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Next Generation Mobile Robotic Drilling and Fastening Systems

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Abstract

Electroimpact has developed a second generation of mobile robots with several improvements over the first generation. The frame has been revised from a welded steel tube to a welded steel plate structure, making the dynamic response of the structure stiffer and reducing load deflections while maintaining the same weight. The deflections of the frame have been optimized to simplify position compensation. The caster mechanism is very compact, offers greater mounting flexibility, and improved maneuverability. The mechanism uses a pneumatic airbag for both lifting and suspension. The robot sled has been improved to offer greater rigidity for the same weight, and dual secondary feedback scales on the vertical axis further improve the rigidity of the overall system. Maintenance access has been improved by rerouting the cable and hose trays, and lowering the electrical cabinet. The mobile robot is sized so it can be shipped complete on a lowboy trailer for deliveries that can be completed by truck. It can also be broken down for container shipping, and reassembly at the customers' site is a straightforward process. The mobile robot can now be placed in position over obstructions by raising the robot on its vertical axis prior to moving it into the final assembly position.

Introduction

The mobile robot is a large volume, high accuracy robotic system for aircraft assembly automation, designed to be quickly redeployed throughout an assembly area, with minimal permanently installed equipment.

It consists of a frame with a vertical axis and mobility equipment, an accurate robot, and an end effector. The frame sets down on 3 hard points, and has equipment for moving the mobile robot, ancillary equipment for the robotic system, and a vertical axis to which the robot is mounted. The ancillary equipment typically includes things such as fastener feed, vacuum systems, chillers, and tool changers. The robot that has been used to date is a KUKA KR500-L340 with secondary feedback mounted. The end effector typically includes a clamp axis, auto-normalising nose piece, and tools such as drill, hole probe, fastener insertion, and resynchronization camera.

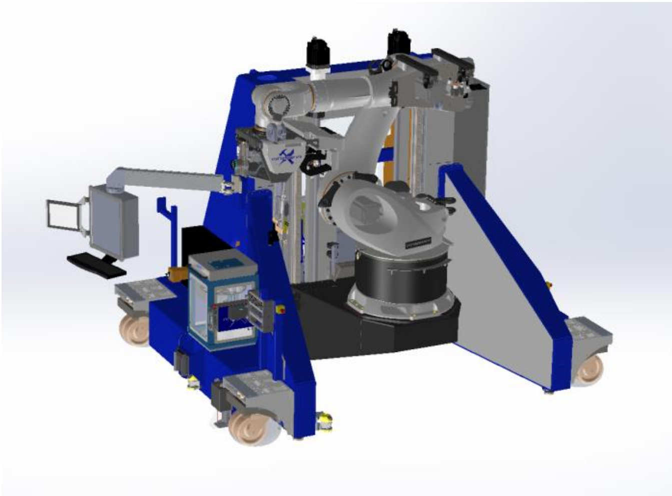

Figure 1: Second Generation Mobile robot

The second generation of Electroimpact mobile robots builds on the foundation built with the first generation, and adds new capabilities and flexibility. Changes have focused on increasing rigidity of the frame, enhancing the customizability of the system as a whole, and improving maintainability.

Mobile Frame

The original mobile robot structure was based on welded tube steel. Inconsistencies in the dimensions of the tube material, along with a desire to increase rigidity while maintaining the same weight, drove a change to a plate steel arrangement. Another consideration was a desire to lower the center of gravity of the system as whole, to allow repositioning the platform while the robot remains at the top of its vertical stroke.

Other changes to the frame included the addition of dual linear scales to the vertical axis, and a more compact Y sled to which the robot mounts.

Frame Structure

Primary changes to the frame structure are a steel plate backing up the Y rails, allowing loads from the Y sled to be transferred efficiently into the frame structure, and a base plate, which describes the plan view of the frame structure, and helps to keep the CG of the frame low. The thickness of the base plate can be varied to help control CG height and position.

