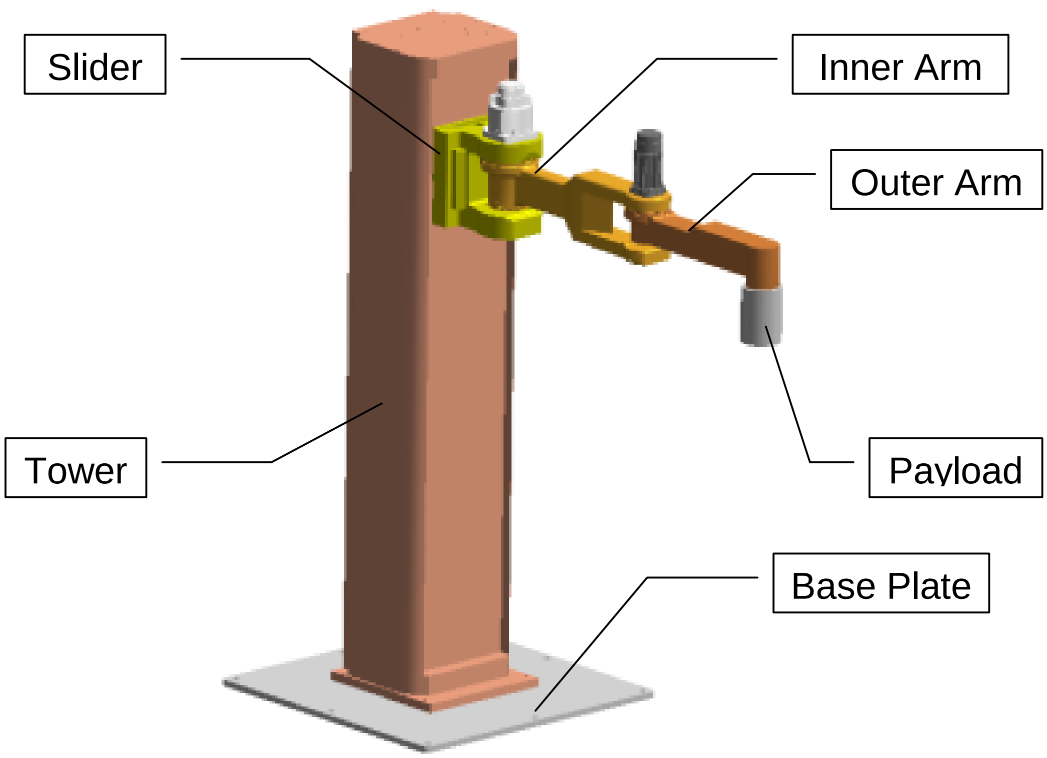


Picture of the Original Model
Figure 1

Model Set Up

Engineering Methods was contracted by RA Jones to understand the specific operation of the robot to simulate the current design configuration and look at an alternative design which incorporated the customer's desired changes while minimizing the loads at the anchor position. The goal was for no bolt load to exceed 1800 Newton tensile load.

A rough model of the existing robot configuration was given to EMI in Solid Edge format. A better understanding how the mechanism operated needs to be appreciated.



Annotated Picture of the Original Model
Figure 2

The motion of the arm represents the slider near the top of it's travel, the inner arm rotates to the right side, and the outer arm is able to rotated more to the right which causes the ability for the arm to reach around and have contact with itself.

The operation of the inner arm involves a rotation of approximately 45 degrees per/sec so it completes in about 4.5 seconds. Its range of motion is +/-110 degrees. Meanwhile the outer arm is swinging between +/-20 degrees in a half second and the slider is going down & back up 174 mm in 1 second. The robot is mounted to the floor on a plate with 8 bolt holes equally distributed around the perimeter of the plate.

At the end of 4.5 seconds, the inner arm has rotated around to the other side (with about 5 pauses along the way); the outer arm and slider completed about 5 cycles.

