CHAPTER 21
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ALL TERRAIN TRANSPORTER FOR TWO DOUBLE AMPUTEES

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INTRODUCTION

An all terrain transporter was designed for transporting two children who were born without forearms or lower legs from the knee and with separation between the residual femurs and the hip sockets. The profiles of the children are illustrated in Figure 21.1. Movement is difficult for either boy. Attempts to move are achieved by crawling on the stomach. Lifting the children into and out of a cart is difficult for the caregivers.

SUMMARY OF IMPACT

The design criteria for the all terrain transporter (see photo in Fig. 21.2) were defined by the limited capabilities of the children. Point-to-point mobility in parks, playgrounds and beaches would be impossible by crawling on the stomach. The children have large waist areas, making usual children's carts impractical. Lifting a total of 115 pounds twice at each stop, and several times in a trip, causes physical difficulties for the caregivers. As a result, the family desired a portable transporter that both the children can safely enter and leave independently. This allows the parents to leave home for parks, swimming and the city circus when they desired.

TECHNICAL DESCRIPTION

After meeting with the parents, the dimensions of the frame were established to be approximately 40 inches long, 18 inches wide and 6 inches high. The frame is constructed welded from 6061-T6 aluminum tube stock with 1/8-inch inner wall thickness. Frame junctures are at 45 degrees. Aluminum was chosen because it is lightweight and has the capability to withstand the load of the two children. This was verified using finite element analysis on the frame.

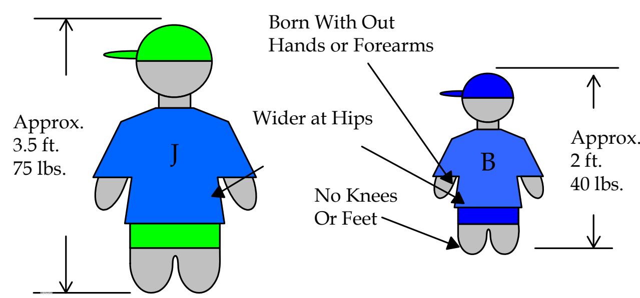

Figure 21.1. Boys' Profile.

Figure 21.2. All-Terrain Transporter.

The transporter is modeled in Pro-E, and a software package called COSMOS Works for Solid Works is used to perform the finite element analysis for the frame. Of particular interest are answers to design questions about structural integrity, deflection, thermal loads, natural frequency, buckling, and safety.

Tests have been conducted with loads above and beyond the intended load for the transporter applied to the frame. The material used is 6061-T6 aluminum with a yield tensile strength of about ~40,000 psi and the ultimate strength about ~45,000 psi. Stress analysis has been performed on the frame, shown in Figure 21.3, at 400 pounds, which is a safety factor of roughly three times the combined weight of the children.

The results (Figure 21.3) show that, during bending, the welded joints are most vulnerable. However, the magnitude of the stress at the highest areas was 1.4e004 psi. The yield strength positively shows that the children may bounce during transportation without forcing the frame to yield. Similar positive results have beenobtained with torsion and displacement tests.

The wheels chosen are bicycle wheels for the back and inflatable casters for the front so that they can travel over various terrains, and can be pushed by one parent. Two lightweight fiberglass composite seats were used for their weight and ease of maintenance. With the push column equipped with bicycle type hand brakes, the final product is completed as illustrated in Figure 21.2. Upon completion, the all terrain transporter was presented to the parents.

The cost of parts/material and some labor is approximately $800.

