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# Review of V50 Values for Armour Materials

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# Purpose

- To provide a comparison of V50 values for various material
- To provide data that can be used as a benchmark for comparison with the performance of new materials
- Review empirical relationships between V50 and material and projectile properties

# Data Analysis

Tobin from the UK Department of Defence appears to have been the first to publish an empirical relationship between V50 and areal density of the armour (Tobin, L. (1985) A Comparison of the levels of protection afforded by various fabrications of Kevlar and Nylon Helmets Technical Memorandum SCRDE/85/8, Part 1 and SCRDE/85/10, Part 2). He found for a given armour material:

$$V50 = k * AD^{0.5} \qquad (1)$$

Where k is a constant determined by the armour material properties and AD is the areal density of the material. Many subsequent studies found similar relationships.

Jacobs and van Dingenen (Ballistic protection mechanisms in personal armour. Journal of Material Science 36 (2001) 3137 – 31) took this a step further as they wanted to find a relationship which allowed the size of different projectiles to be taken into account. They found from a series of tests that:

$$\frac{E}{P_a} = c * AD \qquad (2)$$

Where E is projectile energy absorbed, $P_a$ is the projectile cross-sectional area and c is a material constant.

# Data Analysis (continued)

This is a simple extension of equation 1 as equation 2 can be re-written as:

$$\frac{1}{2}{}^{m_p}/_{p_a} * \ V50^2 = c * AD \qquad (3)$$

Where $m_p$ is the mass of the projectile.  Equation 3 can be re-written as:

$$V50 = \ (2c * \frac{AD}{AD_p})^{0.5} \qquad (4)$$

Where $AD_p$ is the areal density of the projectile i.e. the mass of the projectile divided by the projectile's cross-sectional area.  Therefore what Jacobs and van Dingenen have introduced is the concept that V50 is the same for different projectiles which have the same mass per unit area.

# Data Analysis (continued)

Cuniff (Dimensionless Parameters for Optimization of Textile-Based Body Armor Systems. Proceeding of the 18th International Symposium on Ballistics, San Antonio, TX, Nov 1999.) wanted to be able to compare not only different projectiles but also different armour materials and based on a dimensional analysis approach he introduced a parameter, a dimensionless V50 velocity, defined as the V50 velocity normalized by the cube root of the product of specific work to break the fibre and the acoustic wave speed in the fibre. Therefore he suggested and verified that the following relationship was valid:

