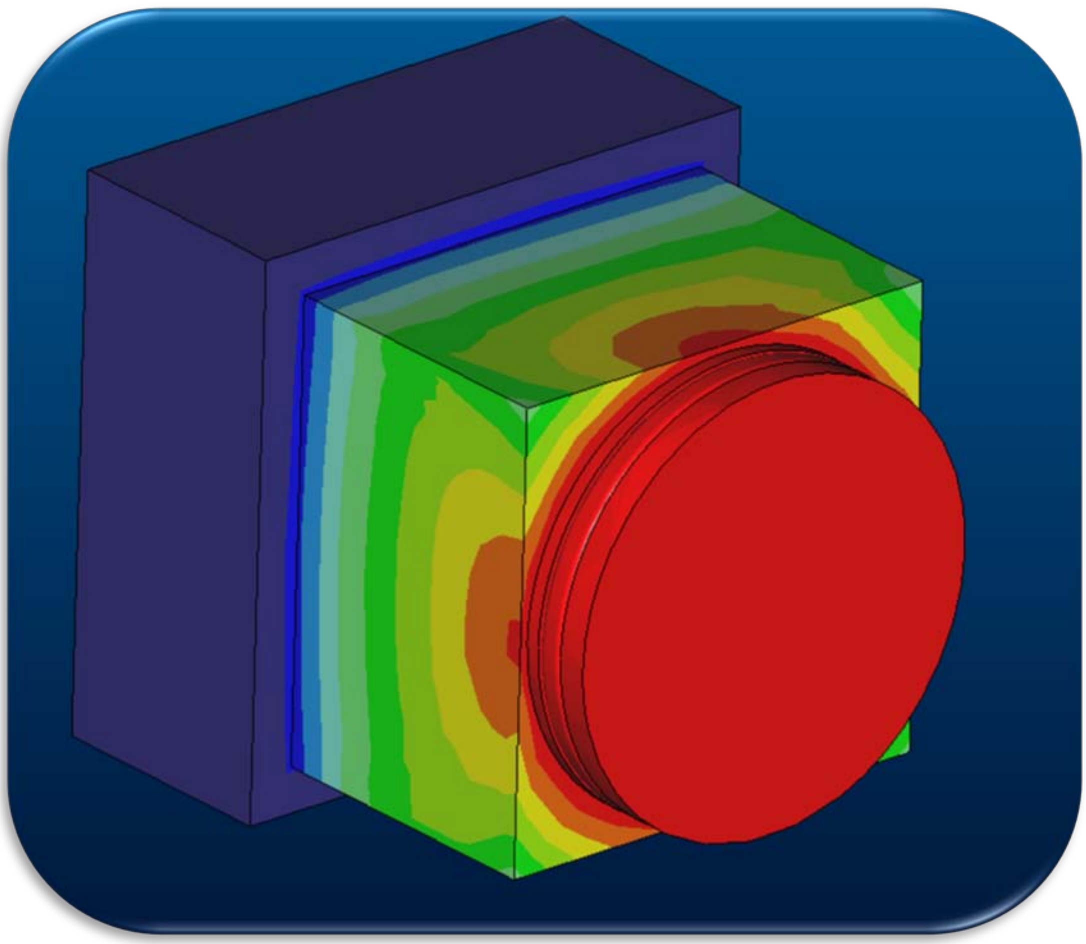
The Tactical Body Armor (TBA) Chest Protector

Lacrosse Protective Gear
Materials Selection
December 6, 2010



Team Members:

Robert Grande

Ben Goldberg

Andrew Rohland

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NOTE:

THE COVER IMAGE IS FROM A CAD MODEL CREATED TO MODEL THE FORCE ON THE ARMOR. DEFLECTIONS DISPLAYED IN THE COVER IMAGE ARE NOT AN EXACT REPLICATION OF THOSE DUE TO THE IMPACT OF A LACROSSE BALL, BUT ARE AN APPROXIMATION. THE PICTURE SHOWS THE TACTICAL BODY ARMOR (TBA) CHEST PROTECTOR AND CLAY BALLISTIC TESTING APPARATUS BEHIND.

TEAM BIO-SKETCH:

Benjamin Isaac Goldberg was born in Avon, CT. He is 20 years old and a junior at Johns Hopkins University, majoring in Mechanical Engineering. He enjoys biking along the coast of Maine and is also an avid golfer. He is excellent at flying remote controlled airplanes and his favorite food is salmon sashimi.

Andrew Dudley Rohland was born in Saint Inigoes, MD. He is 20 years old and a junior at Johns Hopkins University, majoring in Mechanical Engineering. He enjoys building robots and reading. His high school robotics team was semifinalists at the 2008 FIRST-VEX competition in Atlanta, Georgia and accrued numerous other awards during his time at St. Mary's High School.

Robert Grande is from West Chester, Pa. He is 20 years old and a junior at Johns Hopkins University, majoring in Mechanical Engineering. Robert is an excellent guitarist and enjoys arranging music for his a cappella group, the AllNighters. He is currently doing research in the LIMBS lab at Hopkins with Professor Cowan. After graduation, he plans to pursue a PhD and become a professor.

