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MATERIALISE

Scissors

JBH Material Consultants
on behalf of
Roe Designs Ltd.

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Report

1. Summary

JBH Material Consultants were commissioned by Roe Designs Ltd. to make a material recommendation for a pair of scissors. JBH moved quickly to create a brief, expanding it with various figures of merit, before analysing the most important among those. A series of Ashby plots were created, and materials where ruled out with the help of these and several performance metrics, calculated both from primary and secondary research, with Semantic Differential Scales and material perception proving particularly useful.

The material field was slowly narrowed down from nearly 70 to just one: tungsten alloys. These are fairly dense, very strong and hold their edge well. Once this decision had been reached, JBH checked the feasibility of their suggestions though research and found that tungsten-based scissors are already used in medicine for their unusually good properties. For this reason, JBH finds that tungsten-based scissors form the perfect resolution to the brief.

2. Introduction

Roe Designs Ltd., a South Kensington design firm, wanted to add a new product, an elegant pair of scissors, to their existing range of high-quality products. This report, by JBH Material Consultants, looks into the various aspects of their proposed product line from a materials perspective, and provides a final recommendation.

The initial brief simply required that a recommendation be made for a material to be used in an elegant pair of scissors, where cost is no object and the environment is to be preserved. JBH started their work by exploring this brief and making it more specific, thinking of certain properties in particular. They then explored the materials of existing products and modelled simple use-scenarios that allowed the creation of definite limits to material properties. These could then be used in conjunction with Ashby plots to narrow down the material range.

3. Background

Figure 1: It is often plastic parts of scissors that fail ©pioneeringthesimplelife.org

Scissors are used to perform many day-to-day tasks, and variants made of metals or plastics are available. Some historic cutting tools may also have been made of stone, most notably flint.[1] Scissors of the 21st Century remain largely unchanged from their 20thC counterparts, in that they are made predominantly from steels (chiefly stainless and carbon), unless their use dictates otherwise (e.g. nonferrous materials for the cutting of magnetic tape).[2] The handles or 'bows' of scissors tend, for the most part, to be made from plastics but may, in some cases, be made from the same material as the blade.[3] Scissors involving plastics tend to feel of a lower quality and cheaper than those with a full-metal design. These kind of plastic scissors – either those with plastic handles or full-plastic design – are prone to brittle fracture or cracking over time as materials degrade or are exposed to unfavourable conditions such as ultraviolet light.[4]

4. Brief

Roe Designs Ltd. are designers and producers of simple objects, and put quality, practicality and the environment before all other considerations, including cost. They design for customers who are willing to pay the price of quality and sell direct to consumers through their South Kensington shop. With this project, Roe Designs saw potential to add the common cutting tool of a pair of scissors to their collection but wanted theirs to have a twist of elegance. They engaged JBH Material Consultants to provide recommendations for the best materials to use for their new products.

4.1 Figures of Merit

The recommendation should take the following into consideration:

- Environmental credentials:
  - End-of-lifespan impacts must be minimal (reuse/recycling possible)
  - Item must be long-lasting

- Material perception
  - Material & finish must be synonymous with quality
  - Product materials must look and feel the part

- Material Performance
  - Material must stand up to everyday use
  - Material must not break or deform easily

- Practicability
  - Material recommendation must be viable
  - Material must be relatively easy to source
  - Material must stay sharp and useful without regular sharpening

5. Initial Research

JBH conducted research on materials that are currently used in the manufacture of scissors, and the ways in which users use scissors.

5.1 User Interaction

The brief does not specify whether the scissors are to be used in a kitchen setting or at a desk as general-purpose scissors – or even for gardening. As a result, the scissors need to be able to stand up to cutting a variety of items in all these settings.

Very little information exists on uses of scissors, so the research here was carried out first-hand, by asking residents of a university hall.

The following uses for scissors were mentioned:
- Cutting opening of packaging
- Cutting paper/card
- Food preparation
- Piercing holes in objects
- Cutting fingernails
- Sewing
- Trimming stems of flowers
- Collecting of herbs

5.2 Existing Products

Materials used for existing pairs of scissors were investigated as thoroughly as possible – given the surprising lack of information on the topic. The information found was collated into a table displaying important material properties.

Table 1: Properties of existing scissor materials were researched, using information from Granata Edupack.

Material	*Young's Modulus E, GPa*	*Elastic Limit, MPa*	*Embodied Energy, MJ/kg*	*Price, £/kg*
Stainless Steel[5]	190-210	257-1.14x10^3	69.1-76.2	2.36-2.54
Medium Carbon Steel[5]	200-220	255-355	29.3-32.3	0.59-0.61
Silver	68.9-73.1	45-300	1.4e3-1.54e3	317-431
Gold	76-81	20-205	2.41e5-2.65e5	2.8x10^4-3.18X10^4
GFRP[6]	15-28	207-304	99.6-110	26.3-29

6. Investigation

6.1. Material Criteria

Based on the brief, it was decided that the following figures of merit may have a bearing on the fitness to purpose of the scissors, for the reasons outlined below each. Many of these aren't, in themselves, material properties, so analysis was carried out to create performance metrics.

6.1.1. Ability to remain sharp

Scissors must stay sharp: they must 'hold their edge.' In order to do this well, a material must have both a high fracture toughness T /MPa*m$^{1/2}$ and hardness H /HV. This means that the metric of ability to stay sharp, which was defined as ß /HV MPa*m$^{1/2}$, is:

$$ß = HT$$

where ß is a quantity to be maximised.
Plotted on a set of axes, the above can be linearised as:

$$\log(T) = -\log(H) + \log(ß)$$

Analysis was then conducted into the ß values of several of the scissor materials discovered in the *Existing Products* section. When a range was given for a value, the average was used for calculation.

Table 2: The edge-holding ability of various existing scissors was calculated using ß=HT, JBH's performance metric.