$$\frac{V50}{U^{1/3}} = f\left(\frac{AD}{AD_P}\right) \qquad (5)$$

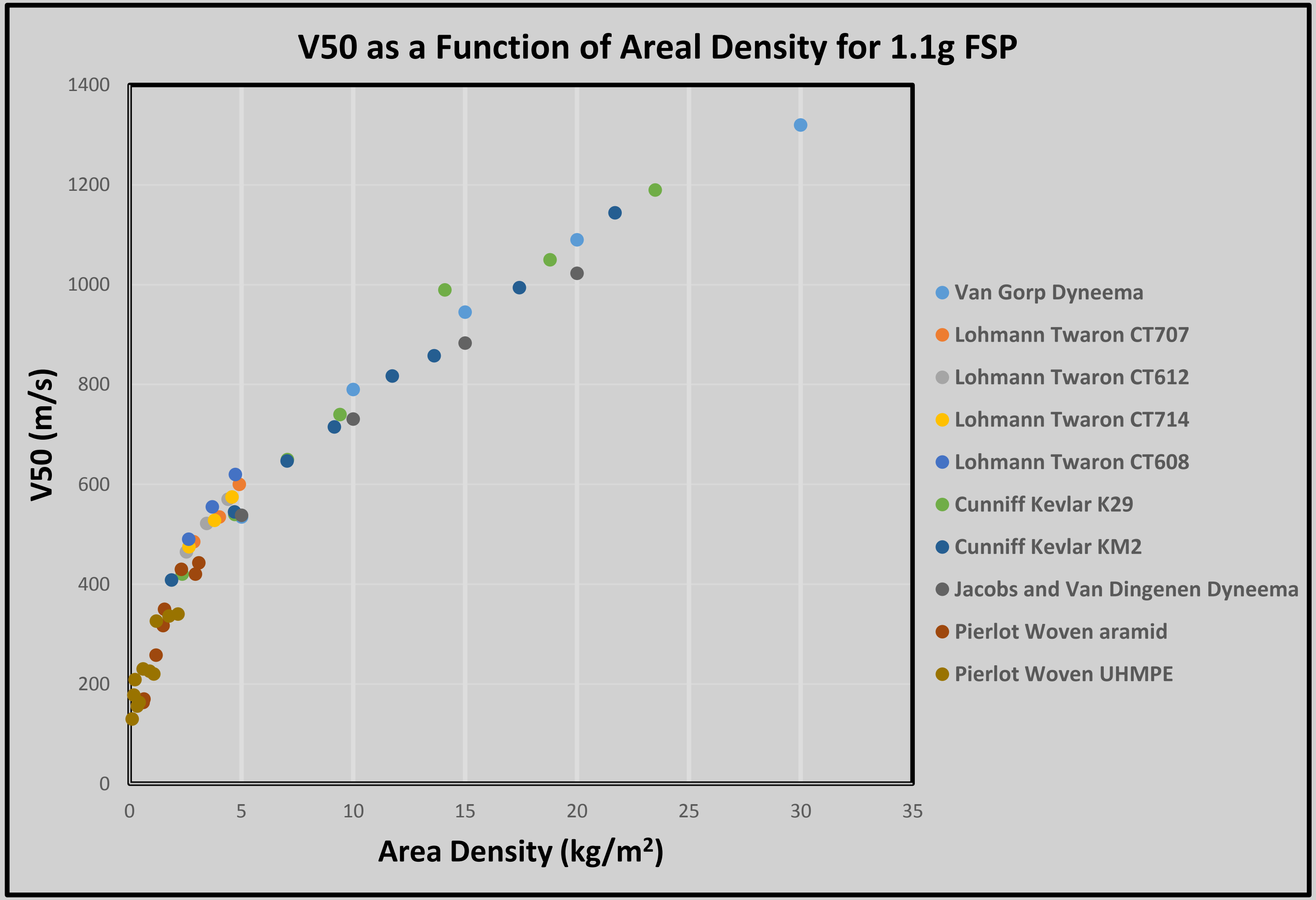
Where U is the product of fibre toughness and strain wave velocity. The function was found to be approximately a square root function as expected from the previous equations.

# V50 Values for High Performance Fabrics

Chart opposite shows data extracted from literature for V50 as a function of fabric areal density.

Data is for 1.1g FSP and for Dyneema, Kevlar and Twaron fabrics.

Jacobs and van Dingenen data is extracted using equation (2), Cunniff data using equation (3) all other data is directly from experiments with 1.1g FSP

