

Olympic Precision, Inc. Tech Brief

A Axis Bracket Analysis

Background

A study using Finite Element Analysis (FEA) is conducted to determine the best design of the A axis bracket with respect to mass, first natural frequency, static stiffness, and cost of manufacture. The bracket, shown as part of the entire assembly in Figure 1, is the structural link between the B axis and the A axis.

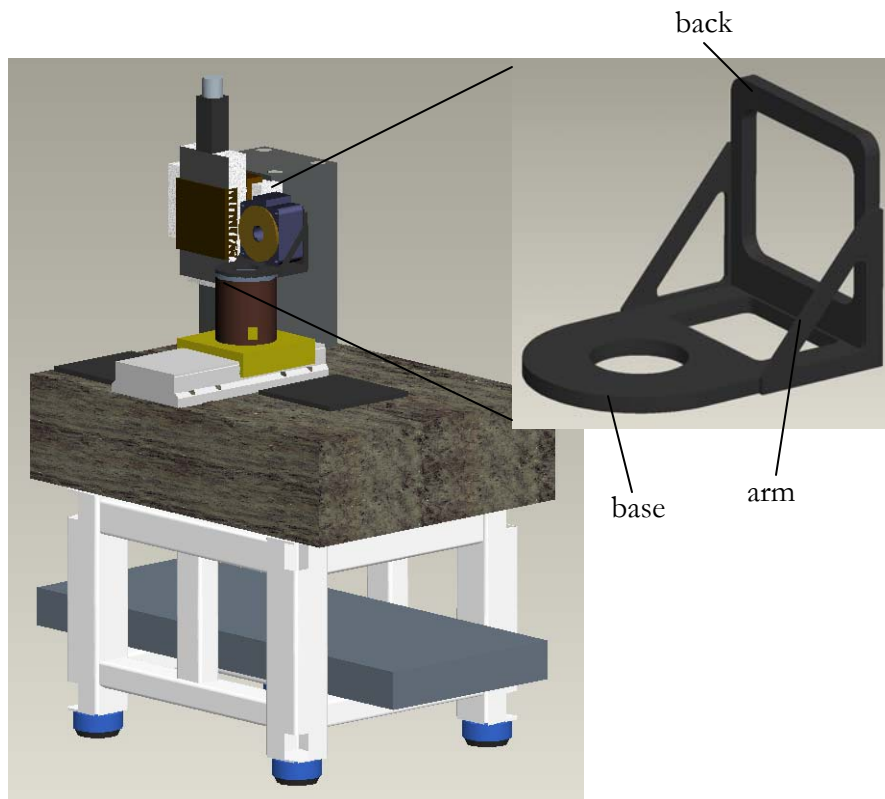


Figure 1: Machine assembly showing the structural link between the A and B axes. The A axis bracket has three major components: 1) base, 2) back, and 3) support arms.

Assumptions

In considering the allowable mass of the bracket, the load capacity of the B axis was the major consideration. The B axis (ADR175-15) has an axial load capacity of 25 kg. By stipulating that the bracket should have a mass of less than 6 kg, the total load on the B axis is 3 kg less than its maximum. The various components that are supported by the B axis are shown in Table 1.

Component	Mass (kg)
A axis	9
A bracket	6
Chuck	4
Workpiece	2
Sensor	1
	<hr/> <hr/> 22
	Total

Table 1: Loading schedule of the B axis.

In addition, it was assumed that the lowest acceptable first natural frequency of the system (bracket with A axis mass), is 120 Hz. The static stiffness in the direction of the A axis should not be less than 10 N/ μm . Finally, it was assumed that the bracket is a bolted assembly made of standard thickness steel flat stock to reduce the cost of manufacture. The preliminary design concept used in the mass optimization is shown in Figure 2.