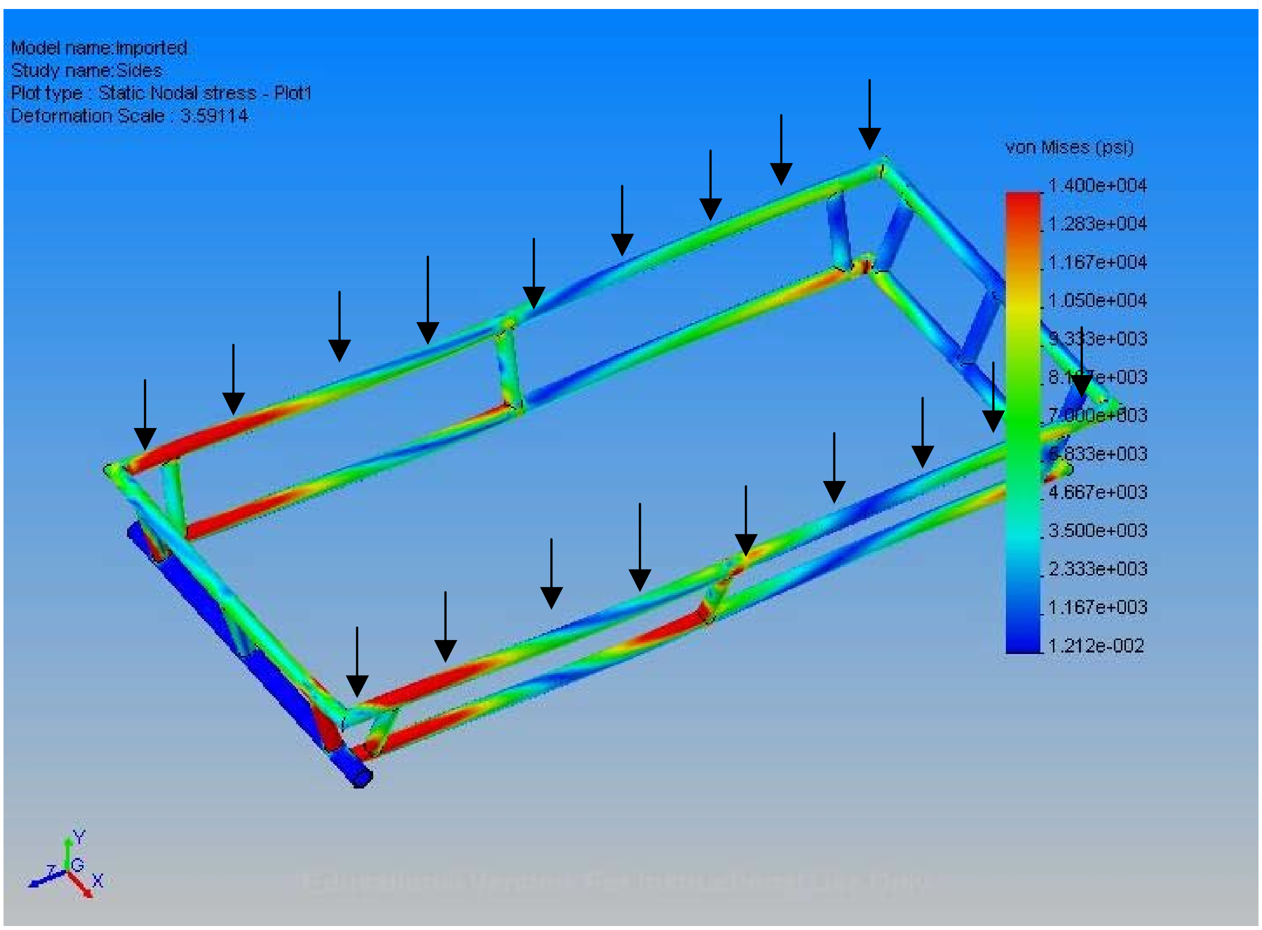

Figure 21.3. Frame's Bending Moment Distribution.

ACUPUNCTURE NEEDLE WARMING AND TEMPERATURE FEEDBACK

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INTRODUCTION

Acupuncture is a practice that consists of inserting extremely fine stainless steel needles into the skin to excite particular anatomic spots in the body for curative objectives. The needles are independently enveloped and utilized only once since they should be sterile before being inserted through the skin. In addition to the customary technique of puncturing the skin, the procedure may include use of heat to warm the needles, pressure, and other methods that help to relieve pain more quickly. This design was focused on the warming process and providing the user with needle temperature feedback. The maximum temperature should be 105 degrees Fahrenheit.