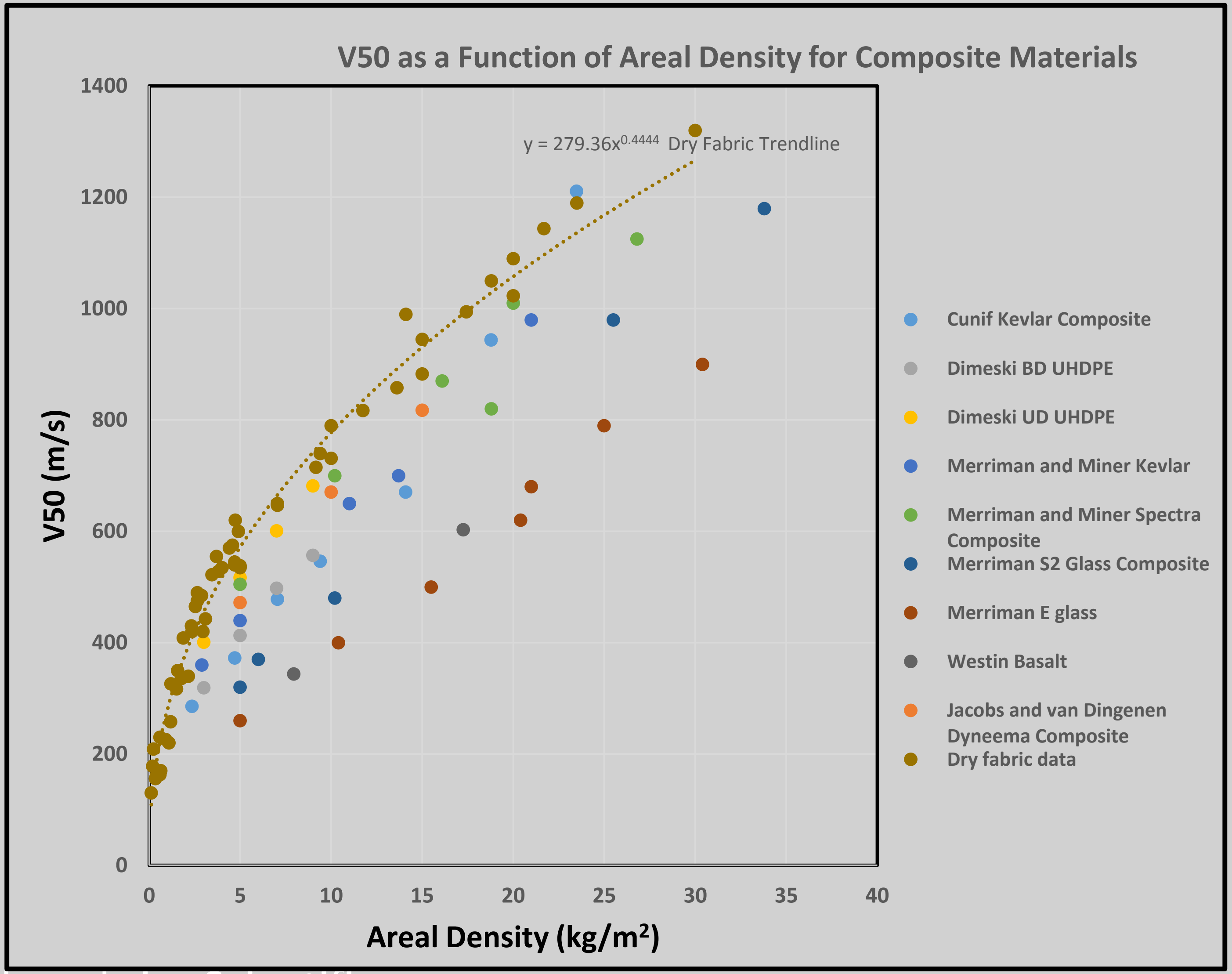


# V50 for Composite Materials

Chart Opposite shows data extracted for V50 for composite materials.

Data is for 1.1g FSP and Dyneema, Kevlar, Spectra, Glass and Basalt reinforcing Fibres

Jacobs and van Dingenen data is extracted using equation (2), Cunniff data using equation (3) all other data is directly from experiments with 1.1g FSP