The center tower that supports the Y axis was increased in section, which allowed it to behave as a freestanding structure with an integrated base structure, rather than a buttressed tower. This arrangement leaves the base structure clear for ancillary equipment.

The surface of the base structure and lifting casters was kept under 600 mm, both to keep the surface clear for equipment, and to provide ease of access onto the base structure when access is required.

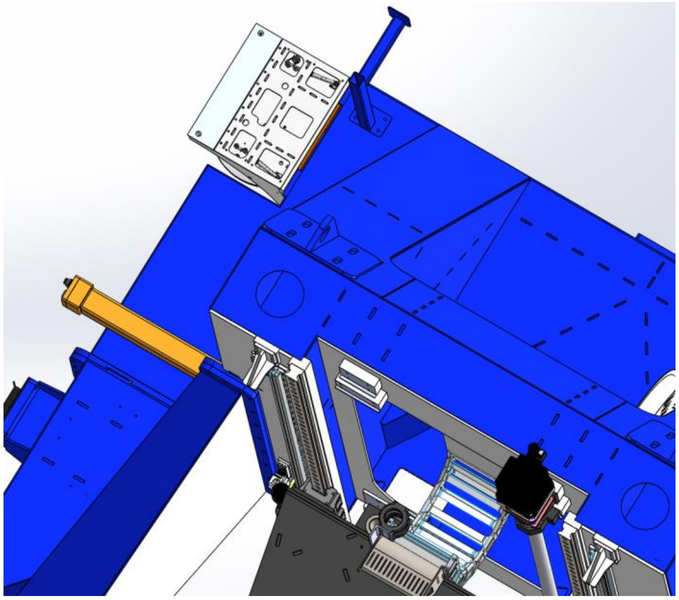

Figure 2: Tower structure with increased section and plate backing up vertical rail

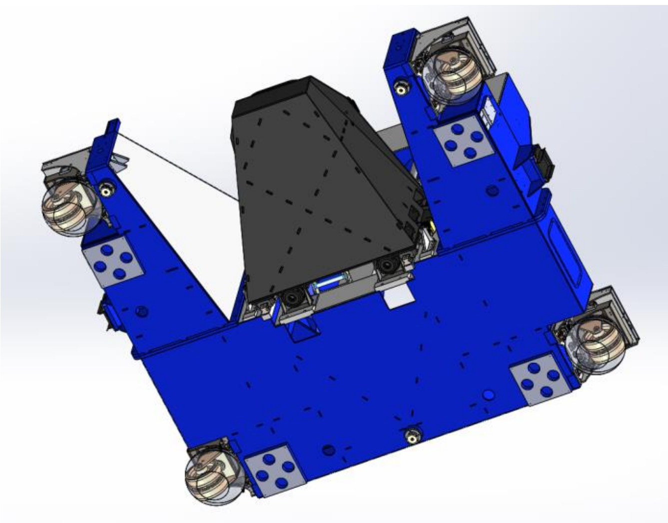

Figure 3: Bottom platform plate keeps CG low

FEA Analysis, Frame

Primary goals for finite element analysis on the second generation mobile robot frames were making the sled-frame deflections consistent, and maximizing natural frequency of the system.

The finite element model included the base frame with the Y sled and robot base constrained to the base frame with linear bearings, each with their own defined rigidity from the manufacturer. All other components (each robot link, electrical equipment, ancillary equipment, etc.) were included in the model as point masses only. This analysis and optimization process resulted in a system with a 7.9 Hz natural frequency, and clamp load deflection at the toolpoint of 0.0016".

