Final Project

Material Selection for Snowshoes

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INTRODUCTION

Snowshoes are used to walk in snow without sinking. Traditionally, they have been used by native people in northern regions of the world for more efficient movement in snow. These snowshoes had wooden frames with rawhide webbing. Later, a tubular aluminum frame was developed for use by emergency personnel. Magnesium frames were used by United States and Canadian military services. The rawhide webbing was replaced by a thin sheet of nylon, called decking.[(1)] Today, snowshoes are used for recreation as well. Aluminum frames and nylon decking are most popular.

FUNCTION

Our objective is to select materials for snowshoes for a recreational user on relatively packed snow. A recreational user would be someone who uses snowshoes for walking, not racing or climbing. They would probably snowshoe about once a week during the winter. They would not want to spend much time on maintenance or pay more than $300 on a pair of snowshoes.

A snowshoe is made of several parts, as shown in Figure 1. The parts explored in this project are the frame, decking, crampons, and front and back crossbars.

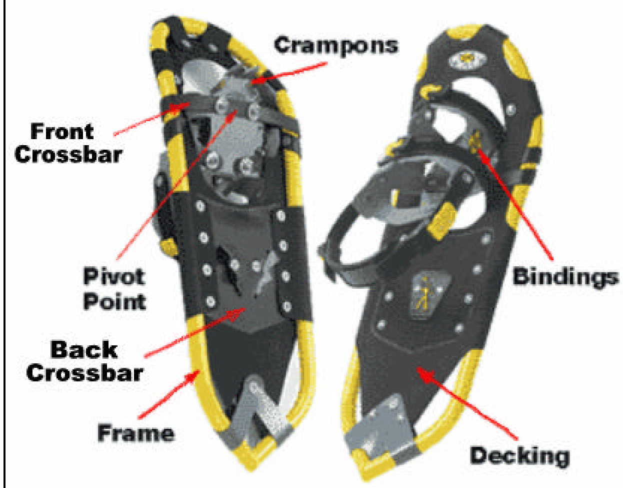


Figure 1[(2)]

We will analyze each part separately using Granta Design Limited's Cambridge Engineering Selector software.

FRAME

FUNCTION

The function of the frame is to distribute the load throughout the snowshoe and to hold the shape of the other parts. See Appendix A for a diagram of the loading conditions. The frame can be modeled as a beam in bending.

OBJECTIVE

- Minimize weight
- Maximize stiffness
- Therefore, maximize the function[3]:

$$M = \frac{E^{1/2}}{r}$$

CONSTRAINTS

The following table describes the constraints specified within the CES software.

Quantity	**Minimum**	**Maximum**
Price (GBP/kg)		10
Compressive Strength (MPa)	150	
Fracture Toughness (MPa $m^{1/2}$)	10	
Tensile Strength (MPa)	150	
Minimum Service Temperature (K)	250	
Environmental Resistance:		
Fresh Water	Very Good	
UV	Good	
Wear	Good	

We selected a minimum strength of 150 MPa based on an estimated stress for a load of 1000 pounds. Minimum service temperature and resistance to fresh water, UV, and wear are very important for a snowshoe. We looked for high fracture toughness, because the frame could come in contact with rocks and other hard objects.

MATERIALS USED

The frame is commonly made of wood, such as ash, aircraft-grade aluminum alloys, and plastics.

MATERIAL SELECTED

See Appendix B for the chart developed using our constraints and objective function. We ruled out cast iron, because it is brittle and difficult to machine. We selected cast duplex stainless steel. Stainless steel satisfies all the constraints that we specified.

DECKING

FUNCTION

The function of the decking is to provide a large area for the snow to react to the user's weight. Appendix A contains a free body diagram for the loading on the decking. The decking acts as a panel in bending.

OBJECTIVE

- Minimize weight
- Maximize strength
- Therefore, maximize the function[4]:

$$M = \frac{s_f^{1/2}}{r}$$

CONSTRAINTS

The following table describes the constraints specified within the CES software.

Quantity	Minimum	Maximum
Density (kg/m^3)		3
Minimum Service Temperature (K)	250	
Environmental Resistance:		
Fresh Water	Very Good	
UV	Good	
Wear	Good	

We specified a low density, because it is important that the decking be light.