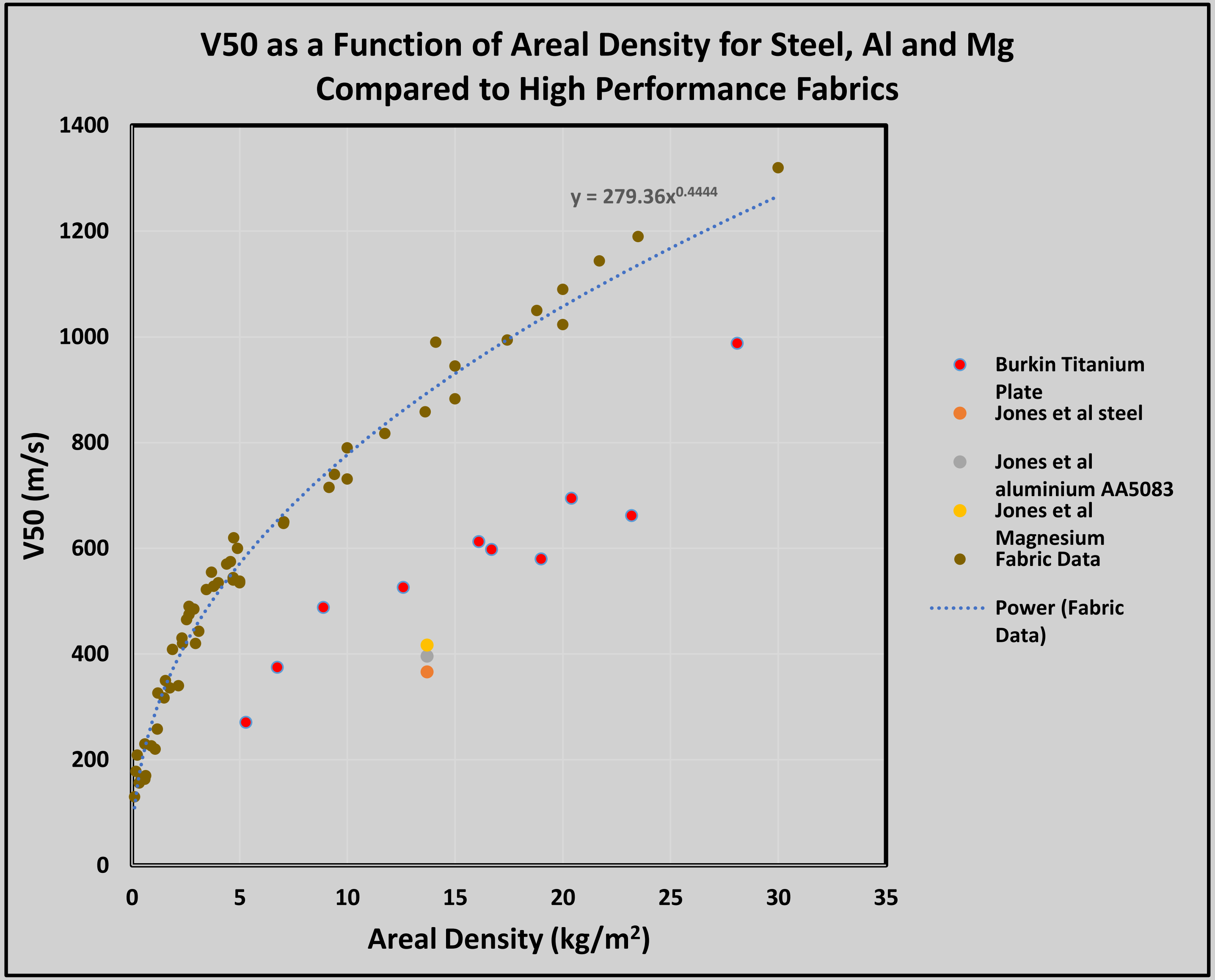


# V50 for Metals