SUMMARY OF IMPACT

Obtaining medicinal herbs for warming the needles is not only far fetched but is unfamiliar to the client. Attempts to use electrical heating without knowing the temperature was not an option since it could produce unwelcoming surprises and pain. The design would allow the client to warm the needle to the desired temperature of 105 degrees Fahrenheit. This will allow the client to use acupuncture more often.

TECHNICAL DESCRIPTION

Two types of acupuncture needles were evaluated for dimensions. Both have a diameter of 12/1000th and 55/1000th of an inch at the tip and base respectively. The common feature was an advantage in designing the rectangular-shaped warming device. The design called for creating multiple chambers for inserting multiple needles for concurrent warming. A rectangular heating structure 3.9" x 2 3/8" x 0.5", illustrated in Figure 21.4, was developed from an aluminum stalk. A photograph of the prototype is shown in Fig. 21.5.

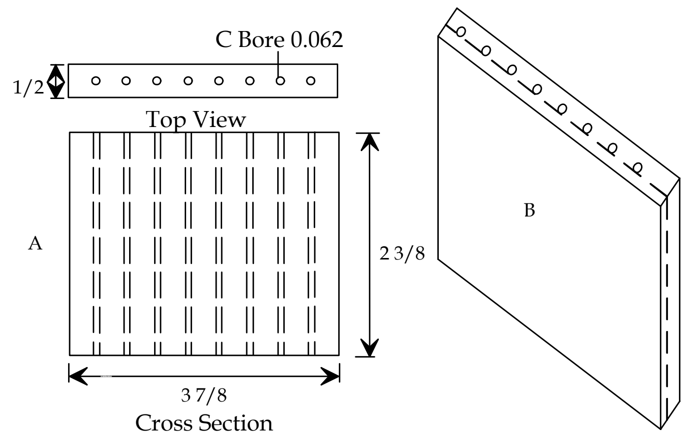

Figure 21.4. Schematic for Warming Eight Needles.

Figure 21.5. Rectangular Needle Warmer.

The desired temperature was between 103 and 105 degrees Fahrenheit. In the absence of a temperature controller, the temperature was set by the amount of current (voltage) flowing through the coil. The necessary voltage that permitted the device to warm up to 105oF using the Kapton flexible heater (see Fig. 21.6) had to be determined. At steady state the rectangular warming system should have been at the optimum desired temperature so that the needles were warmed to that desired temperature. As a result, a Kapton flexible heater heating coil, with measured resistance of 75.4 Ω, was used.

A power supply with a maximum current limit of 1A was determined appropriate at a maximum of 28 volts to quickly warm up the heating structure and the needles to the desired temperature. The level of temperature feedback was provided with an RTD version of the DP 371-P2CX temperature digital panel thermometer (see Fig. 21.7).

Tests were conducted to determine the heating characteristics of the rectangular heating structure in terms of duration, voltage and current level. Tests showed that a 15-volt source capable of delivering 0.2 A of current was able to warm the heating structure to the desired temperature in eight minutes. The warming time could be cut drastically with a slightly higher voltage source and current level. In this case a temperature regulator would be necessary.

The cost of the prototype and parts was $363.

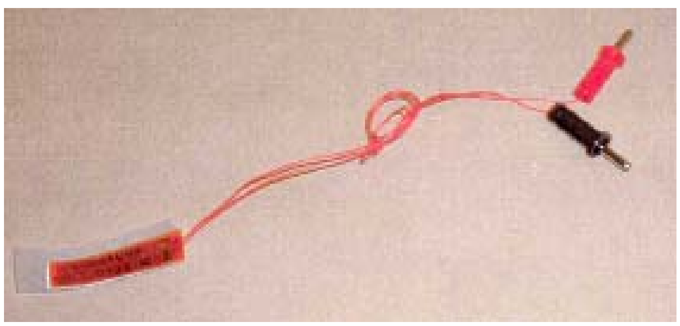

Figure 21.6. Kapton Flexible Heater.