Material	*Vickers Hardness H /HV*	*Fracture Toughness T /MPa*m$^{1/2}$*	*ß – value /HV MPa*m1/2*
Stainless Steel	170-438	57-137	1.20×10^4
Medium Carbon Steel	183-415	32-71.9	1.55×10^4
Silver	50-70	60.1-66.5	3800
Gold	90-110	58.7-64.9	6180
GFRP	10.8-21.5	19.3-31	398

log(T) vs log(H)

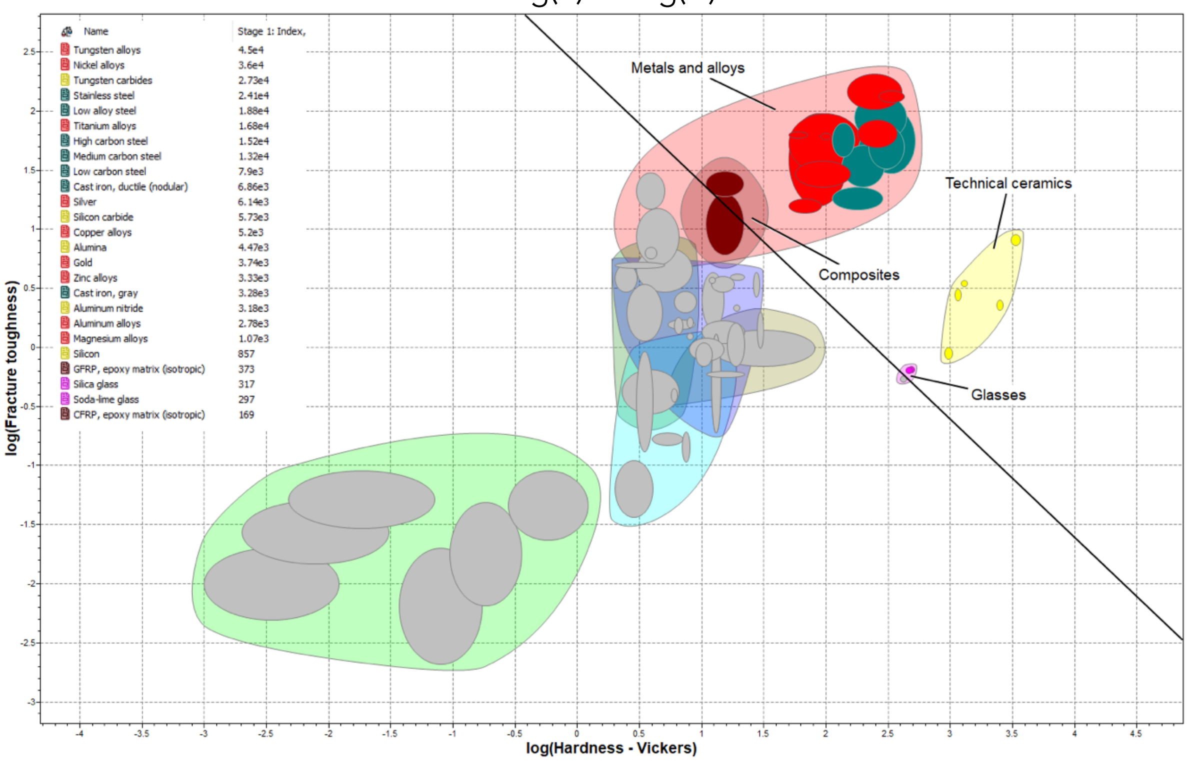


Figure 2: A first Ashby plot looked at minimum values for ß. The ß of CFRP was taken as a minimum, with all materials above the line still in candidacy.

ß was found to vary very considerably (two orders of magnitude) from one material to another. The linearised Ashby plot (above) revealed that taking GFRP as the lower bound for ß excluded the vast majority of materials, however, it included some unsuitable materials, such as (brittle) glasses. This can be refined later.

6.1.2. Hardness

Soft scissors would not work adequately.
The hardness of the material was taken directly into account above, and thus no extra analysis was needed.

6.1.3. Eco-Friendliness

One of the criteria set out by the client was that the product not be too environmentally damaging. Therefore, its recyclability should be high and its carbon footprint low.

Recyclability vs. CO_2 Footprint

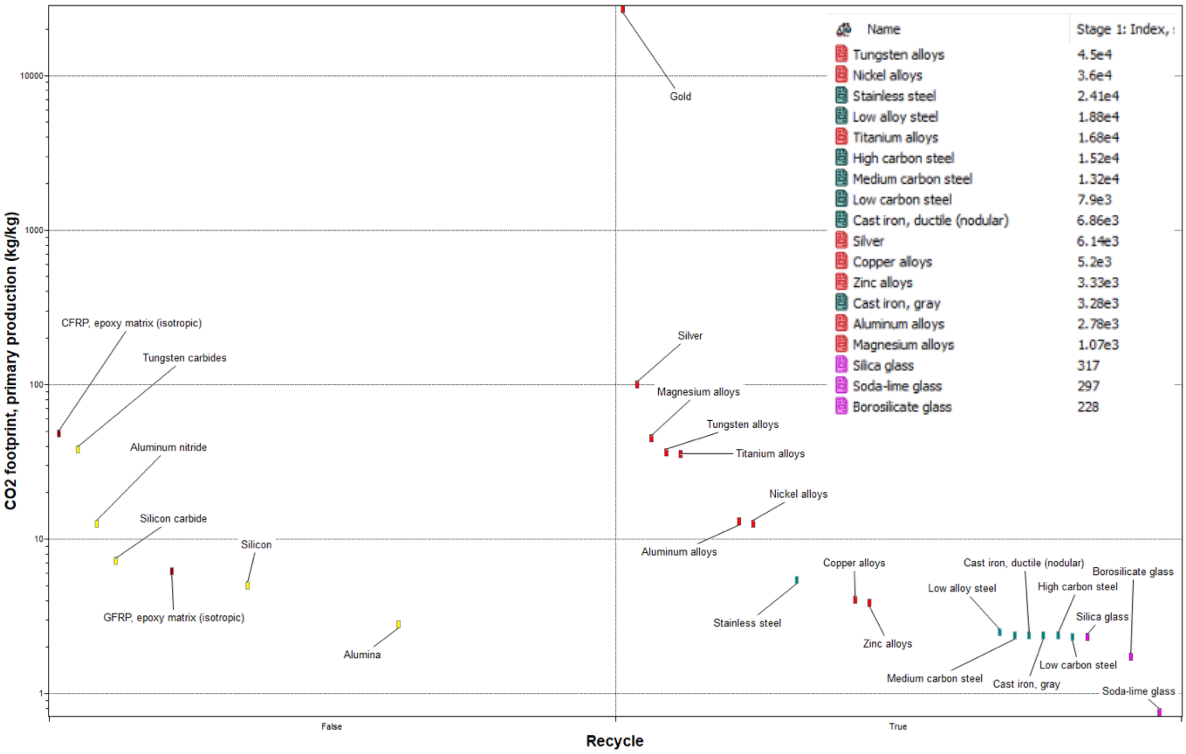


Figure 3: The second Ashby plot focused on eco-friendliness of the material field. The Client had set out that the finished product must have perceived eco-credentials, and recyclability is a good proxy for this.