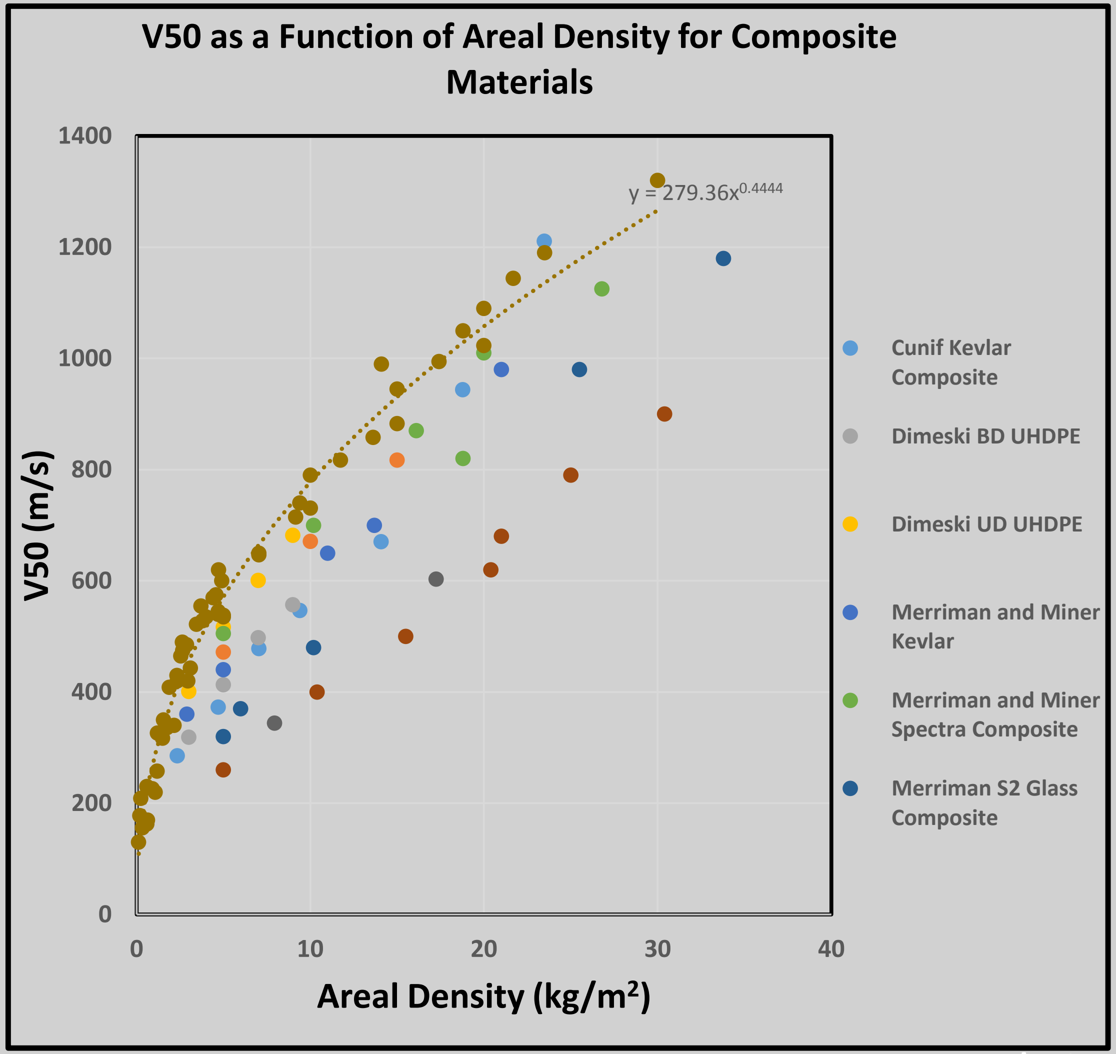
Chart Opposite shows data extracted for V50 for metals