Figure 21.7. Temperature Digital Panel Thermometer.

ADAPTATION OF HEIGHT-ADJUSTABLE OFFICE CHAIR FOR STIFF KNEE SUPPORT

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INTRODUCTION

A height-adjustable office chair was adapted for a data entry clerk who has an immobile left knee joint due to a diseased state and repeated knee joint surgery. Without leg support while seated at work, pain and discomfort occur. The client quit working because of persistent pain and discomfort after trying compensatory changes in body posture (Figure 21.8). Upon completion, the adapted office chair (Figure 21.9) was presented to the client.

SUMMARY OF IMPACT

The design criteria for the adapted office chair to support the left knee joint were defined by the compensatory methods illustrated in Figure 21.8. With zero flex and extension of the left knee joint, some compensatory methods created poor posturing, pulled the body out of alignment and increased muscle tension resulting in recurrent pain. As a result, the client quit work. The design allowed the client to return to work because the pain was eliminated.

TECHNICAL DESCRIPTION

After meeting with the client, the design team decided on the functional aspects of the adaptation. Existing methods of knee joint support in some wheelchairs was considered more favorable than creating a new device. The technical design concentrated on adapting the mechanism to an office chair and in such a way that the adaptation moved up and down and rotated with the seat base of a height-adjustable office chair. The focus of the design was to adapt an office chair to enable the client to return to work. The goal was for the adapted chair to support the weight of the leg and be comfortable. The adaptation had to be easy to operate and allow for height and rotation movements. The chair also had to be aesthetically pleasing. An Office Deport chair D500P was selected because it has armrests, has adjustable seat height, depth, and back tilt, is durable, and aesthetically pleasing.

Figure 21.8. Client with Compensatory Posture.

Figure 21.9. Client with Adaptation.

The adaptation consisted of the following sections: the hinge joint, telescope rod for length adjustment, knee support, and foot support (Figure 21.10).

Adaptations also included a mounting to the seat base, and the channel cutout to allow the use of large knobs for length adjustment to support the knee (Figure 21.11).

Tests were conducted with the leg of an individual bigger than the client without negative results. There was no misalignment at the pivot joint or bending of the inner rod in the telescoping tube.

The cost of parts/material and labor was about $175.

Figure 21.10. Hinge Joint Knee Support and Foot Support.

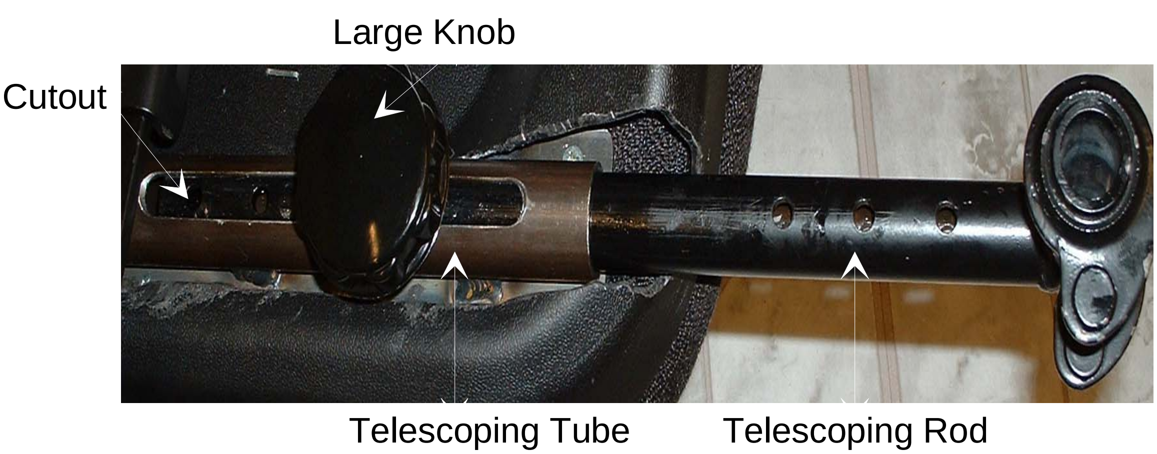

Figure 21.11. Mounting Adaptation to Seat Base and Cutout for Positioning of Left Knee Support.