Based on the client parameters, it was decided that only recyclable materials would be considered. Gold was also ruled out due to the high emissions associated with production. This left the overlayed list.

6.1.4. Weight

In the Semantic Differential Scales (SDS, see Appendix B), it was noted that some users felt that weight was an important metric for quality, while others did not. For this reason, weight was used to remove some, but not many, materials from candidacy – scissors being too light would prevent some from enjoying the product, but for others it was not an issue.

Name	Density, x10^3 /kgm^{-3}
Tungsten Alloys	16.9 – 18.6
Silver	10.5
Copper Alloys	8.18 - 8.85
Nickel Alloys	8.00 - 8.65
Stainless Steel	7.61 - 7.87
Low Carbon Steel	7.80 - 7.82
High Carbon Steel	7.8
Low Alloy Steel	7.8
Medium Carbon Steel	7.8
Gray Cast Iron	6.94 - 7.23
Zinc Alloys	5.71 – 7.16
Ductile Cast Iron	7.05 - 7.15
Titanium Alloys	4.43 - 4.79

The simple metric for weight per object here is density of the material used, so the materials remaining at this stage were ranked by density. Four materials, including the glasses, were eliminated here. The list of materials remaining can be seen to the right.

6.1.5. Resistance to Deformation and Fracture

This was found to be an important metric – the scissors may not break when in normal use. The following equations were used to determine a performance metric for this – and despite geometry and paper cutting forces being taken into consideration, it was found to simplify down very easily.

Figure 4: The various measurements of a pair of scissors, as defined by JBH for this project.

The diagram on the right was created to define variables used for the calculation. The below definitions were used.

$$F = l_c ts$$

This equation was found after research into cutting forces at work in scissors.[7,8]

$$\Delta x = \frac{WL^3}{3EI}$$

This was the supplied formula for end-deflection for a rod under force W.

Taking moments:

$$Fl = WL \;\therefore W = \frac{F \times l}{L} = \frac{l_c ts \times l}{L}$$

Using the Moment of Inertia of a thin rod, I /Kg*m^2:

$$I = \frac{ML^2}{3}$$

We can substitute these into the end deflection equation:

$$\Delta x = \frac{\frac{l_c ts \times l}{L} \times L^3}{3E \times \frac{ML^2}{3}} = \frac{l_c ts \times l \times L^2}{E \times ML^2} = \frac{l_c ts \times l}{E \times M}$$

We can say that mass /kg $M = \rho v$, where v is the volume /m^3 and ρ is the density /kgm^{-3} of the scissor arm.

$$\Delta x = \frac{l_c ts \times l}{E \times \rho v}$$

With the same design of scissors and object being cut, $\frac{l_c ts \times l}{v}$ is a constant. This means that:

$$\Delta x \propto \frac{1}{E\rho}$$

As Δx is to be minimised, $E\rho$ must be maximised. The performance metric that was used, therefore, was $X = E\rho$, linearised as $\log(E) = -\log(\rho) + \log(X)$:

log(E) vs log(ρ)

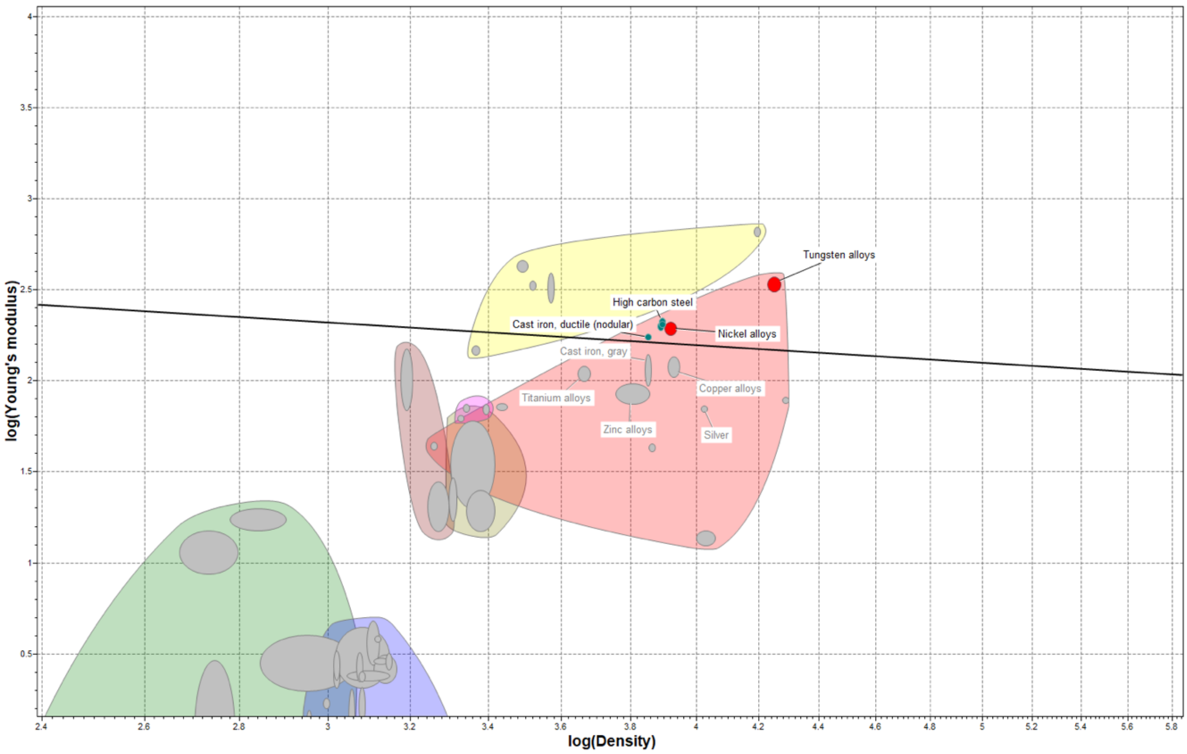


Figure 5: The final Ashby plot created, with a performance metric (aimed at minimising bending) of X=Eρ. This plot suggested that tungsten alloys are most suitable

As can be seen, the materials that perform best on this index are the Tungsten alloys. JBH Material Consultants is thus recommending their use for the production of high quality, durable scissors.