Team RioGrande first competed in the 2009 MechE Freshman Experiences Mousetrap car competition. With one of the most creative designs, using Kool-Aid to mark a line through a slalom course, they were the favorites coming into the competition. Unfortunately, they were disqualified when part of the cycloid pattern went off the track, leaving Kool-Aid on the floor and team RioGrande disqualified. Their exemplary teamwork continued in the annual engineering Pasta Tower of Power Half Hour challenge. They received 3rd place and the judge's award for the most creative design. In their Mechanics Based Design Class, they had one of the best designs for a rotating dobsonian mount called the "RioGrande Rotating Wedge 5000".

ABSTRACT:

Commotio cordis is an event in which ventricular fibrillation and possibly sudden death occur due to impact to the chest. This type of injury can occur in a variety of sports including lacrosse and baseball when the ball impacts the chest in between heart beats. This sort of injury typically occurs to men between the ages of 13-15 due to a lack of protective chest tissue [13]. Currently, there are no pads or protection certified to protect against commotio cordis caused by ball impact, and in our design project, we seek to design a product which can sufficiently protect lacrosse players from this tragic event. Our final design meets a variety of criteria that span over performance, product durability, and minimized weight and cost of production. Our report will focus mainly on the material selection process of the system but will also highlight the mechanics of ball impact.

DESIGN OBJECTIVES:

The primary objective of this design is to protect young lacrosse players (13-15 years old) from commotio cordis. This particular event can potentially occur from being hit in the chest by a lacrosse ball with high velocity. Secondary objectives of the design include the following:

- Lightweight
- Low cost
- Comfortable and Flexible – should not restrict motion of the player
- Ability to be used in spring, summer and fall
- Resistant to moisture and high humidity
- Sustain multiple impacts
- Last for multiple seasons
- Fit a variety of body shapes and sizes

ENGINEERING DESIGN CRITERIA:

The following are engineering design constraints that must be met in order to ensure ample protection:

- The back face deflection of the product must be less than 10mm when impacted by a lacrosse ball with an incoming velocity of 90mph and backed by 10cm of modeling clay
- The system must fit within a 15cm x 15cm x 5cm volume
- The mass of the system must be less than 2kg
- Minimum safety factor of 2 – all stresses must be significantly smaller than the yield strength
- Water absorption less than 10% over 24 hours

OUR APPROACH:

In order to come up with a design satisfying all criteria, we first plan to find the force exerted by a lacrosse ball in impact and find the resulting deflection of the clay and plate. From NCAA rules, we know the ball weighs about 5 oz. [6], and from the mass and velocity of the ball, we can calculate the momentum of the ball. Assuming that the ball velocity post-impact is negligibly small, we can find the change in momentum due to impact. From Dynamics, we know that impulse is equal to change in momentum, and we can use these equations to derive the force exerted by the ball in impact. We will then approximate the dynamic deflection with the deflection of the plate and clay due to a static force of the same magnitude.

MATERIAL SELECTION PROCESS:

Performance Calculations:

1. Maximum force due to impact:
   - Impulse – Momentum equation. For simplicity, a uniform linear force profile is assumed.
   - $m(\Delta v) = F_{avg}(\Delta t)$
   - $F_{avg} = \frac{m(\Delta v)}{\Delta t}$
     - m = 0.145 kg from [6]
     - Δv = 40.53 $^{m}/_{s}$
     - Δt is approximated to be 0.01s from [11]:
     - Δt = 0.01 for hard plate
     - Δt = 0.03 for soft plate
   - $F_{avg} = 587.7\ N$ for hard plate
   - $F_{avg} = 195.9\ N$ for soft plate
2. Deflection of backing clay
   - We can model the clay as a viscoelastic material that can be represented by a spring and a dashpot connected in series. From Impact Mechanics [3], we can calculate the deformation of the clay due to a sudden stress, σ_o.
   - $\delta_c = \varepsilon L = \left[\frac{\sigma_o}{E} + t\frac{\sigma_o}{\eta}\right]L = \left[\frac{F}{AE} + t\frac{F}{\eta A}\right]L$ [3]
     - $A = \frac{\pi D^2}{4} = 0.01767\ m^2$
     - $L = 0.1m$
     - $E = 125\ kPa$ from [5]
     - $\eta = 1000\ Pa * s$
       - Approximated using viscosity of shortening (about 4 times that of shortening) [16]
   - $\delta_c = 26.6\ mm$ for a hard plate
   - $\delta_c = 8.8\ mm$ for a soft plate
     - It is obvious from this criteria that a soft front plate must be used to increase the impulse time and decrease the force
     - To increase the impulse time even more, an additional foam backing can be used as a soft padding.