MATERIALS USED

The decking in modern snowshoes is usually made of nylon, vinyl, or polyurethane-coated nylon. Some popular materials are Hypalon, ArcTec, and TriTec.

MATERIAL SELECTED

The chart in Appendix C shows the results for our constraints and objective function. We ruled out bone for difficulty in manufacturing. We chose polyurethane.

CRAMPONS

FUNCTION

The function of the crampons is to provide traction while walking. See Appendix A for a diagram of the loading conditions. The crampons are modeled as a beam in bending.

OBJECTIVE

- Minimize weight
- Maximize strength
- Therefore, maximize the function[(5)]:

$$M = \frac{s_f^{2/3}}{r}$$

CONSTRAINTS

The following table describes the constraints specified within the CES software.

Quantity	Minimum	Maximum
Price (GBP/kg)		10
Fracture Toughness (MPa $m^{1/2}$)	10	
Environmental Resistance:		
Fresh Water	Very Good	
UV	Good	
Wear	Average	

MATERIALS USED

The crampons are usually made of stainless steel or aluminum.

MATERIAL SELECTED

See Appendix D for the chart developed using our constraints and objective function. We selected a epoxy/glass fiber composite. It was the best material to choose based on our objective function and constraints.

FRONT CROSSBAR

FUNCTION

The function of the front crossbar is to distribute the weight from the ball of the foot onto the frame. It should also allow the foot to rotate. See Appendix A for a diagram of the loading conditions. The front crossbar can be modeled as a beam in bending.

OBJECTIVE

- Minimize weight
- Maximize strength
- Therefore, maximize the function[5]:

$$M = \frac{s_f^{2/3}}{r}$$

CONSTRAINTS

The following table describes the constraints specified within the CES software.

Quantity	**Minimum**	**Maximum**
Price (GBP/kg)		10
Young's Modulus (GPa)		10
Minimum Service Temperature (K)	250	
Environmental Resistance:		
Fresh Water	Very Good	
UV	Good	
Wear	Average	

We specified a low modulus to allow for rotation of the foot.

MATERIALS USED

The front crossbar is commonly made of a polymer.

MATERIAL SELECTED

See Appendix E for the chart developed using our constraints and objective function. We selected polyurethane.

BACK CROSSBAR

FUNCTION

The function of the back crossbar is to distribute the weight from the heel of the foot onto the frame and decking. See Appendix A for a diagram of the loading conditions. The back crossbar can be modeled as a panel in bending.

OBJECTIVE

- Minimize weight
- Maximize strength
- Therefore, maximize the function[4]:

$$M = \frac{s_f^{1/2}}{r}$$

CONSTRAINTS

The following table describes the constraints specified within the CES software.

Quantity	**Minimum**	**Maximum**
Density (kg/m^3)		5
Price (GBP/kg)		10
Fracture Toughness (MPa m$^{1/2}$)	1	
Minimum Service Temperature (K)	250	
Environmental Resistance:		
Fresh Water	Very Good	
UV	Good	

Wear	Average	

We specified a low density for weight issues, and we specified a lower fracture toughness than for the frame and crampons, since it is less likely to hit hard surfaces.

MATERIALS USED

The back crossbar is commonly made of a stiff polymer.

MATERIAL SELECTED

See Appendix F for the chart developed using our constraints and objective function. We eliminated bone for manufacturing issues. Also, the zinc-aluminum casting alloy can be dissolved in food acids and thus was rejected. We selected polypropylene, because it was the cheapest of the three top choices on the chart.

CONCLUSION

Design of the perfect snowshoe takes into account the material that would best achieve the objectives prescribed for each part. The table below outlines our choices of the best materials for each part of the snowshoe.