6.2. Semantic Differential Scales, SDS

For such a product, JBH decided that material perception was essential. As a result, detailed surveying about the natures of materials was carried out. Full results can be seen in Appendix B, but these gathered data were used to inform the process throughout. In particular, they led to the creation of and guided the specification on weight.

Polling carried out on perceptions of tungsten were positive. It was one of only two materials in the survey that was consistently ranked highly (see graph, right). This bodes well for the recommendation.

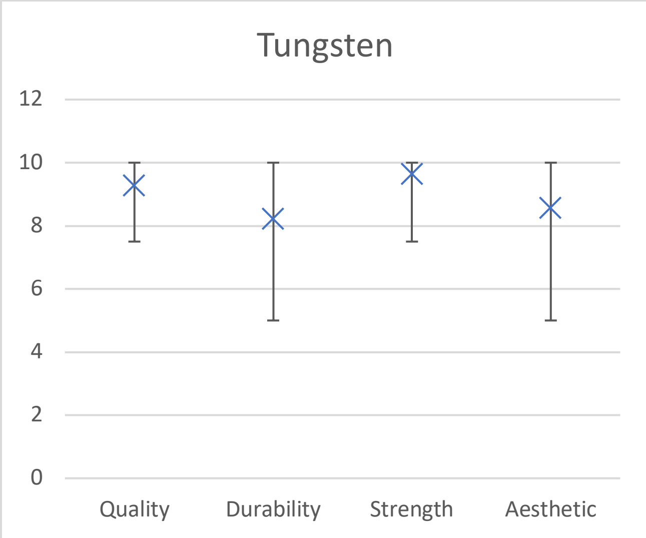


Figure 6: Tungsten's semantic differential scores.

7. Conclusion

After study of existing solutions and analysis of the Client's original brief leading to a series of figures of merit, JBH Material Consultants conducted an in-depth investigation of many of the largest material families, with the end goal of making a recommendation to the client, Roe Designs Ltd., for the material to be used in the creation of a new, high-quality and not cost-limited pair of scissors. The final recommendation is that the scissors be made of a tungsten alloy, as it scored highly throughout the process and was the best-performing material on the all-important final performance index. The SDS section likewise reinforced the selection, by suggesting that smooth and fairly heavy objects are perceived as high quality – tungsten alloys can match all of these criteria. At this stage, JBH conducted some brief feasibility analysis, and discovered that Tungsten-based scissors are already available for quality-critical and not cost-limited medical applications.

Appendices

Appendix A: Exercises:

1.

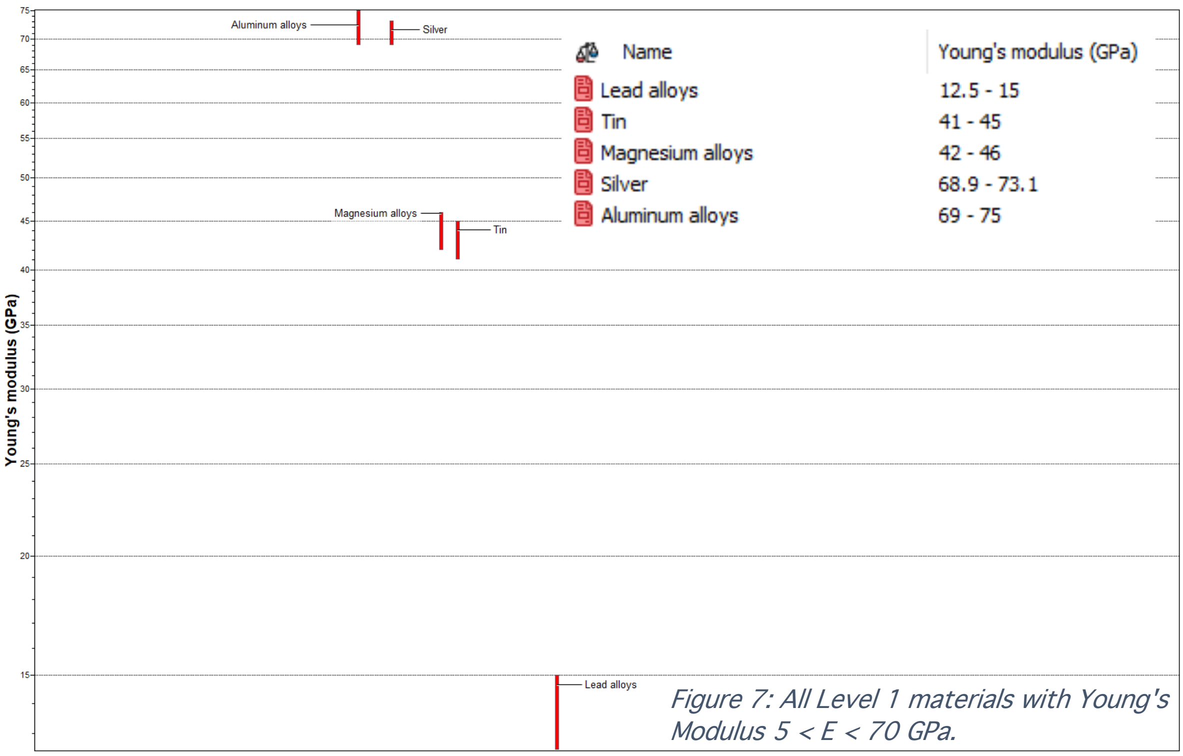


Figure 7: All Level 1 materials with Young's Modulus 5 < E < 70 GPa.