3. Deflection of rigid plate
   - To calculate the maximum deflection of the plate, we use the formula for maximum deflection of a circular plate loaded on a central area r_o, simply supported along the edges from Kent [2]. Given that the deflection is greater for edge supported rather than uniformly supported, this is a conservative assumption:
   - $\delta_p = \frac{5Fr^2}{3\pi Et^3}$ from [2]
   - $\delta_{allowable} = \delta_{max} - \delta_c = 10mm - 8.8mm = 1.2mm = \frac{5Fr^2}{3\pi Et^3}$
     - t = 1cm
   - $E_{min} = \frac{5Fr^2}{3\pi(1.2mm)t^3} = 487\ MPa$
   - E= 487MPa is the minimum Young's Modulus with safety factor of 1 that our rigid plate needs to have in order to keep the deflections within 10mm.
     - From this criteria, it is seen that a stiffer back plate must be used to prevent bowing due to the impact
   - Material Index:
     - $M = \frac{\sqrt[3]{E}}{\rho}$
     - Line of slope 3 in CES plot [12]
4. Stress in plate
   - From Kent [2]:
     - $\sigma_{max} = \frac{3(1+v)P}{2\pi t^2}\left[(1+v)^{-1} + \ln\frac{r}{r_o} - \left(\frac{1-v}{1+v}\right)\frac{r_o^2}{4r^2}\right]$
     - $r_o = 3.2cm$
     - Assume v=.3 for initial calculations
     - $\sigma_{max} = 5.1\ MPa$
5. Weight:
   - $M_{max} = \pi hr^2\rho = 2kg$
     - h = 0.01m
     - r = 0.075 m
   - $\rho_{max} = 11{,}317\ \frac{kg}{m^3}$
6. Cost:
   - $Max\ Cost = 113{,}180\ \frac{\$}{m^3}$
7. Temperature:
   - $Min. T_{max} = 40^0C$
   - $Max. T_{min} = -5^0C$
8. Humidity:
   - Materials that are sensitive to humidity such as woods will be screened and removed