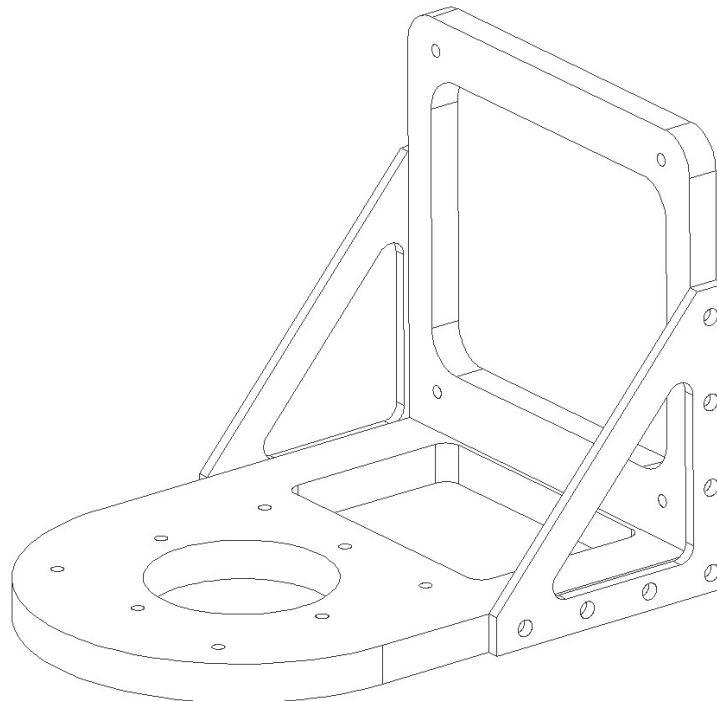


Figure 2: Preliminary design concept used in the optimization.

Modeling

In order to accurately predict the system stiffness and natural frequency, it is important to include the B axis table and the A axis housing in the analysis. The stiffness is determined by applying a 10 N force at the tool tip in the direction of the A axis and measuring the coincident displacement. This is accomplished by using three approximately infinite stiffness springs attached to the A axis housing which converge at the tool tip.

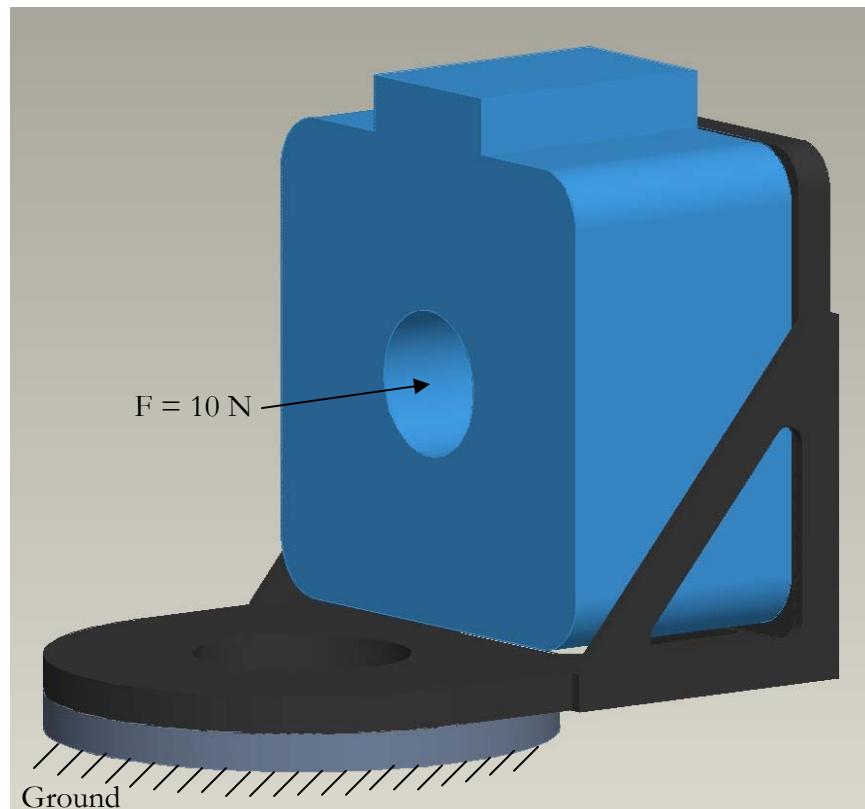


Figure 3: Finite element model of the A axis bracket assembly. The A axis housing is included to simulate its stiffness and modal mass. The B axis table is included to simulate its stiffness and use as a modeling interface to ground.

Results

The optimization procedure for the design of the A axis bracket was conducted in 5 steps: 1) material selection, 2) rib configuration, 3) alternate base plate, 4) optimized lightening holes, and 5) actual thickness selection. Each optimization step was conducted with a goal of minimizing the mass with limits on the stiffness ($> 10 \text{ N}/\mu\text{m}$) and the first natural frequency ($> 120 \text{ Hz}$).

Steel was selected as the bracket material mainly for its stiffness. The competing alternative, aluminum, is 33% lighter than steel, but is also 33% less stiff. From the optimization results, it was determined that the A bracket should be constructed out of steel.

Two support structures were investigated and optimized for the bracket: the support arms and a stepped base plate. It was determined that the optimal thickness of the support arms is less than 5 mm. As a result, a standard plate thickness of 4.76 mm ($3/16''$) was chosen for the support arms. Due to constraints on the design, it was determined that a stepped base plate did not significantly improve the design.