Part	**Material**
Frame	Cast Duplex Stainless Steel
Decking	Polyurethane
Crampons	Epoxy/Glass Fiber Composite
Front Crossbar	Polyurethane
Back Crossbar	Polypropylene

REFERENCES

1. Osgood, William E. and Leslie Hurley. *The Snowshoe Book*. 2nd ed. S. Greene Press: Brattleboro, VT, 1975. pp. 35-36.
2. Hostetter, Kristin. “Anatomy of a Snowshoe”. *Backpacker*, November 2000. www.backpacker.com
3. Ashby, Michael F. *Materials Selection in Mechanical Design*. Butterworth Heinemann, Oxford, 1999. p. 418
4. Ashby, Michael F. *Materials Selection in Mechanical Design*. Butterworth Heinemann, Oxford, 1999. p. 409
5. Ashby, Michael F. *Materials Selection in Mechanical Design*. Butterworth Heinemann, Oxford, 1999. p. 420

APPENDICES

Appendix A: Free Body Diagrams of Snowshoe Parts

Appendix B: CES Chart for Frame

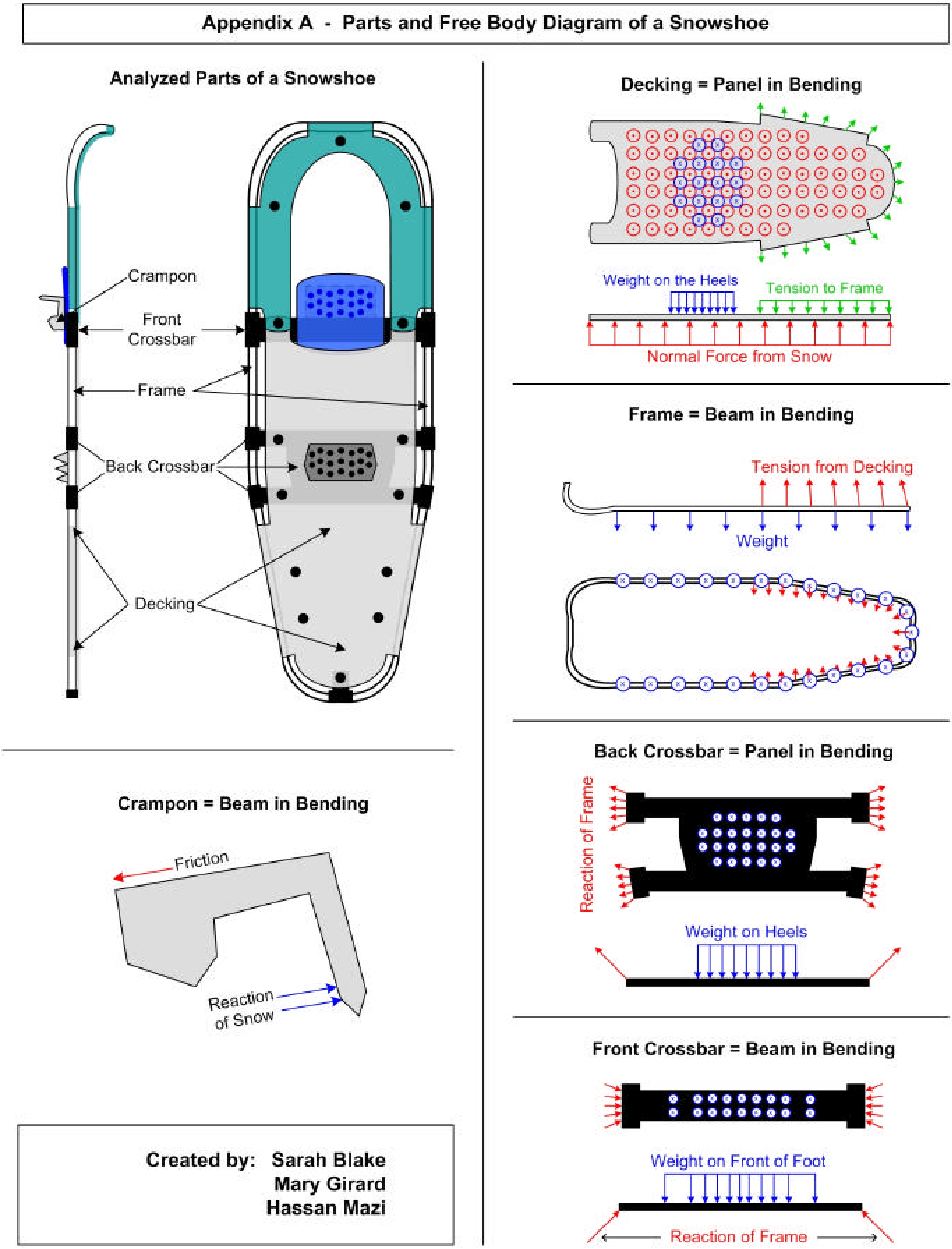
Appendix C: CES Chart for Decking

Appendix D: CES Chart for Crampons

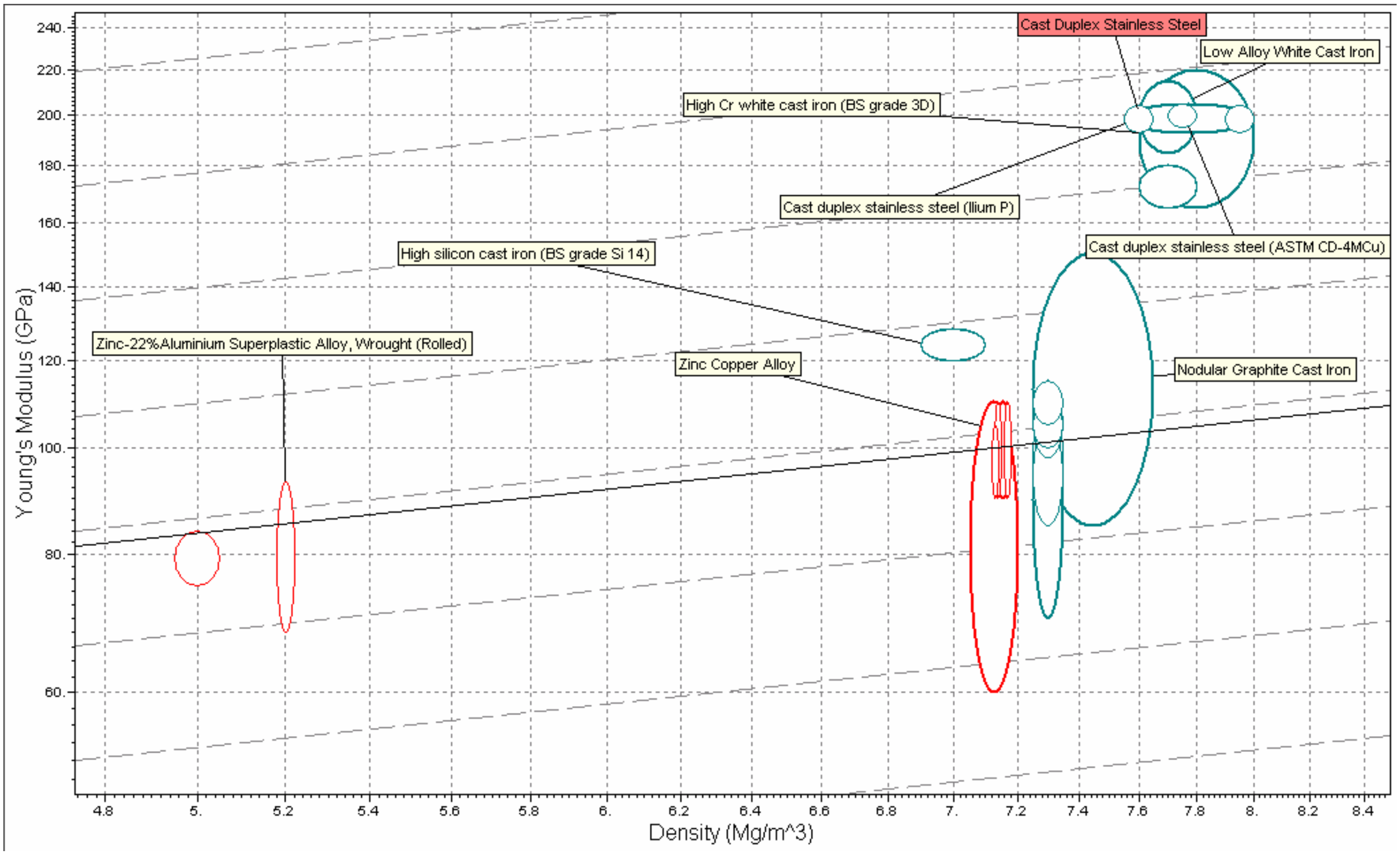
Appendix E: CES Chart for Front Crossbar