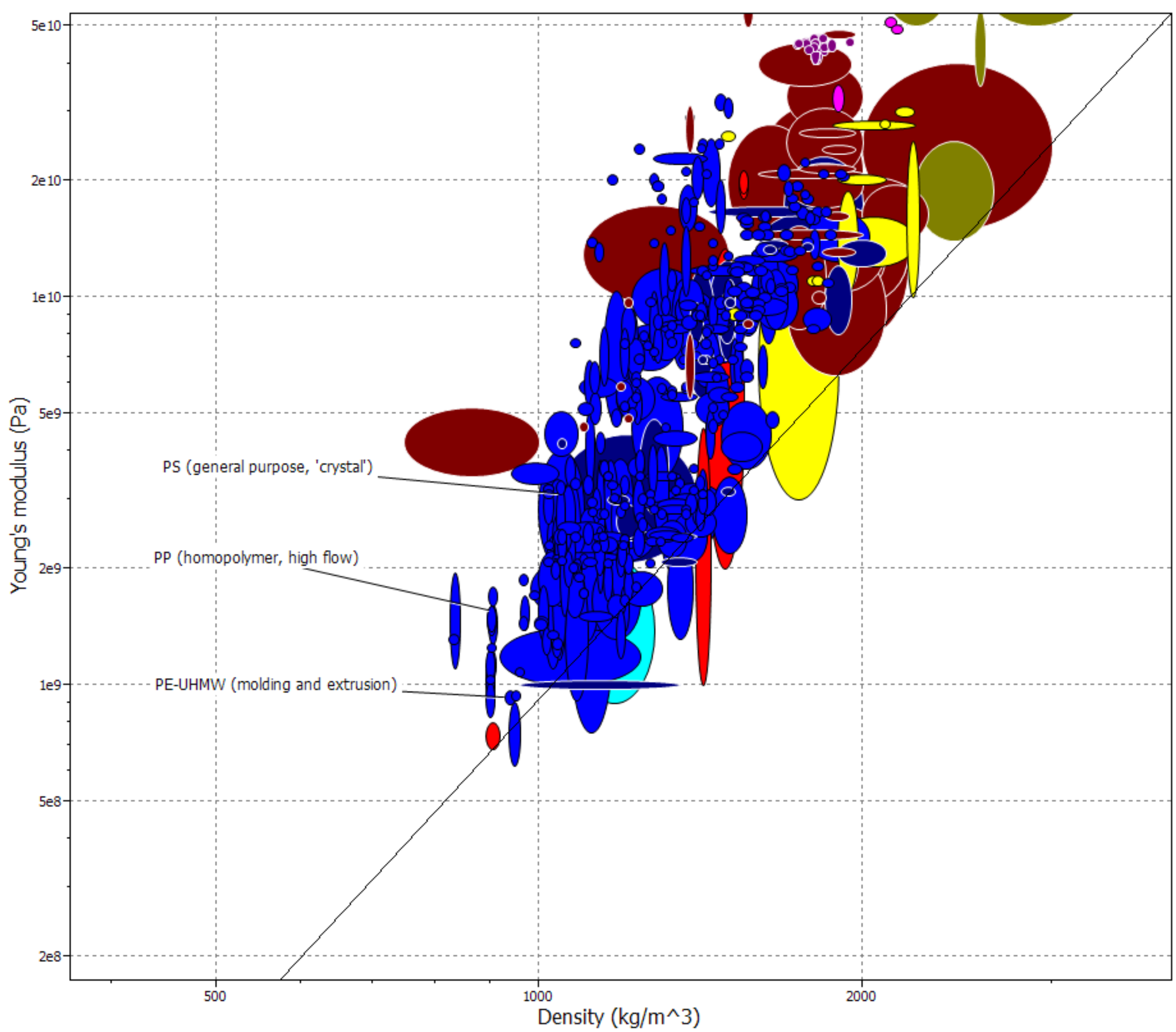
<u>Rigid Plate Selection Process:</u>

For the rigid, deflection resistant plate, we plotted all materials except for wood and foams, for above reasoning, on a graph of Young's Modulus vs. Density as seen in Figure 1.1. After limiting the selection based on above criteria, we plotted the material index line of slope three and moved the line to further limit our selection. We then ranked the materials according to cost per unit volume. For the back plate:

1. PP - homopolymer
2. PE – UHMW
3. PS – General purpose

After investigating availability of materials and researching typical uses of the materials, we selected Ultra High Molecular Weight Polyethylene (UHMWPE)

Figure 1.1: Plate Backing Material Selection in CES



Front Soft Plate Selection Process:

For the soft, front, rubber plate, we used the same strength criteria (σ_{max}=5.1MPa) because the rubber is undergoing the same load as the rigid plate. We did not, however, limit our selection based on stiffness. Rather, we plotted yield strength divided by Young's modulus vs. cost per volume. This was because we want a rubber that won't break under the applied force and that is flexible, i.e. low Young's modulus. Given these criterion, we want to maximize σ_y/E which is plotted on the y-axis in figure 1.2 below. On the x-axis of the same figure, we want to minimize the price*density quantity. Given these two conditions, we want to select materials in the top left corner. We limited this plot in CES to rubbers because we wanted a material stiffer and stronger than foam, but still with good flexibility. By selecting the materials in the top left corner of figure 1.2, we ensure that we have a strong, flexible and low cost material. These rubbers listed below will provide the greatest impulse time at the cheapest cost (see figure 1.2):

1. Natural Rubber
2. Butadiene Rubber
3. Polyisoprene Rubber

After reviewing the top choices and cost and availability of material, we choose Abrasion-resistant Natural Gum Rubber.