SEAT HEIGHT CONTROL FOR A CHILDREN WITH DISABILITIES

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INTRODUCTION

The control of a height adjustable seat was modified to enable a child born without forearms, without lower legs from the knees, and with separation between the residual femurs and the hip sockets. He is two feet tall and, with limited reach, is unable to control seat height adjustments. Upon completion, the adapted chair was presented to the parents of the client.

SUMMARY OF IMPACT

The client's short residual hands to the elbow made it difficult for him to use the original adapted quiet actuator to raise and lower the chair in his classroom. Calling the teacher to help undermined the purpose of the quiet actuator that operates without being noticed by nearby classmates. Incorporating adaptive control positioning with mechanical advantage gave the boy the ability to operate the chair independently. The modified control eliminated the need for the client's teacher to help him raise and lower his chair during class or worry about him falling off the chair.

TECHNICAL DESCRIPTION

From parents' input and limb anthropometrics it became clear that modifications to improve the client's reach should drive the design. A height-adjustable office chair from Office Depot was purchased for the project. A DC actuator (ECOMAG 20) by Magnetic Corporation was used to provide the support of the seat and the telescoping functions to achieve required seat height adjustment. The actuator noise was very low, satisfying the noise condition for classroom use.

A hollow interface was designed with an inside diameter to match the end of the DC actuator pillar. The outside diameter was designed to fit inside an oval space at the center of the wheel base structure. The hollow structure was firmly attached to the end of the pillar with a tight press-fit nut. Modification was made to the seat metal bracket to provide an interface between the other end of the actuator and the seat base. This was accomplished through made-to-fit metal gaskets and a tight fitting fastener. With the wheel assembly firmly coupled to one end of the actuator pillar, and the other end of the actuator firmly coupled with the seat base using the modified bracket, mechanical adaptation was completed.

To supply electrical power to the actuator, an 18-volt rechargeable battery was mounted beneath the seat with the necessary electrical circuitry connected to the switch. To engage the switch as purchased required too much effort and dexterity; also, the switch lever arm has limited length and surface area. A special adaptation was made to provide a mechanical advantage to overcome the limited lever arm length. This was accomplished by extending the switch lever arm by one foot, and the switch with the modified lever arm was mounted from a stand off the base of the seat. An L-shaped stand off illustrated in Figure 21.12 was introduced from beneath the chair to ensure improved reach for the child.

The surface area of the original switch lever arm was then increased by a factor of 10 times from a 0.2" diameter to 2" diameter with surround flexible rubber. The mass of the enlarged lever arm (joystick) was increased to require minimum push to activate the implemented double pole-double throw center tap switch type. The final product is as shown in Figure 21.13.

The total project cost was $352.00 for the pillar and parts.