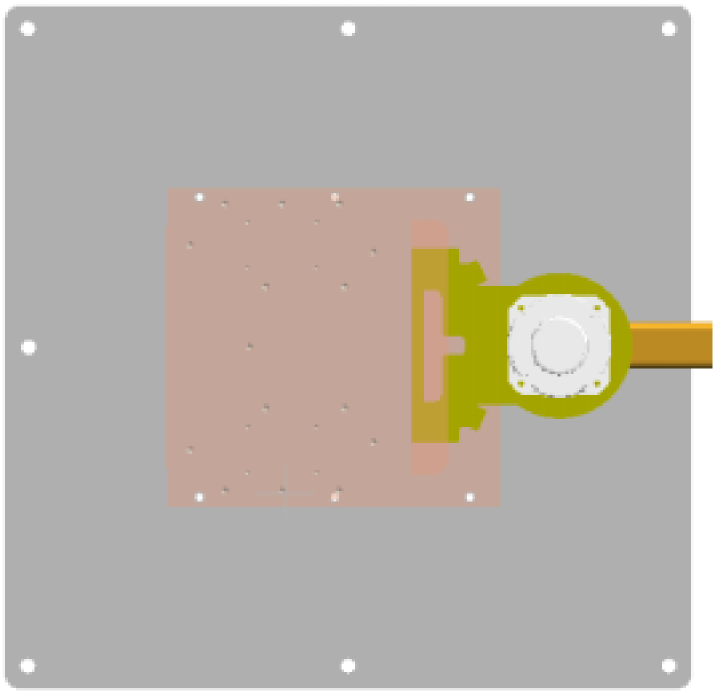
First the current geometry was taken into Dynamic Designer for Solid Edge. The motion model was created by defining the moving and grounded part. Motions were applied to the joints driving the slider, inner arm, and outer arm to represent the worst design case.

To represent the bolts, three springs were used at each bolt hole location. The springs were aligned with the longitudinal and two transverse directions of the bolts. The longitudinal spring values varied from cross sectional ones. The properties were derived from the bolt material and dimensions. Dampers were also included in each direction to account for structural damping.

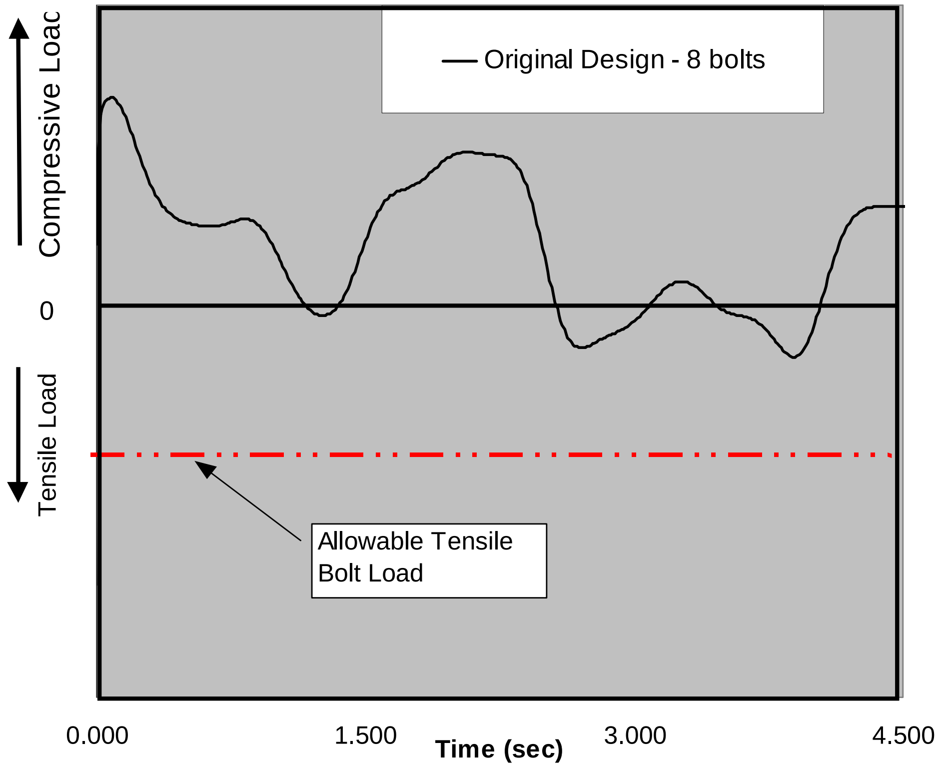
A body was fixed to the end of the outer arm to represent a payload of 68kg.

The pulley cable linking the counterweight to the slider was represented via the use of a joint coupler. This provides proportional movement. The joint coupler was defined such that when the slider went up, the counterweight went down.