Figure 1.2: Plate Backing Material Selection in CES

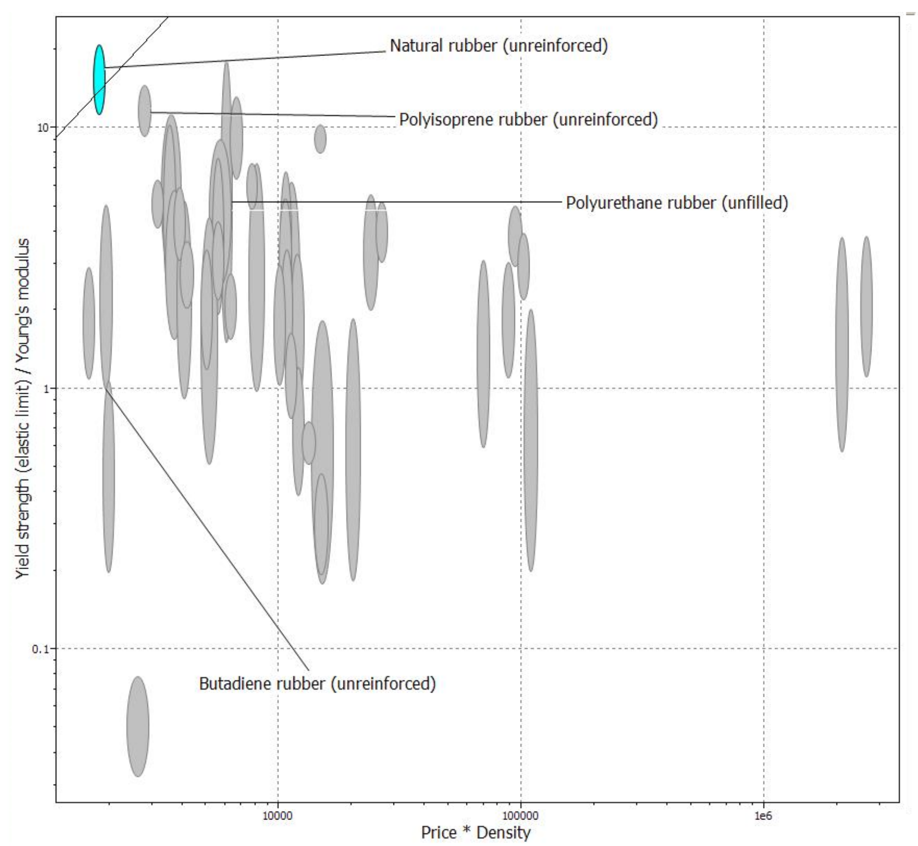


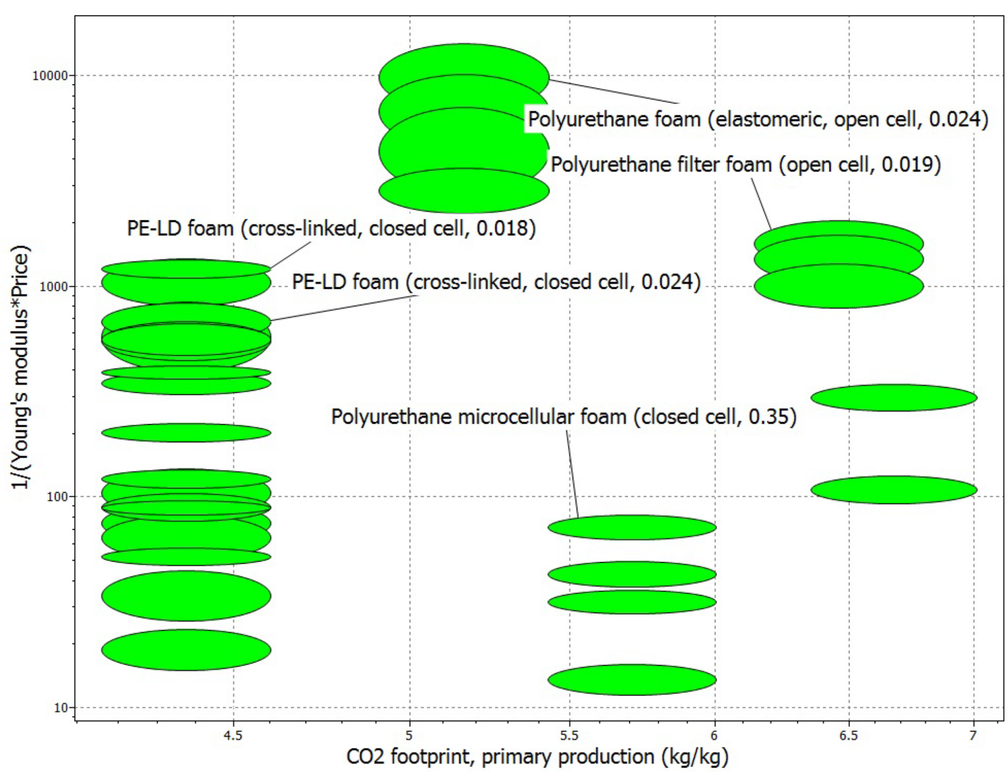
Plate Backing Selection:

First, we narrowed down the possible material choices in CES to elastomeric and flexible polymer foams because we knew we wanted a soft, lightweight and flexible foam. Next, from this subset, we plotted Young's modulus multiplied by price quantity inverse vs. the carbon footprint for primary production. In this plot, we wish to maximize the quantity on the y-axis seen in Figure 1.3 and minimize the carbon footprint. Maximizing the y-axis quantity will result in a material that "gives" some which will increase the impulse time, which in turn minimizes the force of impact. It also accounts for price of material. Given these factors, we want to pick a material that sits in the upper left-hand corner of the plot. The following materials were considered:

1. Polyethylene Foams
2. Polyurethane Foams

In figure 1.3 below, the best material is PE-LD (Polyethylene Low-Density Foam (cross-linked, closed cell, 0.018)). In fact, the materials with a CO2 footprint of 4.3 in the left side of the graph are all polyethylene foams. Polyethylene foams in general have many properties that are desirable in our application. In addition to being very soft and well-suited for cushioning, they are water resistant with an absorption rate of less than .5% in 24 hours. Polyurethane foams (upper right-hand corner) have similar elongation/price quantities. However, their carbon footprint is about twice as large. Also, polyurethane foams are less water resistant (~25% absorption over 24hrs) which will lead to absorption of sweat/rain and quicker deterioration of the product. This is why chose polyethylene foam for the backing.

Figure 1.3: Plate Backing Material Selection in CES



DESCRIPTION OF FINAL DESIGN:

The final design consists of 3 discs that are layered on top of each other and sewn together into a rip-stop nylon fabric pouch. Each disc is 14.5cm in diameter. Due to availability of materials, the actual thickness of the plates is slightly different than the original dimensions. The UHMWPE plate is 1.27 cm thick, the rubber disc is 1.9cm thick, and the foam disc is 1.27cm thick. The UHMWPE disc has filleted edges so it does not cut any of the other materials, as seen in Appendix B Dwg. # 03. The rubber disc is shown in Appendix B Dwg. # 02. The foam disc is shown in Appendix B Dwg. # 04. The total mass of the design is .51kg and the total thickness is 4.45 cm as shown in Appendix B Dwg. # 01.