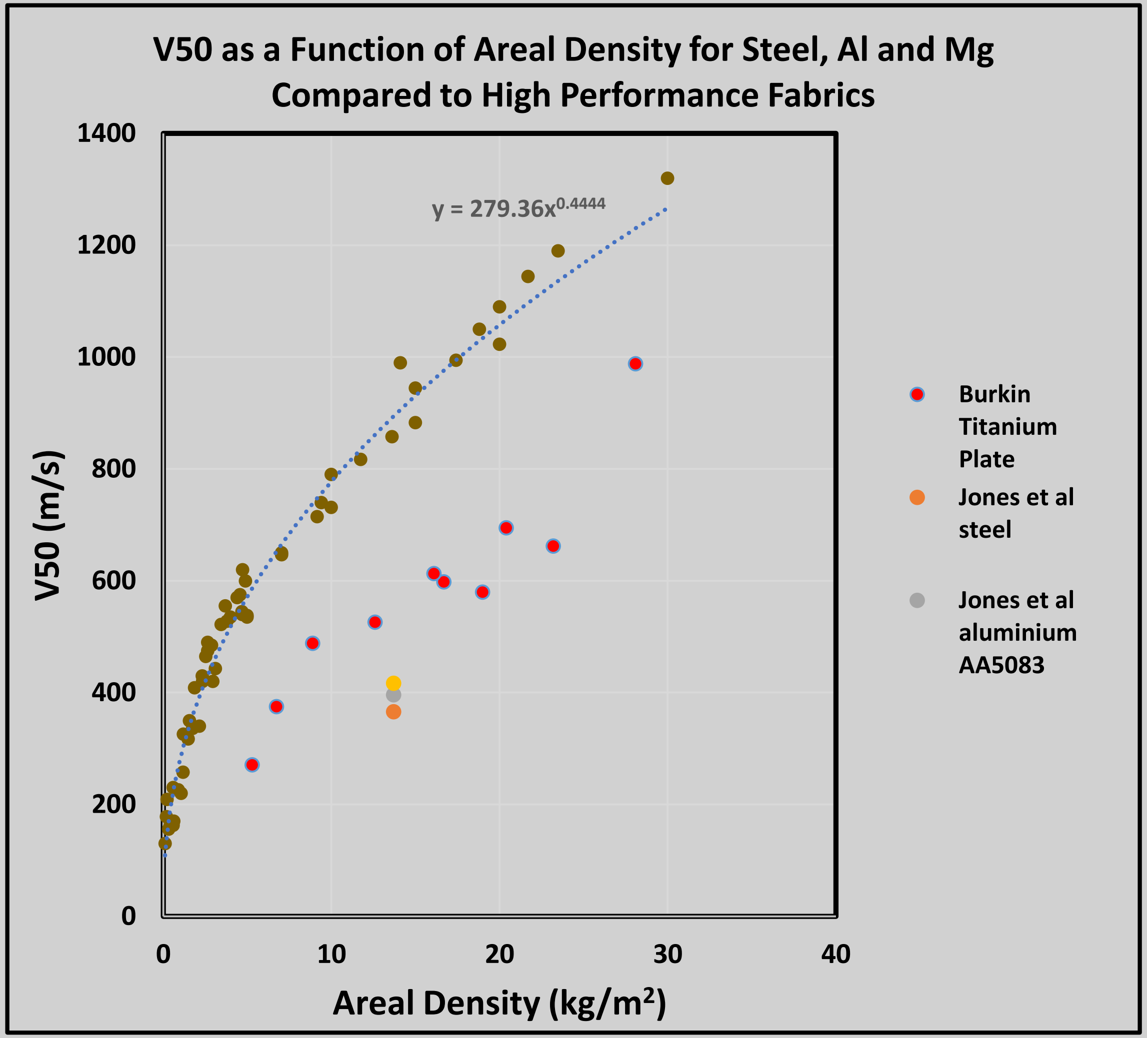
Data is for 1.1g FSP and for titanium, steel and aluminium.

All data is based on experiments with 1.1g FSP.