Once this was complete, the simulation was run. The following results were found:



Original Bolt Hole Configuration
Figure 3

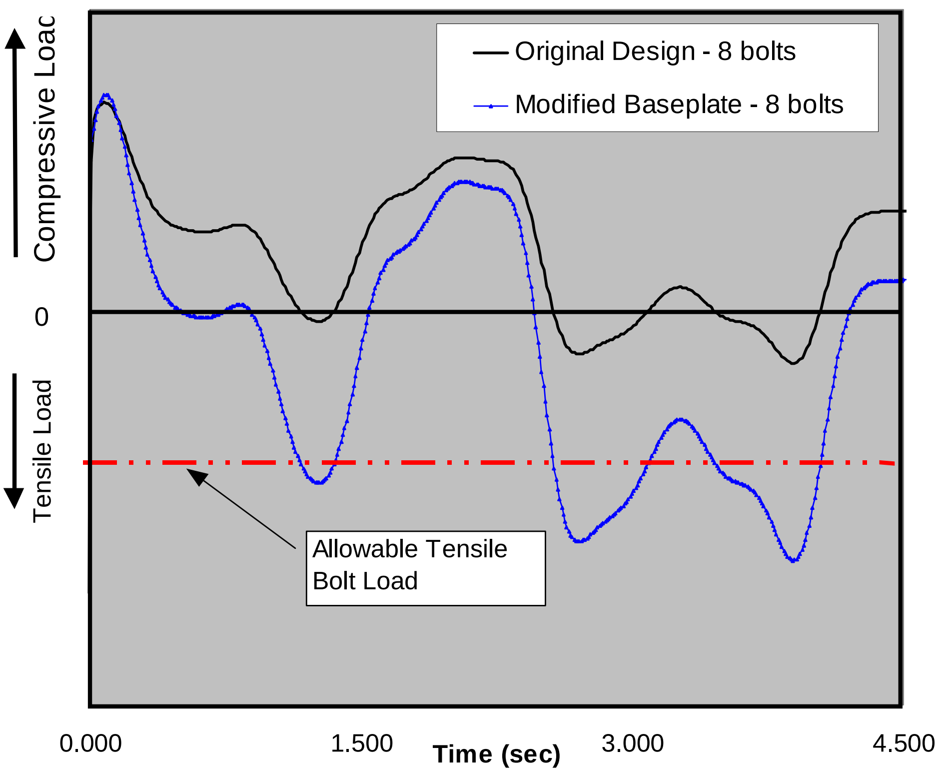


Plot of Critical Bolt Hole Loads for Original Configuration
Figure 4

For a spring, the sign convention is defined so that a positive force indicates the parts are being pulled together (i.e. trying to stay in contact), and a negative force indicates the parts are being pulled away. Therefor if the spring forces becomes negative, the bolt is being pulled apart and the bolt load is tensile (Any compressive load is supported by the ground). The Highest tensile loads occur on the back row of bolts.

We found that with the original configuration, the peak loads at the bolthole locations were 18% below the allowable load. This correlated with work already done by R.A. Jones.

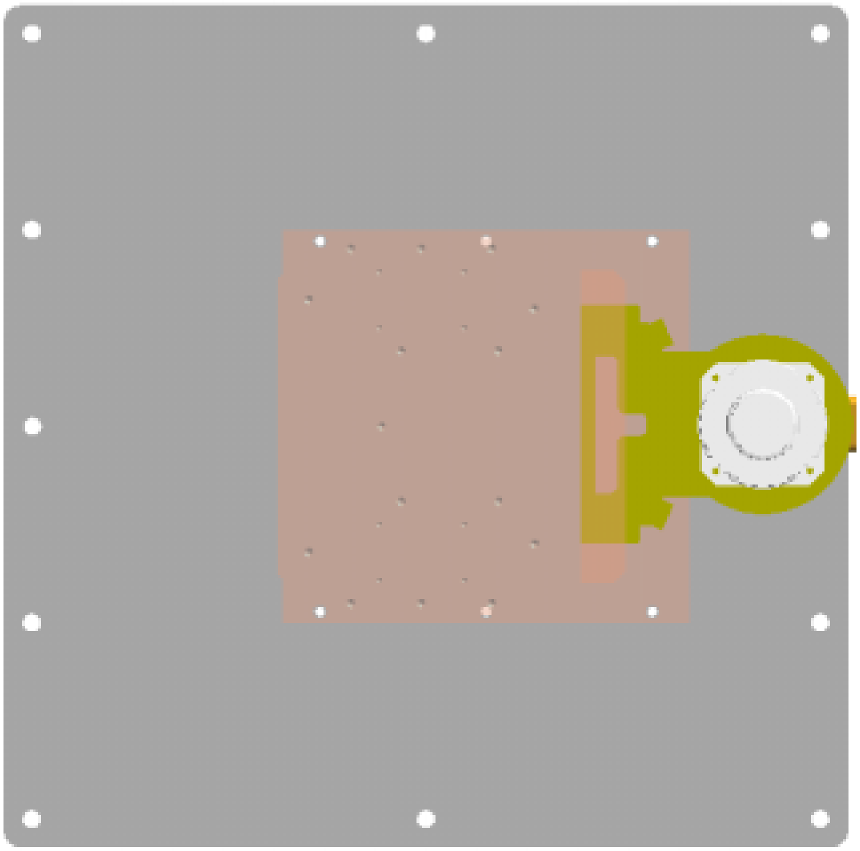
From this point, we changed the configuration of the robot and its mounting position on the baseplate as per the customers specification. Solid Edge provided the ability to easily change the geometry. At this time, the new configuration was run with Dynamic Designer, and the bolt loads were found to be 16% above the allowable tensile load.



