FAMU & FSU COLLEGE OF ENGINEERING
Department of Mechanical Engineering

EML 4552C – Senior Design – Spring 2013

Design for Manufacturing, Reliability & Cost

Mobility Lift for European Insider Applications

Group # 19

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Project Sponsor: Harmar Mobility Inc.

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MANUFACTURING

Our senior design project called for the design and construction of a full size mobility lift prototype for the European market. Sponsored by Harmar Mobility, our tasks were to design a cost effective, lightweight, and compact product with a “European look”. Also, the final design was required to pass static test and cycle test of 10,000 times. Lastly, the final design was required to handle normal real world usage and be compatible with Harmar’s consumer warranty.

One of the constraints set forth by Harmar was that the steel material be used for the bulk of the mobility lift structure. Steel is strong and fairly cost effective. However, its heavy nature increases the overall weight of the structure. Therefore, an FEM structural analysis was performed to determine the lightest and strongest design possible. Our initial design, shown in Fig. 1, had the upper half of the structure comprised of one piece of smooth bent tube. In doing so a minimization of the number of parts needed was reduced, as well as cutting down the amount of time needed for the assembly process. Additionally, this would also aid in lowering the chance of mismatching such as hole alignment.

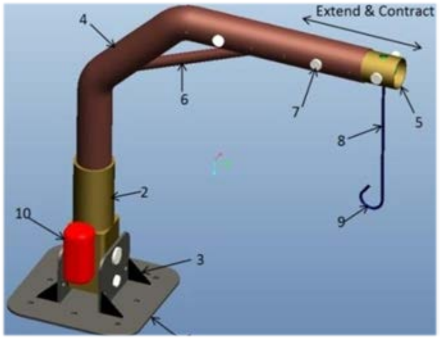


Figure 1: Initial design

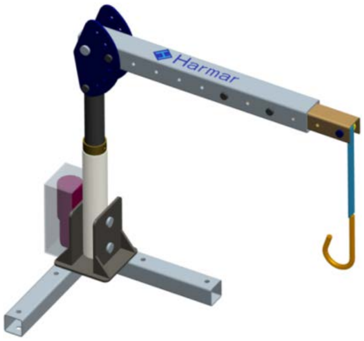


Figure 2: Interim design

As the design process went on, a realization that Harmar’s facilities would not have tube-bending capabilities to manufacture the required part was determined. It is important to note that the majority of these parts for the prototype were to be manufactured at Harmar’s Sarasota production facility. Therefore, an effort was made to redesign the concept and utilize square tubing that would be connected by shoulder bolts and pin. A redesigned base was begun on the results of FEM analysis and sponsor recommendations. The use of square tubing simplified the machining process, as all tubing could now be milled to their correct length and the holes drilled.

After a request by Harmar's European marketing team, movement of the motor closer to the base was implemented and later mounted on gusset plates. The lifting strap was also replaced in favor of a cable in order to minimize the spool dimension to fit in the base. Lastly, and most significantly, a folding hinge was designed to allow for a fully collapsible structure. After testing the motor to determine the torque requirement and the time of lifting, the chain driven sprocket system was done away with and the cable spool was then mounted directly to the motor. This reduced the cost significantly and simplified the assembly process. The number of part was reduced to 26 parts.