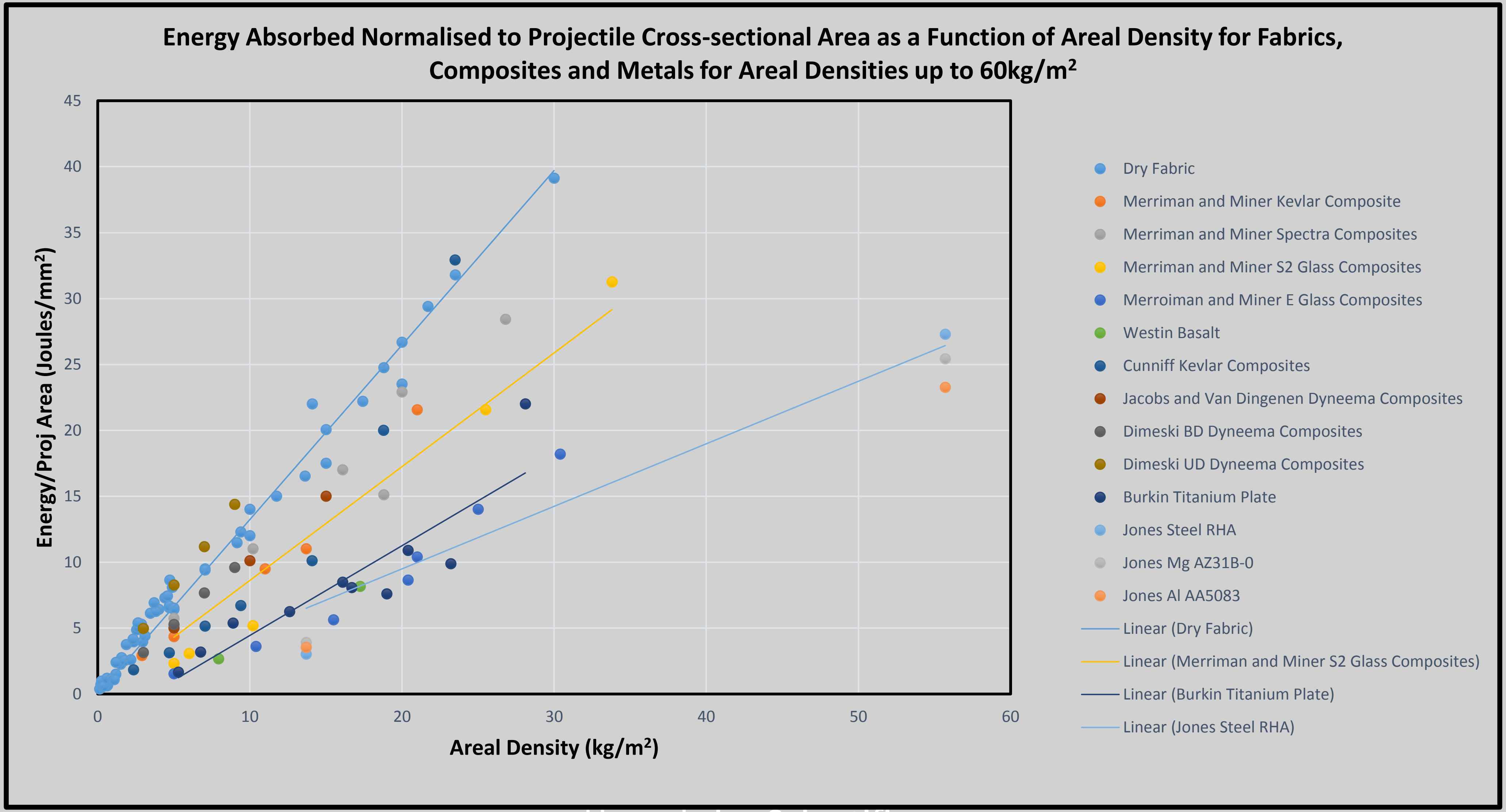


# Comparison Fabric, Composites and Metals



# Summary Information in Terms of Energy Absorbed



# Conclusion

For FSPs

- There is a consistent relationship between V50 and areal density for Kevlar, Twaron and Dyneema with surprisingly little scatter considering the data is sourced from a number of different organisations
- Kevlar and Dyneema composites perform better than glass and basalt composites
- At least up to areal densities of 60kg/m$^2$ composites outperform metals