Appendix F: CES Chart for Back Crossbar

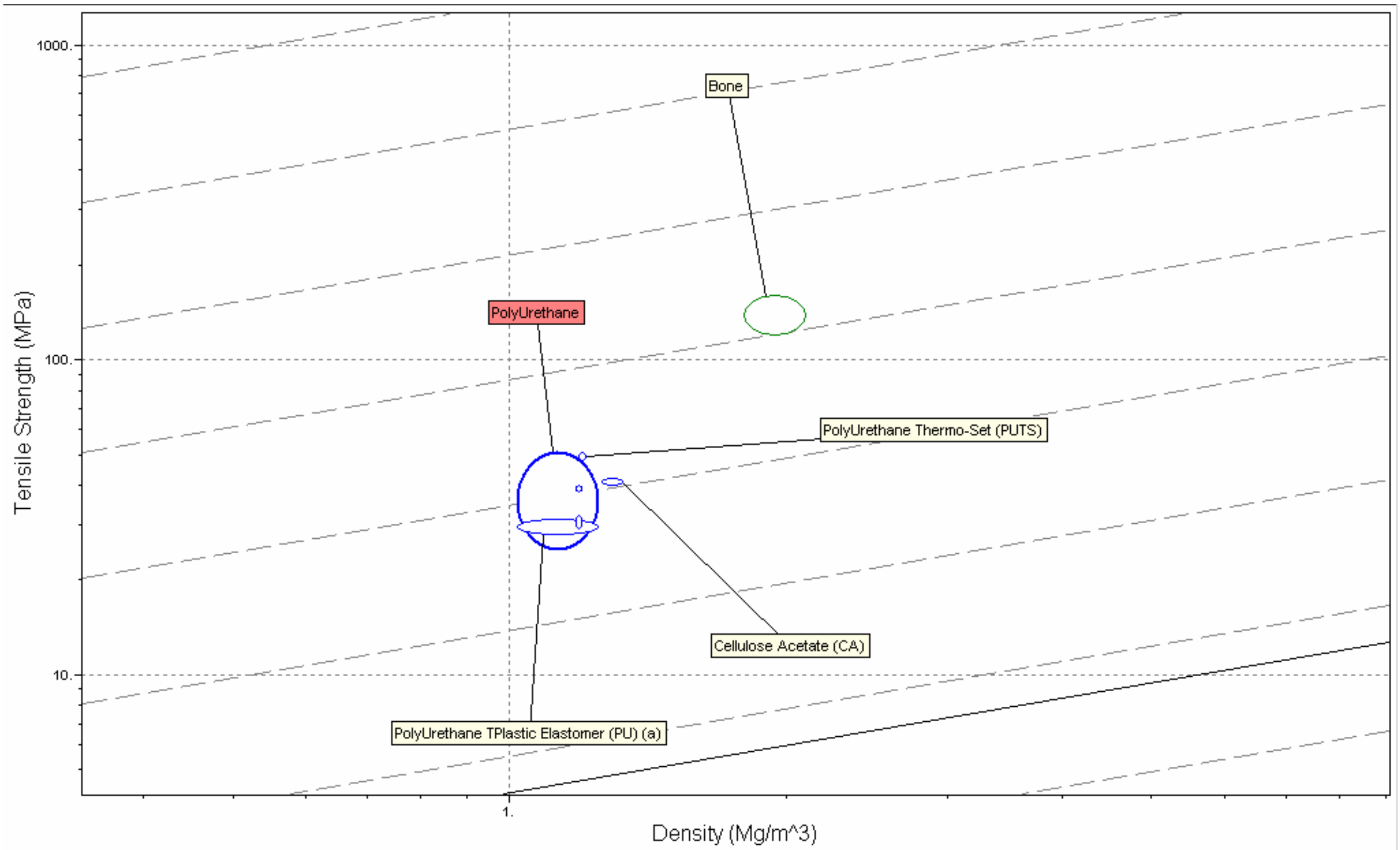
Appendix A: Free-Body Diagrams