2.

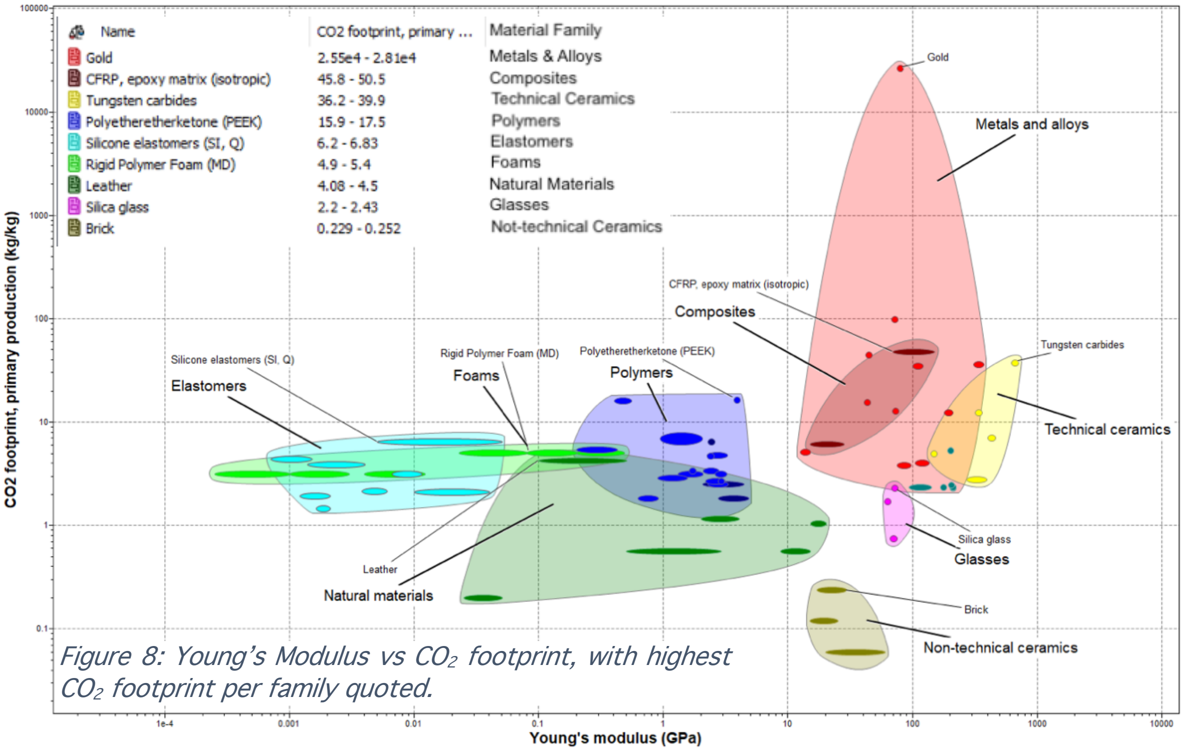


Figure 8: Young's Modulus vs CO_2 footprint, with highest CO_2 footprint per family quoted.

3.

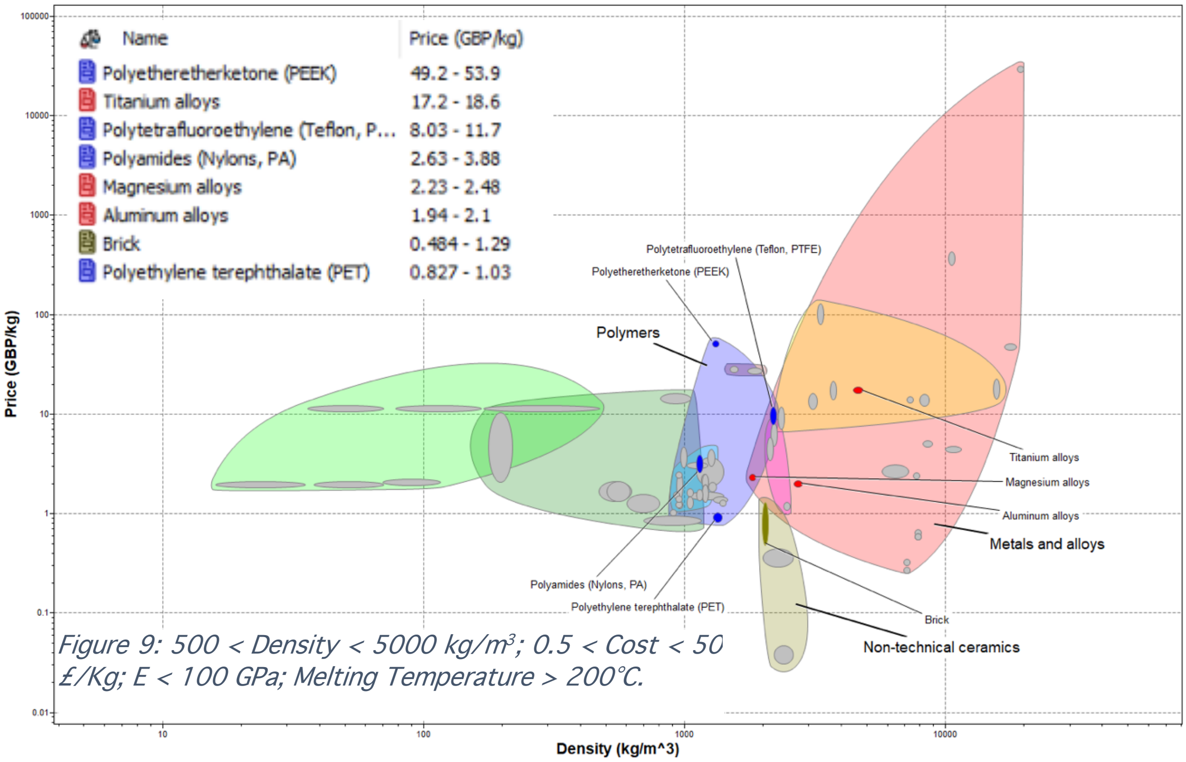


Figure 9: 500 < Density < 5000 kg/m³; 0.5 < Cost < 50 £/Kg; E < 100 GPa; Melting Temperature > 200℃.