# Data References

| Ref no | Title | Authors and Affiliation | Reference | Materials | Projectile |
|---|---|---|---|---|---|
| 1 | Fragmentation Resistance of Fiber Reinforced Ballistic Structures | Merriman, E.A., and Miner, L.H., E. I. DuPont de Nemours and Co. Inc | 10th International Ballistics Symposium of the American Defense Preparedness Association in San Diego, California.1987 | Composites<br>4000 to 35,000 gsm | 1.1g FSP (0.22 Caliber) |
| 2 | A Model for HDPE Based Lightweight Add-on Armour | Van Gorp, E.H.M., van der Loo, I.L.H., and van Dingenen | Ballistics '93 14th International Symposium on Ballistics (1993) | Dyneema Unidirectional Fabric (UD 66) | 1.1g FSP (0.22 Caliber) |
| 3 | Dimensionless Parameters for Optimization of Textile-Based Body Armor Systems | Philip M. Cunniff<br>U.S. Army Soldier and Biological Chemical Command Soldier Systems Center, Natick Natick, MA 01760-5019 | Proceeding of the 18th International Symposium on Ballistics, San Antonio, TX, Nov 1999 | Fabrics and Composites<br>270 – 25000gsm | 0.12, 0.26, 1.0, 4.1, and 8.2g steel or tungsten |
| 4 | Ballistic protection mechanisms in personal armour | M. J. N. Jacobs, J. L. J. Van Dingenen<br>DSM High Performance Fibers | Journal of Material Science 36 (2001) 3137 – 31 | Dyneema Fabrics and Composites<br><br>UD Dyneema 2000 to 20,000 gsm | 0.237, 0.486, 1.1, 2.8, 5.3 and 13.4g FSP |
| 5 | Teijin Aramid | Rene Lohmann<br>Teijin Aramid GmbH, Wuppertal, Germany | Techtextile Middle East, Dubai February 2014 | Twaron Fabric<br>CT608, CT612, CT707, CT714<br>2500 – 5000 gsm | 1.1g FSP |
| 6 | Ballistic Impact Properties of Fibre Reinforced Composite Structures | Westin, J | Master's Thesis for Swedish Defence Research Agency 2011 | Composites<br>5000 to 30000 gsm | 1.1g FSP |
| 7 | Ballistic Properties of Polyethylene Composites Based on Bidirectional and Unidirectional Fibers | Dimko Dimeski, Gordana Bogoeva-Gaceva, Vineta Srebrenkoska1<br>1Faculty of Technology, "Goce Delcev" University, Stip, FYRM<br>2Faculty of Technology and Metallurgy "Ss. Cyril and Methodius" University, Skopje, FYRM | Zbornik radova Tehnološkog fakulteta u Leskovcu ISSN 0352-6542 UDK 004/.007+3+5+6(05)<br>20 (2011), 184 – 191 UDK 677.494.7:623.5:620.1 Originalni naučni rad | Composites<br>Plain woven Dyneema and Dyneema unidirectional tape 3000 to 9000gsm | 1.5g FSP |
| 8 | Ballistic Evaluation of Magnesium Alloy AZ31B | by Tyrone L. Jones, Richard D. DeLorme, Matthew S. Burkins, and William A. Gooch., Us Army Research Laboratory | ARL-TR-4077 April 2007 | Magnesium, Aluminium, Steel<br>13000 to 135,000 gsm | 1.1, 13.4 and 53.8g FSPs |
| 10 | Ballistic Performance of Thin Titanium Plates | Matthew Burkins<br>U.S. Army Research Laboratory, | 23rd International Symposium on Ballistics. Tarragona, Spain 16-20 April 2007 | Titanium Plate 5,000 to 28,000 gsm | 1.1g FSP |
| 11 | Ballistic Testing of Australian Bisalloy Steel for Armor Applications | W.A. Gooch1, D.D. Showalter, M.S. Burkins, V. Thorn, S.J. Cimpoeru and R. Barnett., US, Army Research laboratory and DSTO | 23rd International Symposium on Ballistics. Tarragona, Spain 16-20 April 2007 | Steel Plate<br>80,000 to 160,000gsm | 13.4 and 53.8g FSP |
| 12 | "High Strength Fabrics for Combat Clothing" | A Pierlot | Future Land Force Conference 2014 | Twaron, Kevlar and Spectra Fabrics | 1.1g FSP |

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# Thank You

Contact Details

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