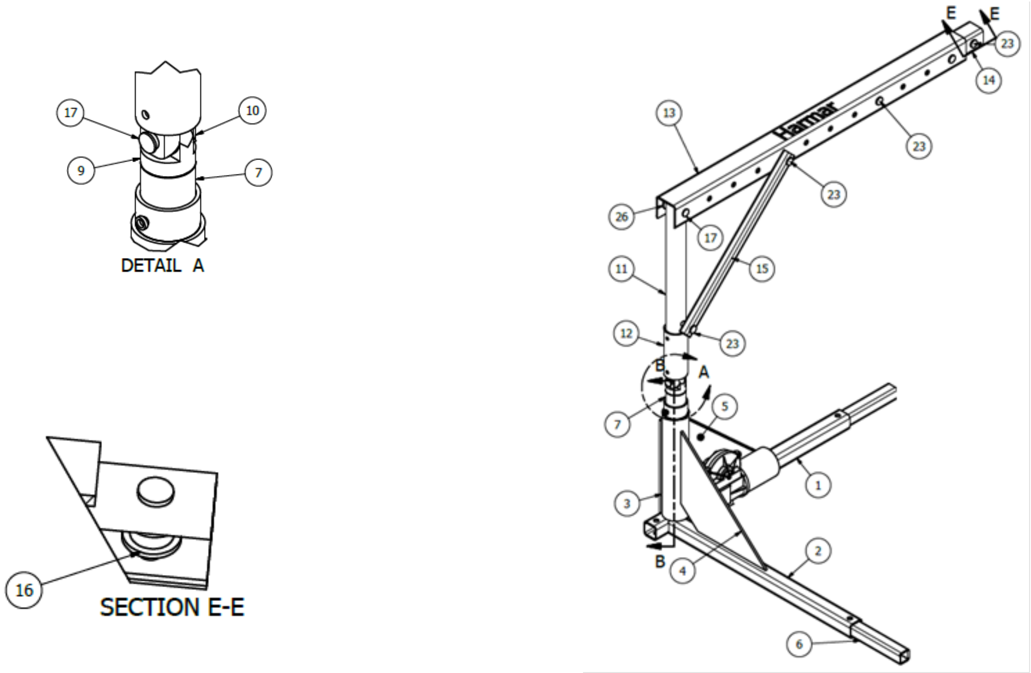


Figure 3: Bill of Materials

As the mobility lift went into the manufacturing stage, there were a few modifications made to the hinges to ease the welding process and lower the chance of misalignment. Extendable legs were also added to allow for placement in a wider range of vehicle trunk and cargo sizes. Harmar's engineers reviewed the assembly drawings and processes and a suggestion to add more detailed sections was suggested. For example, from above picture some details included "A" and "E-E" can be seen. As a request of machining company standards, the tolerance in all holes size was increased

There were a few challenges encountered with the design process. First, being a consumer product, the proposed design must withstand user normal wear and tear, as well as out-live the warranty period. Another, major challenge encountered was the need to work with a nonengineering marketing specialist in Europe aw well as the engineers in Sarasota, FL. Thus, our communications process was a particular challenge. As a result, the approval for a final design was not determined until March. Additionally, the machining process took longer than what was initially determined. Therefore, communication with Harmar twice weekly was needed in the final stages of the semester to account for any modifications necessary. Lastly, Harmar's machine shop had trouble with the tight tolerance initially given to each part, so modifications were implemented and tolerances increased. In anticipation with conflicts stemming from the interface between the motor and hardware, such as the hinge connection, further discussion with Harmar engineers was raised.

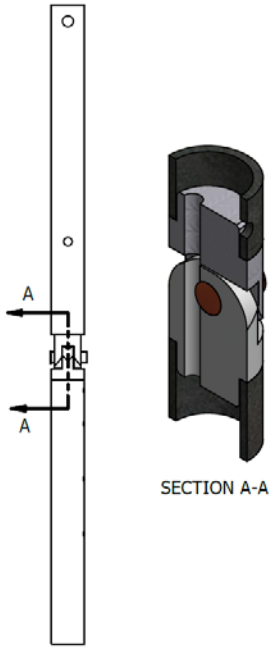
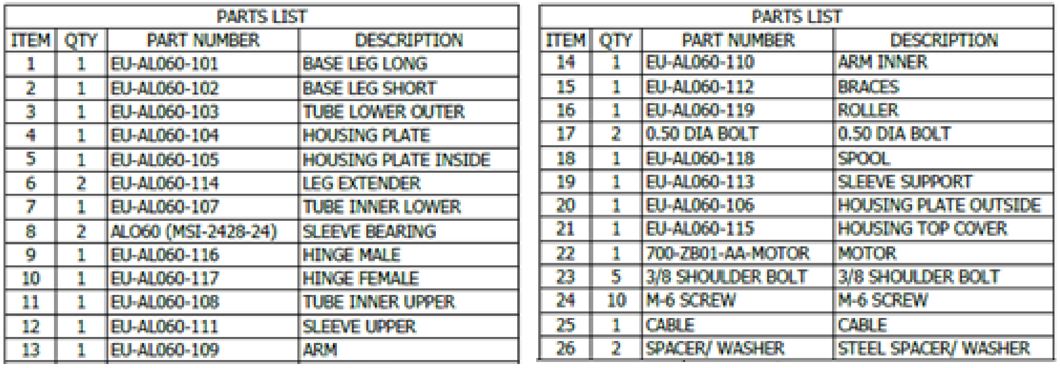