ANALYSIS OF MATERIALS CHOICE:

1. Rigid Plate:
   - Material: PE – UHMW
     - Yield strength criteria
       - $\sigma_{max} = 3.16\ MPa$
       - $\sigma_y = 25\ MPa$
       - SF = 7.9
     - Back face deflection
       - E = 925 MPa
       - $\delta_p = \frac{5Fr^2}{3\pi E t^3}$ = 0.31 mm
       - SF = $\frac{\delta_p}{\delta_{allowable}}$ =3.9

We chose to use ultra-high-molecular-weight-polyethylene (UHMWPE) for our product for a variety of reasons. Firstly, UHMWPE is already used in bullet proof vests and a variety of other protection based applications. For this reason, we have confidence that it will withstand an impact without failure. Additionally, the safety factor calculated for the actual dimensions is 7.9. Of all thermoplastics, it has the highest impact strength [14]. The great strength of UHMWPE comes from the orientation of its polymer chains, nearly 95% of which are arranged parallel to each other and in the same direction [14]. UHMWPE can be used at temperatures up to 100 ^{0}C, which ensures safe use at all times of the year. Additionally, UHMWPE is resistant to water moisture, UV rays and micro-organisms [14]. This ensures that the product will not be deteriorated by water, sweat, or bacteria. If a plastic lacrosse absorbs water, it may become brittle and fracture under subcritical conditions [14]. Since our product must protect a child's life, it is imperative that product safety is not diminished with time. The safety factor based on back face deflection of 3.9 will be maintained. Additionally, UHMWPE has been used in all weather applications previously, which makes it an attractive choice for our product. Other useful properties of UHMWPE include: its abrasion resistance which is 15 times than that of steel [14], its low density of 930 kg/m^3, and its high yield strength which is in the range of carbon steels [15].

2. Soft front plate:
    - Material: Abrasion-resistant natural rubber:
        - Yield strength criteria
            - $\sigma_{max} = 0.75\ MPa$
            - $\sigma_y = 25\ MPa$
            - SF = 33

As seen in the analysis section of our report, impact time is vital in determining total impact force and thus total impact deflection. Thus, while the UHMWPE plate will not deform significantly due to the impact, the tissue behind it will. Natural Rubber has a low modulus of elasticity which will allow a larger impact time than if just the UHMWPE were used. It also has yield strength equal to that of the UHMWPE, which means that it will not fail due to stress. Its safety factor is 33. Natural rubber is also water resistant, which makes it attractive for outdoor use.

3. Plate Backing - Polyethylene Foam:

The polyethylene foam is an important part of the system because of the effect it has on the average impulse time of the lacrosse ball impact. The soft foam and rubber combine and allow us to make the assumption of the impulse time of 0.03s. The foam, however, also is used to prevent injury due to the hard UHMWPE plate hitting the skin at high speeds. The foam acts as a buffer so that minimal bruising and rib fraction will occur. The foam however is negligible in the back face deflection analysis. In other words, the energy absorbed by the foam is negligible, and this is why it was not included in our original calculations. Additionally, we do not anticipate our foam to rip during use since the applied load will be compressive.

4. System
    - Minimum SF = 3.9
    - Weight:
        - Rubber: $m = 0.316\ kg$
        - PE – UHMW plate: $m = 0.166\ kg$
        - Foam: $m = 0.007\ kg$
        - Nylon Case: 0.02 kg
        - Total: $m = 0.51\ kg$
    - Cost:
        - $23.91 for one
        - $17.93 for mass production
        - See table 1.1 for product description

PARTS LIST/COST ANALYSIS:

Table 1.1: Parts List and Manufacturing Cost

Quantity	Description	Vendor	Part #	Total Price	Price Per Unit
1	Ultra-High Molecular Weight Polyethylene (UHMWPE) Sheet	McMaster-Carr [7]	84765K125	$6.68	$6.68
1	Abrasion-Resistant Natural Gum Rubber	McMaster-Carr [7]	8633K63	$42.19	$10.55
1	Polyethylene Foam	McMaster-Carr [7]	8865K111	$5.73	$1.43
1	Ripstop Nylon	Beacon Fabric [8]	845	$7.99	$0.26
1	Manufacturing Costs	N/A	N/A	$5.00	$5.00
				$67.58	$23.91

The total cost of the materials for our product is determined primarily by the price of the UHMWPE and rubber sheets. The above total price per unit is $23.91 but will likely be reduced by buying from a wholesale supplier. At a reasonable estimate of 25% saved; the cost per unit would be $17.93. See appendix A for printouts of the individual

The simplicity of our design helps limit manufacturing costs. Each part is a simple 15 cm diameter circle, which can be cut out with a laser cutter or a hole saw drill bit. After being cut out, the UHMWPE discs would have its sharp edges filleted to prevent tearing of other materials. The rubber and foam would be ready to use after the discs are cut out. Since UHMWPE does not adhere well to other polymers, the 3 pieces will be sewn together into a rip-stop nylon fabric pouch. This simple machining and assembly process would help minimize the total price of the product. The machining costs are approximated to be $5.00 by estimating that it would take approximately 2 minutes to cut out the pieces using a laser cutter then fillet the edges(at $60/hr) and approximately 5 minutes of finishing and assembly time (at $15/hr). This cost analysis is based on a production volume for approximately 2000 pieces.