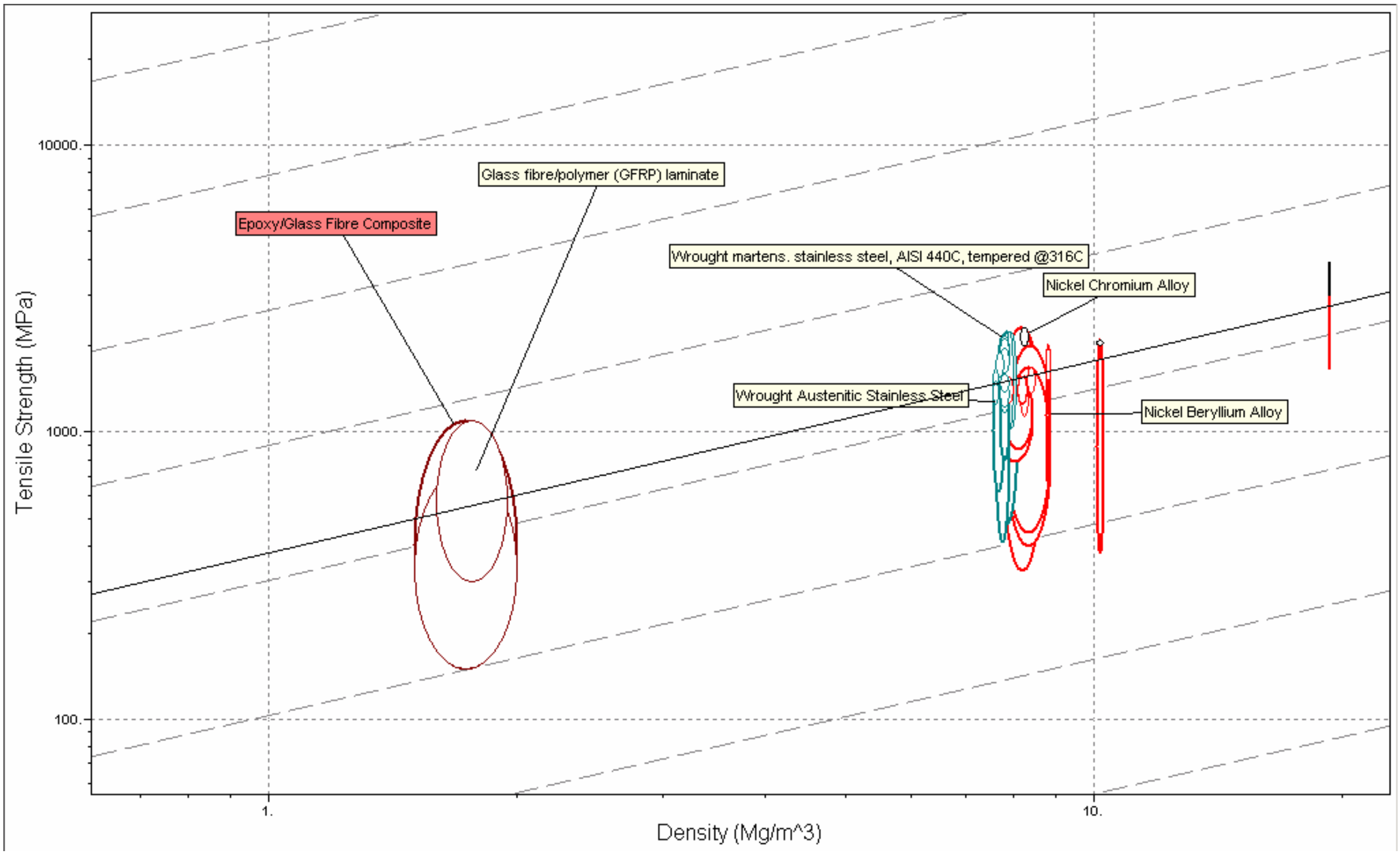
Appendix B: CES Chart for Frame Selection