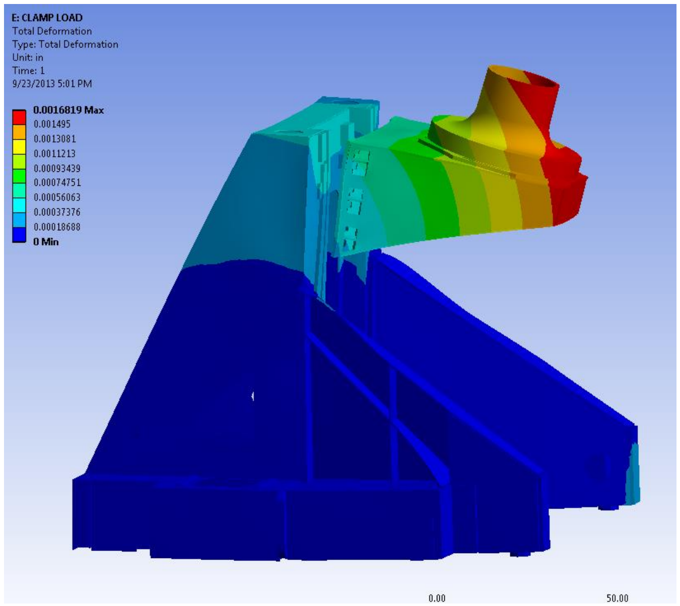

Figure 4: Plate structure gives good control of deflections

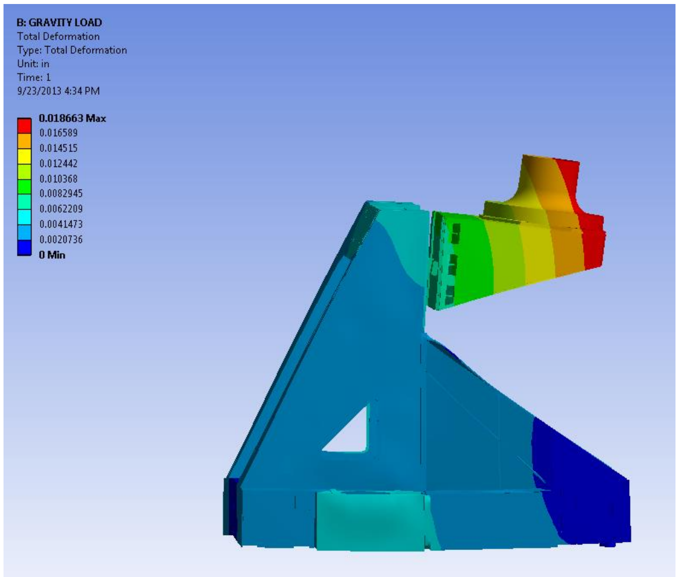

Figure 5: Sled at top of stroke: overall toolpoint deflection 0.034"

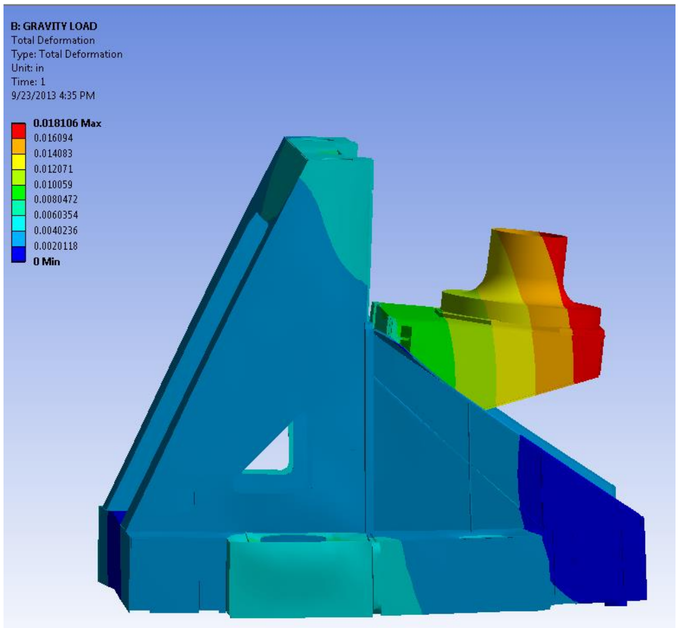

Figure 6: Sled at midpoint of stroke: overall toolpoint deflection 0.033"