DESIGN TESTING:

To test the performance of the proposed protective torso plate, modeling clay can be used in a laboratory setting to determine the back face deflection when impacted by a lacrosse ball at 90mph. The setup will consist of a rotating wheel, similar to a baseball machine pitch device, which can propel a lacrosse ball at the protective plate. The protective plate will be placed in a fabric pouch that is draped over the modeling clay as seen in Figure D1. The modeling clay will be placed in a rectangular support box that is fixed on the bottom and back. To determine the deflection of the modeling clay, a calibrated laser is placed to measure the speed and resulting deflection of the impact. For redundancy and higher accuracy, a high-speed camera is also mounted out of the page in the figure to observe the side-view of the impact and measure the dynamic back face deflection. Multiple trials at a range of velocities will be done to ensure accuracy. See figure D1 for a drawing of the testing apparatus. Figure D1 is modeled after the testing apparatus as used in the NIJ standards in [4].

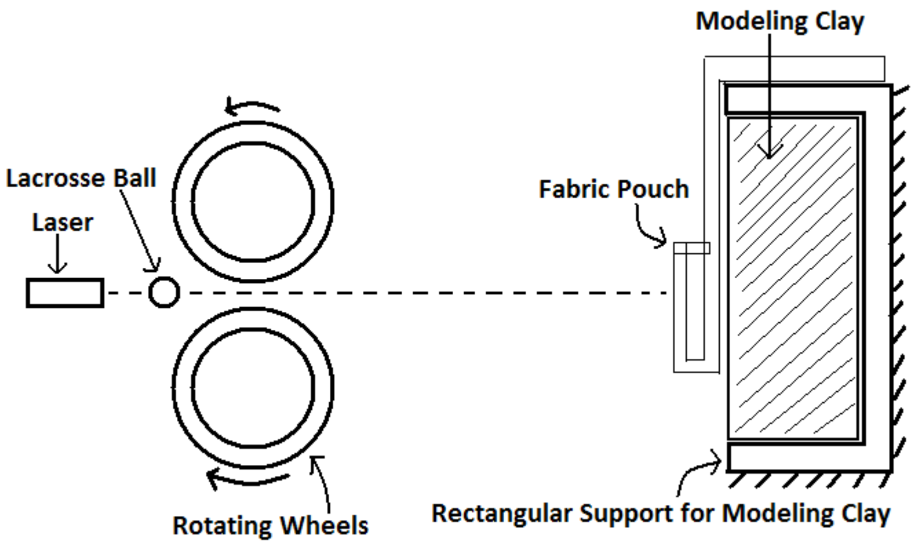


Figure D1

DISCUSSION AND SUMMARY:

After designing and testing the protective plate system as described above, we can confirm that the TBA Chest Protector fits all of the design criteria. The design consists of very lightweight materials. The materials are UHMWPE (Ultra High Molecular Weight Polyethylene) which has a density of 930 kg/m^3, abrasion resistant natural gum rubber which has a density of 950 kg/m^3 and a polyethylene foam which has a density of 50kg/m^3. All together with the rip-stop nylon pouch, the design has a total mass of 0.51kg. The cost of the TBA Chest Protector as outlined above for a production quantity of 2000 units is $23.91 per unit. This design successfully fills the criteria of being both light weight and relatively cheap.

While designing the TBA Chest Protector, we chose a circular layered plate design because it allows for more flexibility and comfort than a square, rigid tile design. The filleted edges on the UHMWPE disc not only promote comfort to the user but also extend the lifetime of the product. The smooth edges reduce the chance that the fabric will tear under abrasion. In addition to this, we chose a rubber that is also abrasion resistant. This foam backing is made of polyethylene foam which is commonly used in cushioning. Ultimately, the product provides a natural, soft feel to the user.

The effects of weather were also an important design consideration. Each of the materials can be used up to 100 degrees Celsius (212 degrees Fahrenheit) safely. This means that even in the heat of the summer where a car can heat up to 200 degrees Fahrenheit [9] the TBA Chest Protector will not deteriorate or warp. All of the materials have low glass transition temperatures which ensure a consistent performance even in temperatures below -5 degrees Celsius. Humidity was also an important consideration given how much lacrosse players can sweat "during a typical Baltimore summer" [10]. All of the materials chosen are water resistant. Overall, the design will be able to withstand high humidity, rain, sweat, and abrasion from a player which ensures a long product lifetime. The round shape of the TBA Chest Protector and the tight fabric layer allows for easy placement into a variety of lacrosse padding. In the future, a variety of pads could be designed, and consumers would be able to easily insert new pads after a recommended product life expires.

From a protection standpoint, the TBA Chest Protector has a minimum safety factor of 2. When a child's life is in danger, it is important that all product safety factors are 2 or greater. This ensures that a child could withstand an impact of slightly greater velocity or from an angle slightly different than that tested. Additionally, it ensures that all stresses in the product are well within the yield strength, and that the product will not fracture. In our model, the total deflection is within the original criteria of 10 mm. In summary, our product satisfies all functional requirements and contains materials which function in all weather conditions. The product can be integrated fairly easily into current pads, and the product is unobtrusive to the user. Additionally, the foam pad will provide a very natural feel to the user.