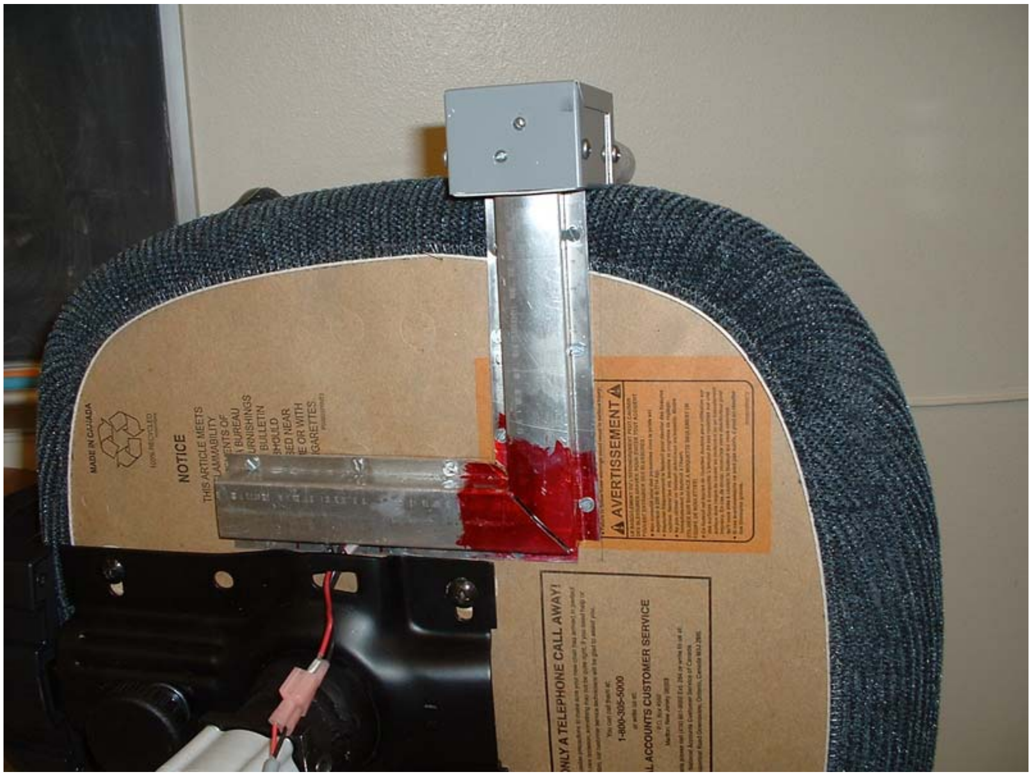

Figure 21.12. L-shaped Standoff to Increase Reach to Control Joystick.

Figure 21.13. Raising and Lowering Control Using Enhanced Lever Arm (Joystick).

NEUROMUSCULAR EXERCISER FOR DIABETIC AMPUTEE

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INTRODUCTION

The purpose of this design project was to develop a mechanically-induced muscular contraction system for a client with diabetes and lower extremity amputation who has a sedentary lifestyle. With a history of reluctance to exercise and a diabetic condition, the impact of blood pooling in the lower extremity had progressed to below-the-knee amputation. The client is seeking alternative methods of exercise to improve circulation and his general health condition. Alternative methods of induced muscular contraction include functional electrical stimulation, but this causes pain. Compression methods are used to induce venous return but are not very effective and show little improvement in muscle tone. The engineering design aspects of a mechanically-induced muscular contraction system were completed.

SUMMARY OF IMPACT

The design criteria for the mechanically-induced muscular contraction were defined by the sedentary lifestyle of the client, the loss of his lower limb and the safety factors regarding responses of human organs to vibration intensities. With sedentary lifestyle the client's health worsened. With clinical advice, he was seeking ways to exercise. The design would allow the client to get more venous return, better muscle tone due to contraction and more bone density due to stresses on the bone during exercise.

TECHNICAL DESCRIPTION

After investigating susceptibility of body parts to resonance of types of vibrations, a controlled mixed mode of vibration was implemented. After considering the modes of application, transmission distance and pathways, a two-stage application mode was developed. Technical design concentrated on adapting the mechanism to an office chair in such