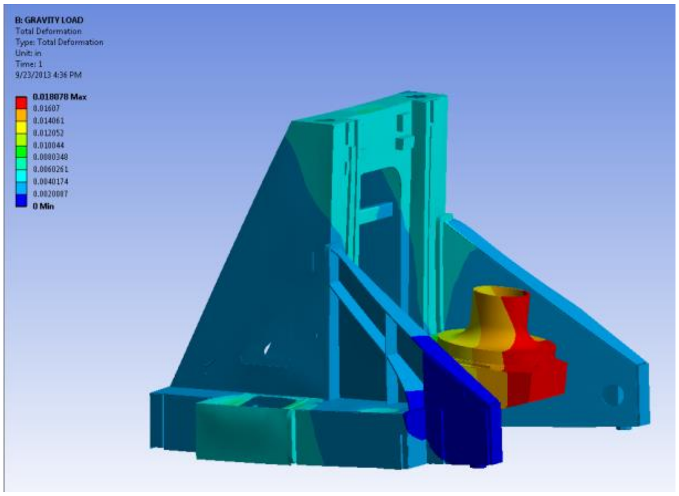

Figure 7: Sled at bottom of stroke: overall toolpoint deflection 0.033"

Y Sled

The Y sled is the welded structure that the robot is bolted to, and it moves vertically to give the robot the expanded vertical envelope. A revision to the KUKA KR500-L340 allowed the distance between the Y axis hardware and center of the robot base to be reduced. This provided an opportunity to revise the overall structure of the Y sled and its stiffness was increased as a result.

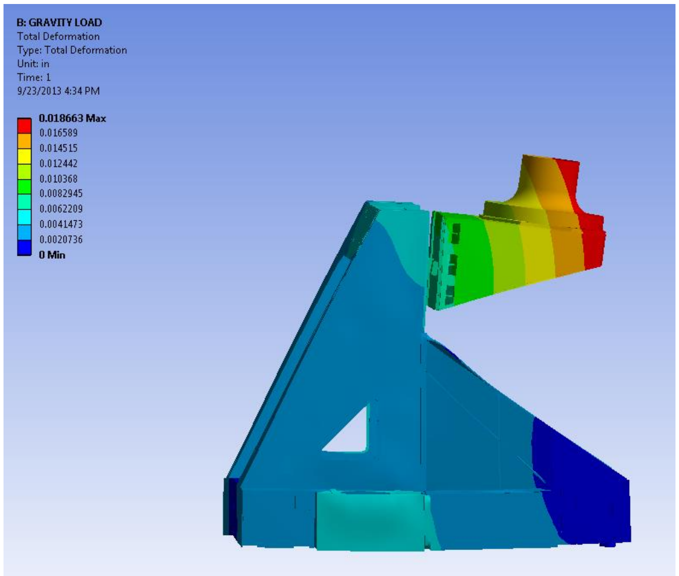

Figure 8: The Y sled was analyzed as part of the system with the frame and the robot base

Y Scales

Dual Y scales were added to the second generation mobile robots. This was done to reduce the springiness of the Y axis ballscrews, and allow the Y axis to behave more like a rigid structure. Coupled with dual Y screws, the dual Y scales significantly enhance the ability of the screws to react the changing loads resulting from the swing of the robot.

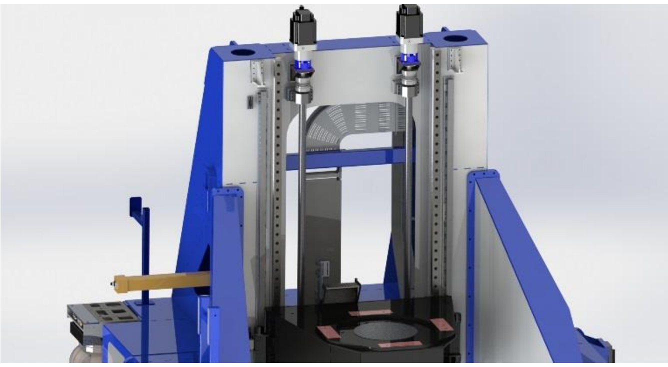

Figure 9: Dual Heidenhain absolute glass scales, mounted outboard of the Y rails

Lifting Casters

The mobile robot frame sits on swivel feet that are rigidly mounted to the frame. This results in robust and predictable contact with the floor during use, when high accuracy is required.