APPENDICES:

Appendix D: Other designs

- Ceramic Dragon Skin
  - This idea was inspired by a type of armor that is successful and already used in bullet proof vests. The design consists of solid boron carbide disks (or a similar material) that overlap to produce a flexible vest that resists large blasts. While this design would allow for easier movement, it is not designed to prevent back face deflection. It is better suited to prevent fragments of projectiles from entering the body.
- Domed Plate
  - This plate would be made of a stiff polymer and have a convex, parabolic shape that would convert some of the force from the lacrosse ball into a vertical force. In the sport of paintball, similar designs are used on top of guns to deflect paintballs without breaking them. While this idea could be potentially very effective, it would be much more costly to product, and could be aesthetically unpleasing. The backing would be made of soft foam to increase the impulse time.
- Thin aluminum layers
  - We would thin layers of aluminum that are design to bend elastically a maximum amount of 5mm under the expected impact of the lacrosse ball. The device would act in the fully elastic range of the aluminum so it could resist multiple impacts. The design, however, would likely be too stiff and heavy for our particular application.

Rubber and Foam

Part Number: **8633K61** $31.32 Each

Material Type	Abrasion-Resistant Natural Gum Rubber
Shape	Sheets, Bars, and Strips
Backing	No Backing
Thickness	3/4"
Thickness Tolerance	±0.094"
Length	12"
Length Tolerance	±1/2"
Width	12"
Width Tolerance	±1/2"
Durometer	Medium Soft
Durometer Rating	40A
Durometer Hardness Tolerance	±5
Temperature Range	-20° to +180° F
Tensile Strength	3000 psi
Color	Brown
Finish	Smooth
Tolerance	Standard
Specifications Met	American Society for Testing and Materials (ASTM), Food and Drug Administration (FDA)
ASTM Specification	ASTM D2000 AA
FDA Specification	FDA Compliant
Properties	Abrasion Resistant, Tear Resistant, Impact Resistant, Electrical Resistant

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Rubber and Foam

Part Number: **8865K111** $5.73 Each

Material Type	Polyethylene Foam
Shape	Sheets, Bars, and Strips
Backing	No Backing
Polyethylene Foam Type	Polyethylene Foam
Thickness	1/2"
Thickness Tolerance	±0.063"
Length	12"
Length Tolerance	±1/4"
Width	12"
Width Tolerance	±1/4"
Temperature Range	-65° to +200° F
Cut With	Scissors, Knife, or Saw
Tensile Strength	28-50 psi
Stretch Limit	105-220%
Density	1.5 to 2.5 lbs./cu. ft.
Foam Structure	Closed Cell
Texture Type	Fine Cell
Foam Firmness	Soft
Firmness, psi	4-8 (25% Deflection)
Compression Recovery	Good
Color	White
Finish	Textured
Tolerance	Standard
Specifications Met	Not Rated
Properties	Oil Resistant, Abrasion Resistant, Tear Resistant, Impact Resistant, Weather Resistant, Chemical Resistant
Notes	Material has a firm, elastic feel, and has a skin on the top and bottom.

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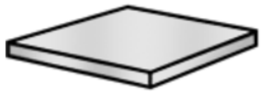
Plastics



Part Number: **84765K125** $6.68 Each

Material	Polyethylene
Polyethylene Material	Ultra-High Molecular Weight Polyethylene (UHMW)
UHMW Material Type	Premium
Backing	Plain Back
Finish	Smooth
Shape	Sheets, Bars, Strips, and Cubes
Sheets, Bars, Strips, and Cubes Type	Square Sheet
Thickness	1/2"
Thickness Tolerance	±.050"
Length	6"
Length Tolerance	±.125"
Width	6"
Width Tolerance	±.125"
Opaque	Blue
Operating Temperature Range	-450° to +180° F
Performance Characteristic	High Impact Strength
Tensile Strength	3250 psi
Impact Strength	30 ft.-lbs./in.
Tolerance	Standard
Hardness	Shore D: 69
Specifications Met	Not Rated

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- **59 inches wide, sold by the yard.**
- **Silver and Gold Metallics are Black Fabric with a Shiny Metallic coating on one side and are 54" wide**
- **20 yard rolls available, at a savings over the per yard price. Contact Customer Serivce**

Colors are difficult to represent over the Internet. For a more accurate representation of the Ripstop colors, go to Color Cards and download the "Nylons" Color Chart. The Fluorescents, Metallics and Neons cannot be accurately represented on a computer screen or on paper. For the most accurate representation of colors, order the color card, shown below. If you have questions about the suitability of this fabric for your application, please Contact Customer Service. Please note that cut yardage is not returnable. To order, Click on the underlined color. Then click "back" on your browser to return to this page.

Ripstop Nylon Color Card
$5.00

White, 59"
$7.99

Black, 59"
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