4.

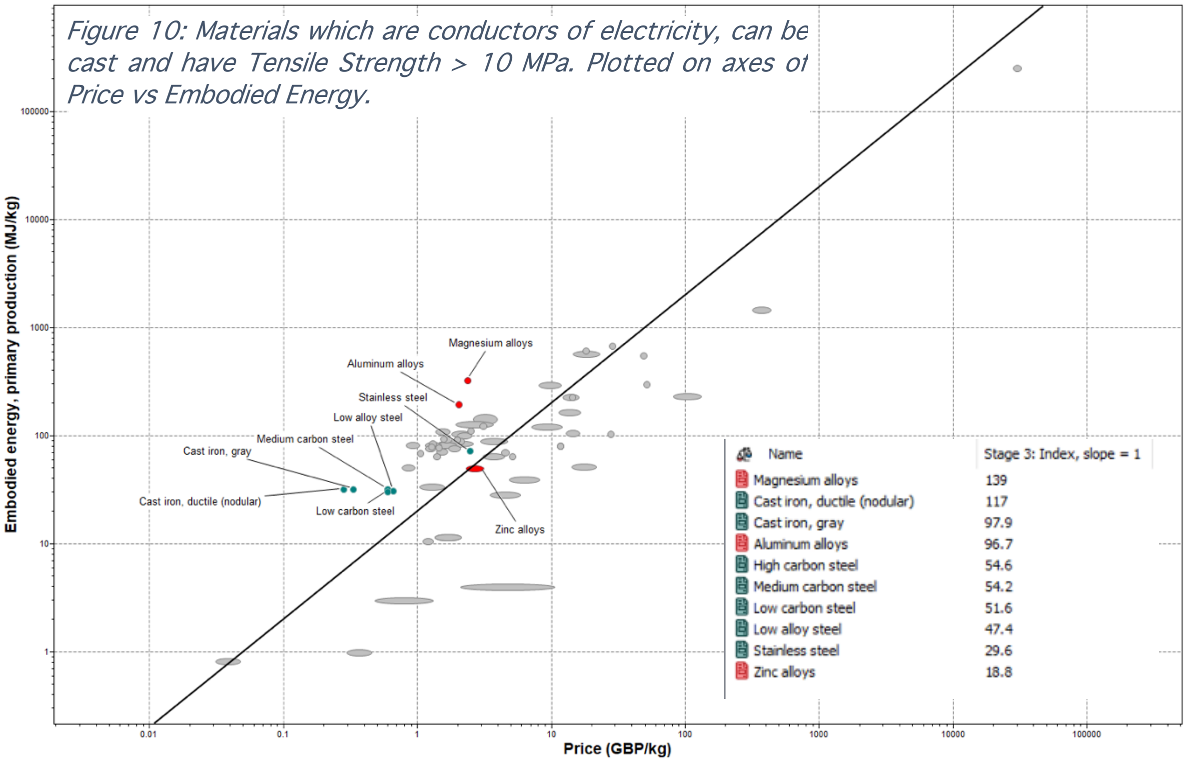


Figure 10: Materials which are conductors of electricity, can be cast and have Tensile Strength > 10 MPa. Plotted on axes of Price vs Embodied Energy.

5.

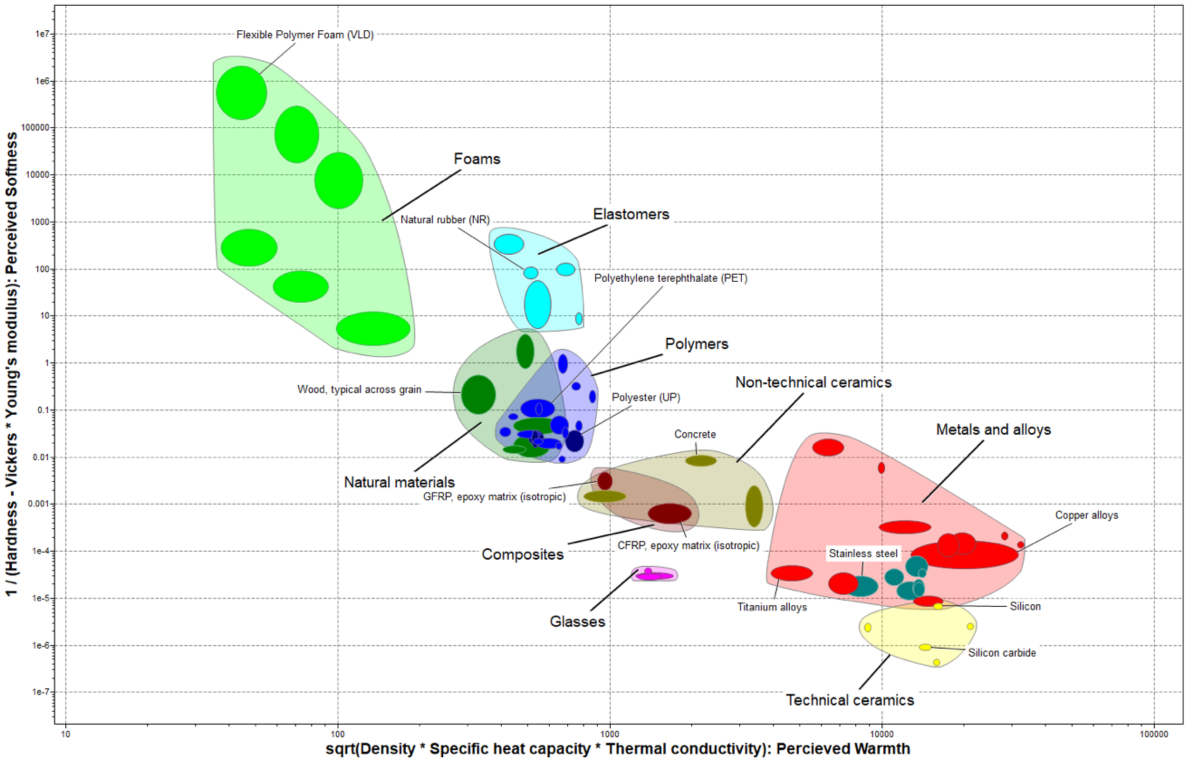


*Figure 11: Perceived warmth vs perceived softness. 1/(Hardness * Young's modulus(was used so that a high value denotes a soft material, rather than a hard one.*