Figure 4: Hinge modification

Figure 5: Exploded/Assembled View



ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	EU-AL060-101	BASE LEG LONG
2	1	EU-AL060-102	BASE LEG SHORT
3	1	EU-AL060-103	TUBE LOWER OUTER
4	1	EU-AL060-104	HOUSING PLATE
5	1	EU-AL060-105	HOUSING PLATE INSIDE
6	2	EU-AL060-114	LEG EXTENDER
7	1	EU-AL060-107	TUBE INNER LOWER
8	2	ALO60 (MSI-2428-24)	SLEEVE BEARING
9	1	EU-AL060-116	HINGE MALE
10	1	EU-AL060-117	HINGE FEMALE
11	1	EU-AL060-108	TUBE INNER UPPER
12	1	EU-AL060-111	SLEEVE UPPER
13	1	EU-AL060-109	ARM
14	1	EU-AL060-110	ARM INNER
15	1	EU-AL060-112	BRACES
16	1	EU-AL060-119	ROLLER
17	2	0.50 DIA BOLT	0.50 DIA BOLT
18	1	EU-AL060-118	SPOOL
19	1	EU-AL060-113	SLEEVE SUPPORT
20	1	EU-AL060-106	HOUSING PLATE OUTSIDE
21	1	EU-AL060-115	HOUSING TOP COVER
22	1	700-ZB01-AA-MOTOR	MOTOR
23	5	3/8 SHOULDER BOLT	3/8 SHOULDER BOLT
24	10	M-6 SCREW	M-6 SCREW
25	1	CABLE	CABLE
26	2	SPACER/ WASHER	STEEL SPACER/ WASHER

Figure 6: Bill of Materials

RELIABILITY

Because this design project will ultimately be marketed to consumers, great effort must be taken to ensure the unit is safe and reliable. To verify the structural integrity of the design, computer simulations were run to identify where (if at all) failure would occur. To accomplish this, a final design was submitted for approval to our sponsor, Harmar Mobility, Inc. With our sponsor's consent of, the design was built in COMSOL Multiphysics for further analysis.

Figures 7 and 8—shown below—provide the geometry mesh along with the respective output. It is important to note the configuration of the model with the lifting arm opposite of the base is made to reflect the alignment of the structure just prior to lifting. From here, the lifting cable is then lowered and attached to the user's wheelchair for placement into the trunk or cargo space of the vehicle. The model mesh was composed of roughly 28,204 elements. This relatively large number of helped provided a better resolution for the subsequently performed stress analysis that was performed next. The distribution of the von Mises stress throughout the structure was determined for a maximum static load of 250 lbs. This translated roughly to a factor of safety of roughly 2 (recall that a normal operating load of 60 kg was specified). This 250 lb. load incurred a maximum stress of 503.73 MPa near the base of the structure, along with a maximum displacement of 0.52 in. The determined safety factor was presented to our sponsor with approval.