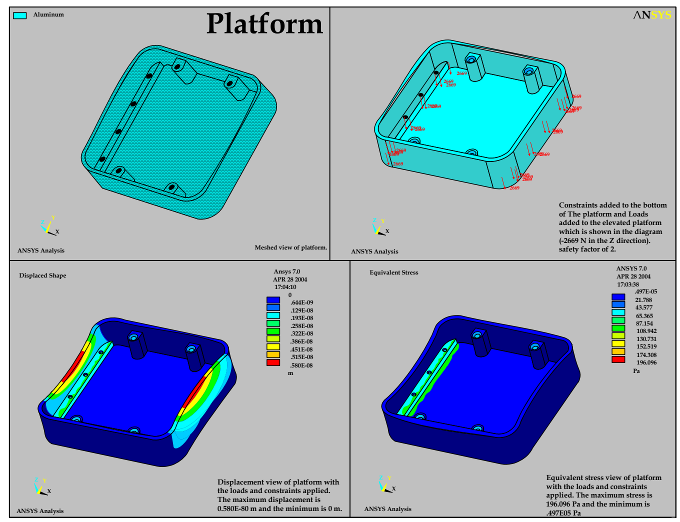

Figure 21.14. FEA results of maximum displacement and equivalent stress test of support platform.

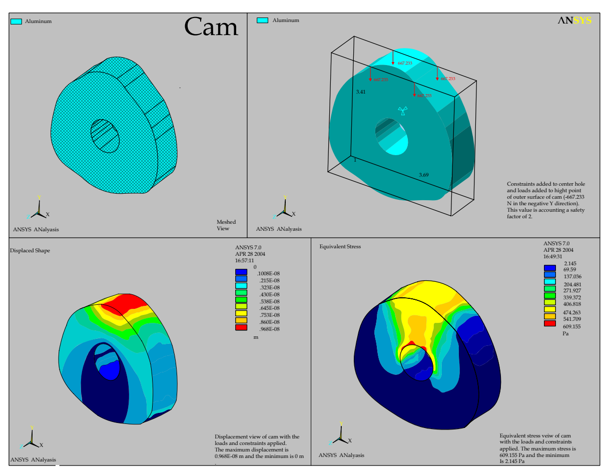

Figure 21.15. FEA Results of Maximum Displacement and Equivalent Stress Test of Cam with Aluminum Stalk.

a way that the application could be implemented in single or two-stage mode.

The focus of the design was to incorporate the exerciser into an office chair. The adaptation had to be easy to operate. An office chair with armrests, and adjustable seat height was purchased from Office Depot. The seat was used to model the support for the mechanical stimulation system. Some of the subcomponents were designed with steel and aluminum stalks. Typical physical and mechanical properties of aluminum stalk considered were 215-505 MPa yield strength, 230-570 MPa tensile strength, and elastic modulus of 70-79 GPa for density 2600-2800 kg/m3. Similarly for the steel stalk considered were 380-440 MPa, yield strength, 640-2000 MPa tensile strength, and elastic modulus of 190-210 GPa for density 7720-8000 kg/m3 all at room temperature.

Finite element analysis (FEA) was performed on parts of the system to determine if the design could withstand the necessary loads that would be applied. All FEA analysis was conducted in ANSYS. It had to support the weight of the seat assembly, seat support assembly, platform assembly, and the weight of the client. FEA was performed on the cams, platform, frames seat support and shaft at different loading conditions with a safety factor of two. Figures 21.14 and 21.15 are the FEA results of the platform with the cams and drive mechanism, and the weight of the individual.

FEA results were obtained for the cams, frames and shaft. The results under the loading and constraining conditions are shown in the Table 21.1.

The results show stresses under the yield strength. Displacements were small for both aluminum and steel stalks. The unique shapes to satisfy design requirements required detailing the parts for rapid prototyping production.

The cost of Office Depot chair was about $75.00.

Part	Load (Lb)	Max. Stress	Max. Displacement
Cam: (Maximum distance)	150	609.155	9.68e-09
Cam: (Minimum distance)	150	691.653	9.64e-09
Platform	600	196.096	5.80e-09
Frame	800	81971	1.74e-05
Seat Support	600	1096	9.73e-09
Shaft	300	8253	2.91e-07

Table 21.1. Load and Constraints for FEA.