Appendix B: Semantic Differential Scales

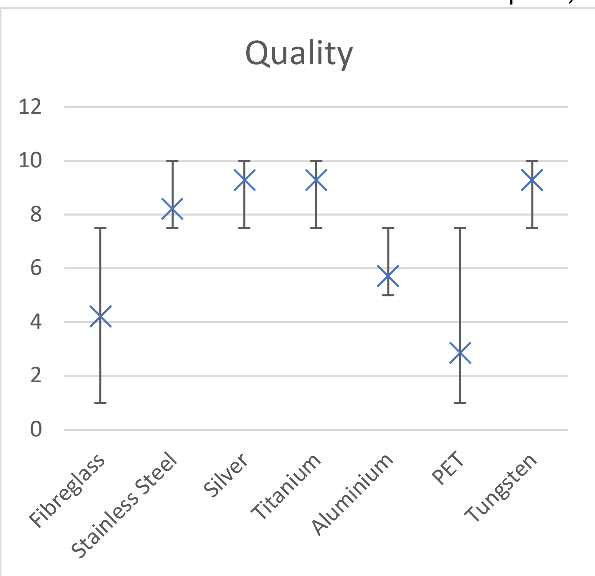
In order to gain insight into people's perception of everyday objects, JBH created an online survey and carried out polling, the data from which are shown, in condensed form, below.

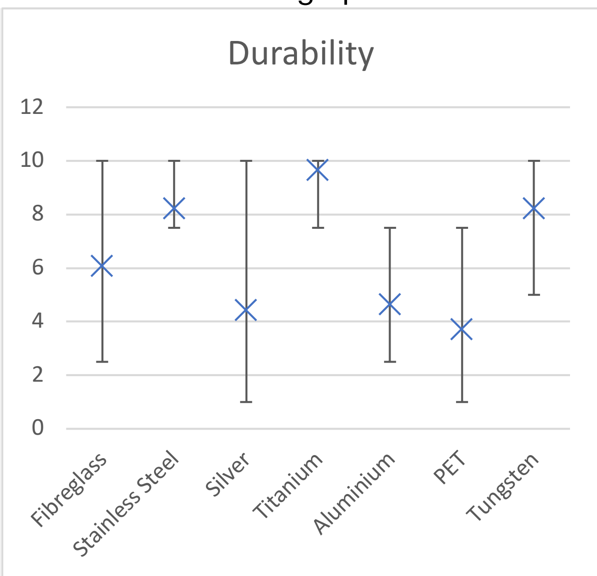
Table 3: Results for polling about various materials and their perceived properties. Data are condensed.

				Quality			
	Fibreglass	**Stainless Steel**	**Silver**	**Titanium**	**Aluminium**	**PET**	**Tungsten**
AVG	4.2142857	8.214285714	9.2857143	9.2857143	5.7142857	2.8571429	9.2857143
Min	1	7.5	7.5	7.5	5	1	7.5
Max	7.5	10	10	10	7.5	7.5	10
				Durability			
	Fibreglass	**Stainless Steel**	**Silver**	**Titanium**	**Aluminium**	**PET**	**Tungsten**
AVG	6.0714286	8.214285714	4.4285714	9.6428571	4.6428571	3.7142857	8.2142857
Min	2.5	7.5	1	7.5	2.5	1	5
Max	10	10	10	10	7.5	7.5	10
				Strength			
	Fibreglass	**Stainless Steel**	**Silver**	**Titanium**	**Aluminium**	**PET**	**Tungsten**
AVG	5.7142857	8.928571429	2.7857143	9.6428571	5	3.7142857	9.6428571
Min	2.5	7.5	1	7.5	2.5	1	7.5
Max	10	10	5	10	7.5	7.5	10
				Aesthetic			
	Fibreglass	**Stainless Steel**	**Silver**	**Titanium**	**Aluminium**	**PET**	**Tungsten**
AVG	2.6428571	7.5	8.5714286	8.5714286	5.3571429	2.7857143	8.5714286
Min	1	5	7.5	7.5	2.5	1	5
Max	5	10	10	10	7.5	5	10

The above table ranks seven either common or potential materials by their perceived quality, durability, strength and aesthetic appeal. The data are condensed, showing only average, minimum and maximum values.

The table on its own is hard to interpret, so each of these was graphed:





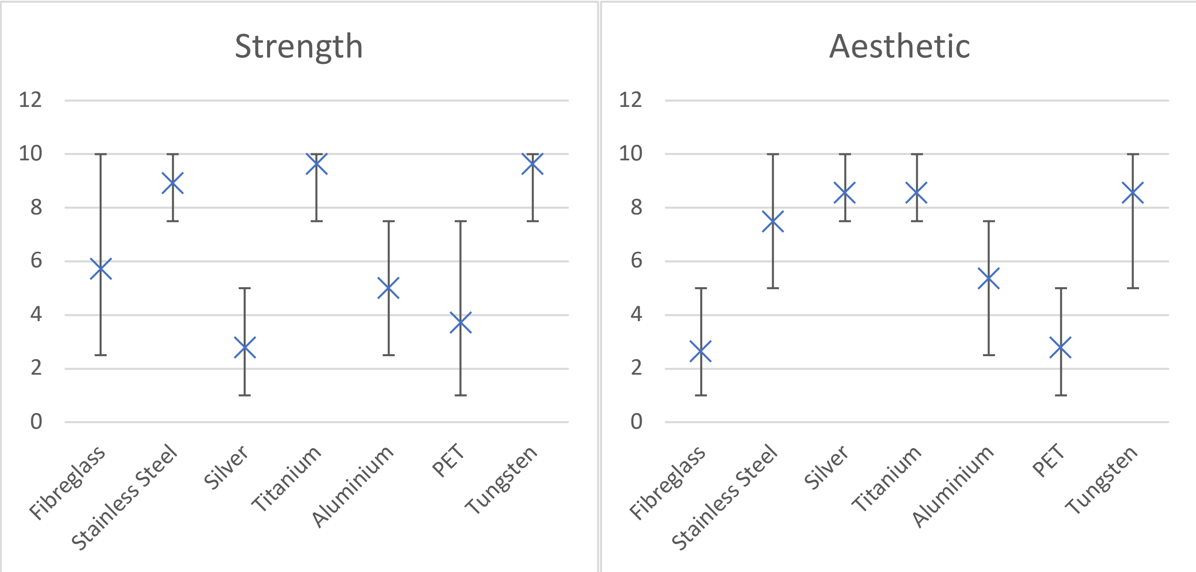


Figure 12: Graphical representations of user data on material perceptions.