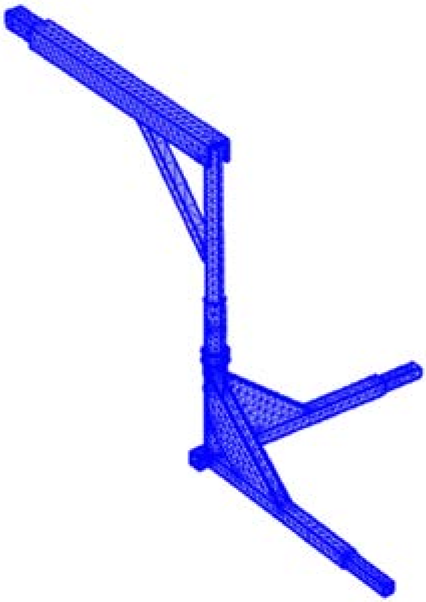


Figure 7: FEM Mesh

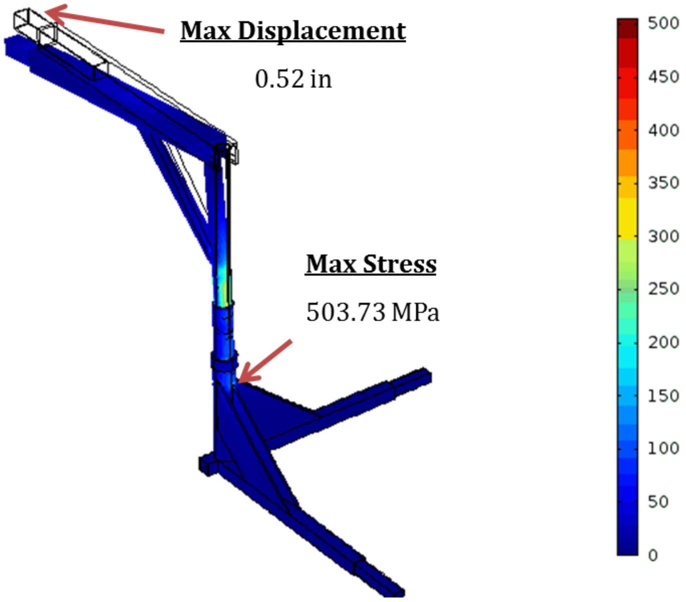


Figure 8: FEM Output

To account for the maximum stress incurred of 503.73 MPa in the structural tubing at the base of the structure, a more robust material was determined to be needed. Given the catalog from which our sponsor is supplied their tubing material, a drawn-over-mandrel ASTM A-513 Type 5 steel with a carbon content of that of 1026 was decided upon. This particular type steel tubing is seen to provide a yield stress of 517.1 MPa, which is enough to account for the 503.73 MPa seen at the maximum designed for static load.

As for the long term reliability of the design, the life of the product is largely dependent on the proper use of the lift. Certain guidelines are given to the user in the accompanying owner's manual (can also be found on the Team 19 design website). To reiterate these guidelines, the user is recommended to regularly check for any worn, loose, or damaged parts on the lift prior to use. Failure to do so may lead to injury to the user and/or further damage to the lift. Additionally, users should consult with their installer or dealer when changing their application needs as the lift is constructed for a particular set of design needs. When attaching the cable hook to the user's wheelchair, the user must insure the lifting cable is secure, taught, and pointing straight down or risk the chair swinging towards the operator or the vehicle. As a further precaution, when using the lift, the user should keep his/her hands and feet from under the chair as it is being loaded or unloaded. The loading process should be stopped before the cable hook contacts the roller mounted on the lifting arm. Contact will ultimately result in damage to the lift. Lastly, the user should insure the chair being lifted sits firmly on the floor of the vehicle and is not suspended by the lift during transportation. If not, movement of the chair may occur will driving and cause damage to the lift, vehicle, passengers, or the chair itself.

Additionally, the amount of care and maintenance provided by the owner will aid in the longevity of the lift. It is recommended that dealers schedule annual preventative maintenance inspections on the entirety of the lift. This includes that motor, lift frame, wiring harness, and internals. The lifting cable, however, should always be checked by the user before each use. Although the lift and hand controller are somewhat weather-proof, prolonged exposure to the elements while loading or unload should be kept to a minimum. If the lift should prove to be faulty, the proposal of a three year warranty period is suggested. This warranty period is consistent with other products offered by Harmar with similar applications.

ECONOMICS

In our case the most cost effective approach to creating the prototype was to allow the sponsor, Harmar Mobility, to obtain the parts. Since the company already utilizes the majority of the items we are using to build this prototype, they had many in stock, and those they didn't have in stock, they could order through their supply company, ALRO, at their 'bulk' rates. There were only a couple items that the company did not have access to, which included the Kevlar rope and the hinge that was machined in house at the college of engineering. The Kevlar rope can be obtained in bulk to cut the cost, but for this prototype, only 20 ft. were purchased through Amazon.com because the cost was lowest. The hinge is the only unique part that we created, and can possibly be made in bulk to cut the costs. All of the parts are to be powder coated, and the sponsor also took care of that, utilizing the company that does all of their powder coating.

The manufacturing process cost can only be estimated at this point. Because of the simplicity of our design as compared with other design projects, our cost should be quite low. Since the parts are not actually being manufactured, and simply ordered, the manufacturing cost falls into the material cost category, with exception of the hinge.

Assembly and finishing cost will include the labor time to assemble, the tools required to assemble (like files if the tolerances are not enough to allow a snug fit, etc.), the time to install the unit into a vehicle, the time to instruct the user on how to use the lift system, as well as other variable that cannot be determined at this time. All of the above costs can only be estimated. The prototype has not yet been assembled, and the time it requires cannot be estimated. However, any tools we may need to assemble, the sponsor already has in their 'assembly' department and are available for us to use at no cost.

Testing the prototype we will be using a battery pack that Harmar will be loaning to us. This battery pack is similar to the battery that would be in a vehicle, since that is the power supply that will normally power the lift. The testing will take some time, it needs to run through 10,000 cycles at the max capacity to make sure the lift and components can withstand the daily use by consumers.

With respect to inspection cost and competition cost, these are not associated with our prototype. There are currently no laws or regulations in place with regards to mobility lift in vehicles.