Plot of Configuration 2 Critical BoltHole Loads overlay on Configuration 1
Figure 5

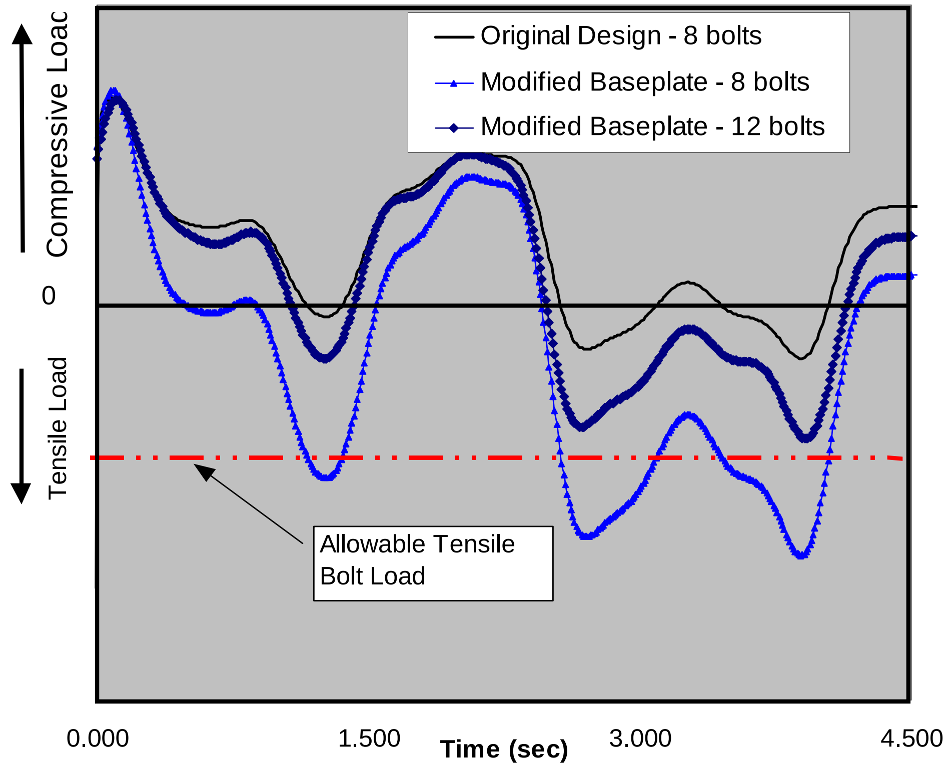
We now have determined that this configuration will work, but the bolt hole loads will exceed our target of 1800 Newton tensile load and therefore ultimately cause failure.

The most desired option to reduce the bolt loading was to add additional bolts to the mounting baseplate. Several options were evaluated under the determined operation conditions and ultimately the following bolt configuration was determined.



Zoom in on Mounting Base of Robot with 12 bolt locations
Figure 6

At the current operating condition, with the new robot configuration and the added mounting points the loading dropped from being 16% above allowable, to 5% below the allowable tensile load and hence result in meeting the customer requirement.



Plot of new Configuration with 12 bolt mounting points
Figure 7

Conclusions

Our goal was to provide the customer with the confidence that the desired changes to the robot configuration would perform under desired operating conditions. Further, our goal was to reduce the risk that the customer had in the failure of the robot either causing a costly shutdown of the assembly process or worse yet, a human injury.

By using sound simulation techniques and Dynamic Designer for Solid Edge, we were able to provide both R.A. Jones and their customer that confidence.

For future simulations we could evaluate additional modifications to the configuration as well as how changes in the speed of operation effect the bolt loads.