In order to move the mobile robot about the manufacturing area, both lifting casters and air bearings are utilized. The lifting casters must be capable of lifting as much as 10,000 lbs, because they need to be able to lift the mobile robot even if the robotic arm cannot be properly stowed, in the event of a mishap. In order to keep the lifting caster arrangement small, provide this lifting capacity, and provide a small amount of suspension, an air spring coupled with a rigid swiveling caster was employed.

The lifting casters typically lift the platform in approximately 20 seconds; the time can vary with the specific loading on each platform corner. Initial set down takes about 5 seconds, and the wheels lift off the floor at about 20 seconds. Movement of the platform is accomplished with Mastermover electric tugs.

The lifting caster assembly was designed to be slightly lower than the deck of the mobile robot, to maximize the area available for ancillary equipment.

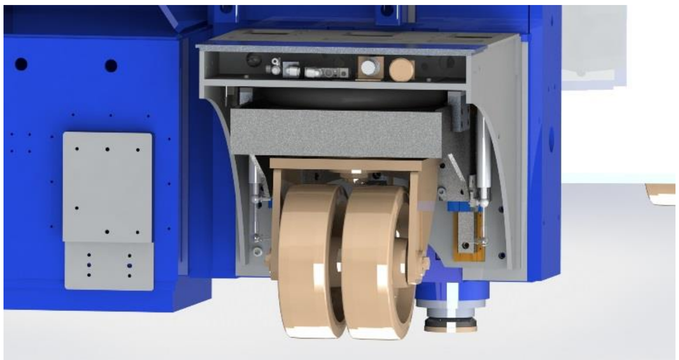

Figure 10: pneumatically deployed caster with rigid mount swivel foot in background

Maintenance Access

Access to equipment for both maintenance and repair was a design consideration for the second generation of mobile robots.

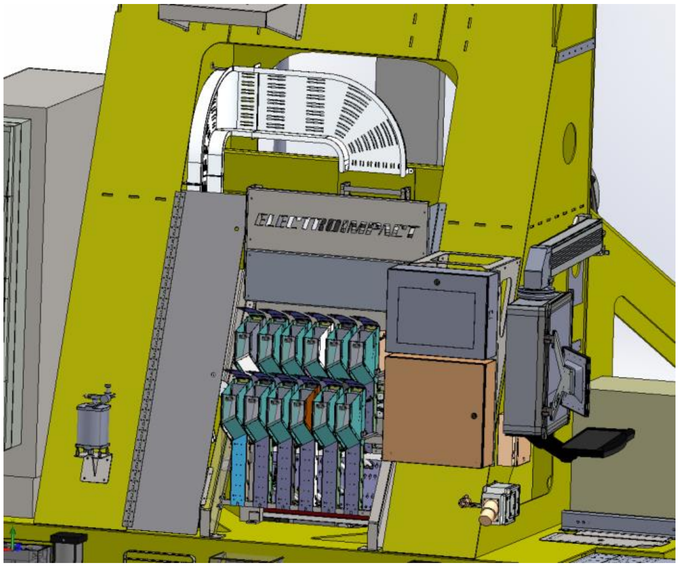

Figure 11: Routing of wireway allows freedom to place equipment, and access to equipment from both sides when it is in place