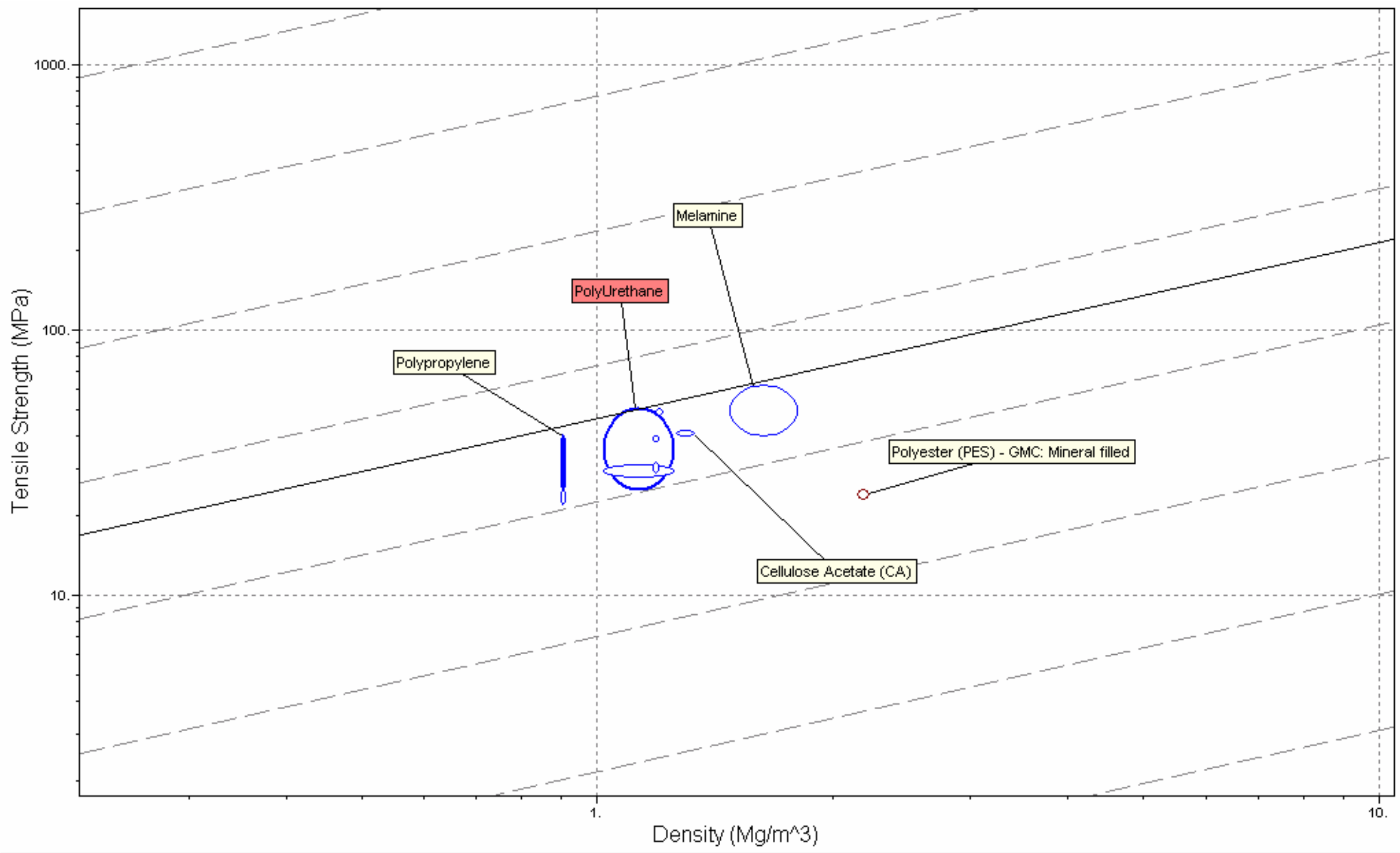
Appendix C: CES Chart for Decking



Appendix D: CES Chart for Crampons



Appendix E: CES Chart for Front Crossbar



Appendix F: CES Chart for Back Crossbar