As can be seen from these graphs, Titanium and Tungsten are the only two materials which score highly on all metrics.

Further polling was carried out on metrics associated with quality. Surveyees were asked to rank, from 1-10, how important they find various elements in a high-quality product. The data, again condensed, are below:

	Smoothness	**Shininess**	**Weight**	**Coolness**	**Cost**
AVG	8.21428571	7.07142857	8.21428571	6.07142857	8.92857143
Min	5	1	5	2.5	7.5
Max	10	10	10	10	10

Despite very wide spreads in the data, some trends were visible. These become clearer when represented graphically.

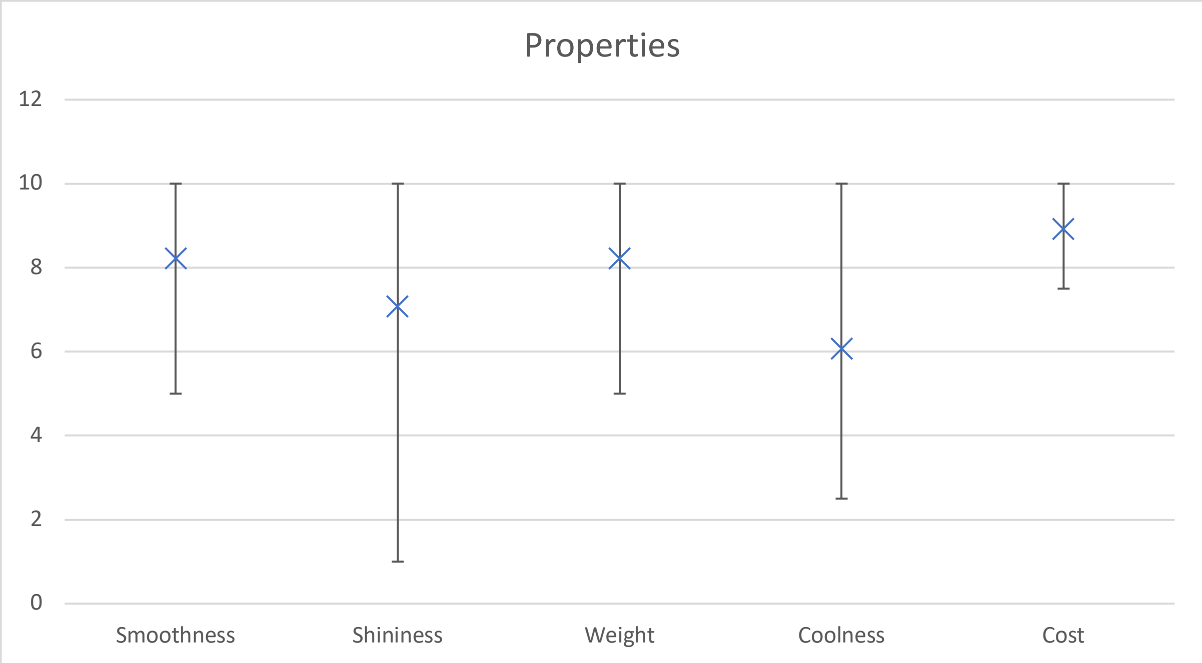


Figure 13: General material properties, as evaluated by surveyees.

Interestingly, it was noted that, while there were disagreements about shininess and coolness of a high-quality item, smoothness, weight and cost were all deemed to be high. For this reason, it was decided that an extra specification should be added for material weight (smoothness is included in sharpness: sharpened edges have to be smooth in order to cut well).

Appendix C: References:

Resources Referenced:

- All uncredited figures & tables were created by JBH Material Consultants
- All uncited values and information on materials are taken from Granata EduPack's Level 1 materials database.

Figure 1: From Pioneering the Simple Life, *Fix Broken Scissors,* Available from: https://pioneeringthesimplelife.org/2016/03/09/fix-broken-scissors/ [Accessed 03/12/2020]

1. King HM, *Uses of Flint: Tools, weapons, fire starters*, Available at https://geology.com/rocks/flint.shtml [Accessed 12/11/2020]
2. Bold Barber, *How Scissors Are Made*, Available at https://boldbarber.com/how-scissors-are-made/ [Accessed 12/11/2020]
3. Craft Industry Alliance, *Scissors for All*, Available at https://craftindustryalliance.org/scissors/ [Accessed 12/11/2020]
4. Essentra Components, *UV and its effects on plastics*, Available at https://www.essentracomponents.com/en-gb/news/product-resources/uv-and-its-effect-on-plastics-an-overview [Accessed 15/11/2020]
5. Made How, *Scissors: Raw Materials*, Available at http://www.madehow.com/Volume-3/Scissors.html [Accessed 20/11/2020]

6. Maped, *Kidi Cut Scissors*, Available at https://www.mapedhelix.co.uk/en_uk/kidi-cut.html [Accessed 20/11/2020]
7. Mahvash M, Voo LM. Modelling the Forces of Cutting With Scissors, *IEEE Transactions on Biomedical Engineering*, 2008;55(3), pp.848-856, DOI: 10.1109/TBME.2007.908069
8. Hussain Ather S, *Blade Cutting Force*, Available at https://sciencing.com/calculate-cutting-force-7572575.html [Accessed 04/12/2020]