The final phase of the optimization included the addition of lightening holes and selection of the base and back material thicknesses. The optimal base thickness is 17 mm while the optimal back thickness is 14.7 mm. The actual thicknesses, based on availability of standard plate, are 15.8 mm ($5/8''$) for the base and 12.7 mm ($1/2''$) for the back. The static deflection and first mode shape with the actual thicknesses is shown in Figure 4. The optimized design has a mass of 4.9 kg with a stiffness of $10.6 \text{ N}/\mu\text{m}$ and low mode of 120 Hz. A dimensioned sketch is included in Figure 5.



Figure 4: Final bracket design showing the deformation due to the static load. This is also the first mode shape for the modal analysis. The mass is 4.9 kg while the static stiffness is $10.6 \text{ N}/\mu\text{m}$ and the first natural frequency is 120 Hz.

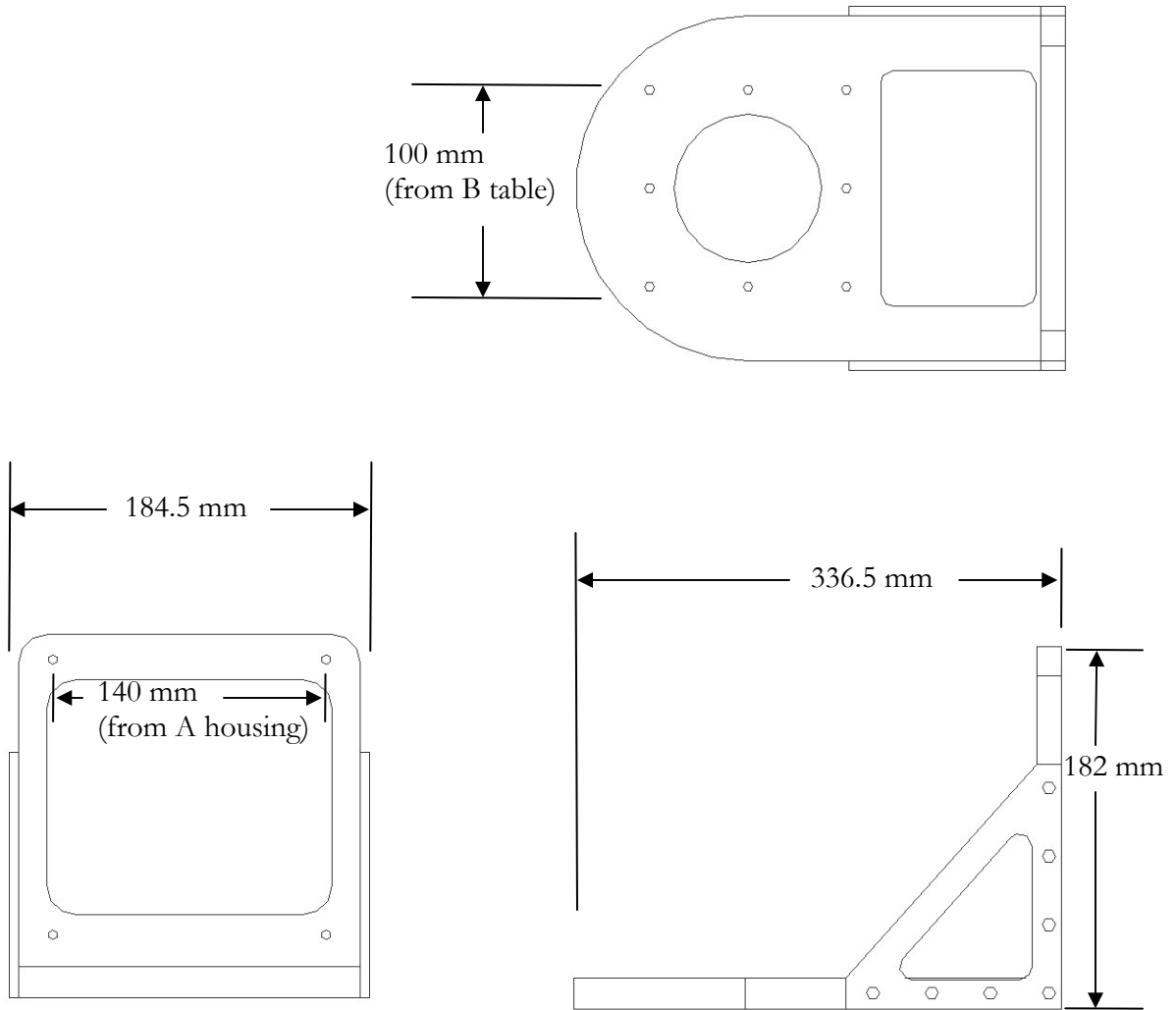


Figure 5: Dimensioned sketch of the final design of the A axis bracket.