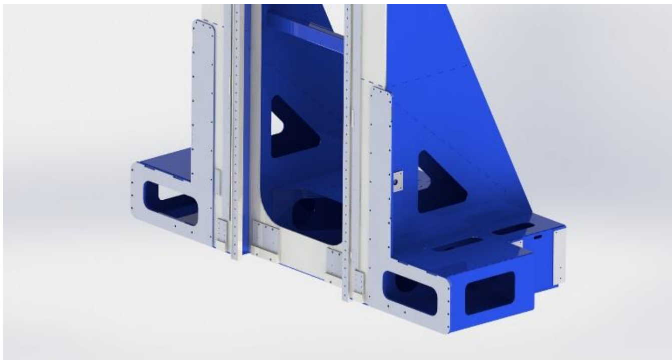

Figure 12: Side bolster and platform deck are designed to be a structural plinth and mounting surface, with good access from top and sides

Over-part access

In order to extend the reach of the mobile robot system and allow access to difficult to reach areas, a system was developed to allow the robot to be positioned over the top of the work piece. This consists of a rail on the floor, a method of engaging the rail, and method of moving the platform while the rail is engaged. In this case, Strothmann rail and wheels are employed because it allows the floor to remain relatively obstruction free. Movement is obtained with Mastermover electric tugs, which are also used for all other platform movement. Prior to moving over the part, the robot is raised to the top of its stroke and a pair of moving hardstops are deployed, which act as functional flags to indicate that the system knows it is over the part and Y movement is locked.

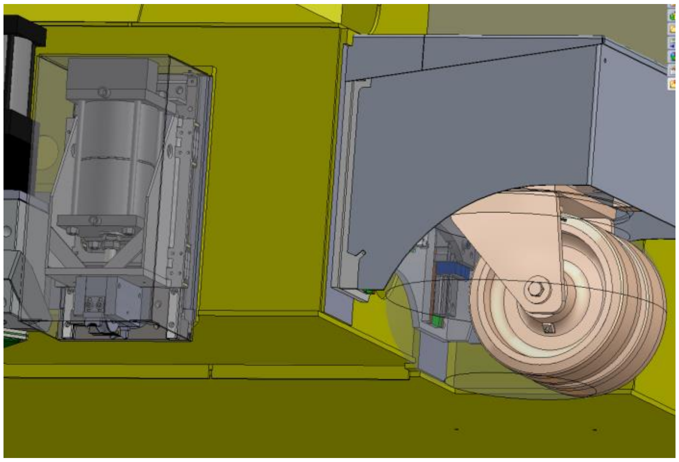

Figure 13: Pneumatically deployed Strothmann wheel for rail guidance, mounted near lifting caster

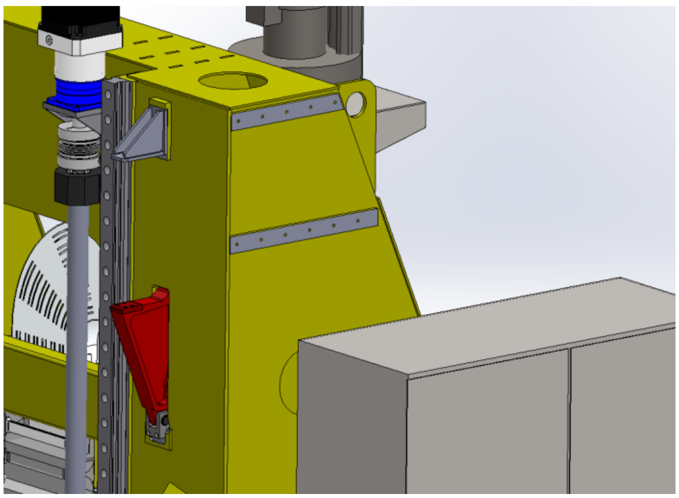

Figure 14: Hardstop/Flag indicating the Y axis is locked out; usually the Y sled would be postioned above the moving hardstop when the hardstop is extended

Summary/Conclusions

While each mobile robot is intended to be highly customizable to match the needs of the customer and task, the second generation of mobile robots aims to provide a rigid basic platform structure that capitalizes on the benefits of the accurate robot and can be quickly reconfigured to the match the task at hand.

References

1. Russell DeVlieg, "Applied Accurate Robotic Drilling for Aircraft Fuselage," SAE Technical Paper 2010-01-1836, 2010.

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