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Potential applications for steel and titanium metal foams

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Techniques for making metal cellular structures have been successfully developed to commercialize aluminium and nickel foam. Work to extend these methods to create steel and titanium foams is well advanced. The question arises: in which applications might they find success? Here we apply a general methodology for exploring potential applications to answer this question..

1. Introduction

Cellular metals promise significant advantages in structural applications. Their specific stiffness and impact energy and sound absorption capacity are of particular interest [1, 2]. Aluminium foams are currently used in "crash protection" systems and certain structural applications, and nickel foams have long been used as the electrodes and current collectors [3]. Cost is the main obstacle to wider use of aluminium foam sandwiches as light-weight structural elements, but refinements of the processing continues to drive price down [4].

It is expected that, emerging technologies will offer steel and titanium foams at an affordable price [5, 6]. Here we apply a general methodology for finding applications [7, 8] and its computer software implementation FAS [9] to explore potential applications for two "virtual" materials: open-cell foams of low relative densities (0.05–0.3) made of the medium carbon AISI 1040 steel (water quenched and tempered at 540°C) and of the alpha-beta titanium alloy Ti 6Al 4V (aged). Since they do not yet exist, direct measurement of their properties is not yet possible; but the understanding and modelling of the properties of metal foams is sufficiently well advanced that—given the properties of the parent material from which they are made—their properties can be estimated with some confidence.

To do this we first calculate the values of the most important *performance indices* characterizing the performance of materials in given applications. Then, following each of three separate strategies, we compare the performance of the virtual materials with that of a large number of established materials currently used in different application fields. The details of the calculation procedure can be found in ref. [8].We recall here only briefly the principles of the three strategies:

- The "Search through function" strategy. The virtual material is compared with existing materials of a certain material class using the values of performance indices as criteria of excellence. The performance indices are normalised by the range of values in the class of materials choosen for comparison [8]. This identifies the attractive "functions" that are related with the performance indices, i.e. the ones for which the virtual materials appears to be better than say 80% of the materials used for comparison..
- The "Closest match" strategy. The search through existing materials to find those with values of predefined performance indices and/or properties that are similar to those of the virtual material. The distance D is obtained as a euclidean distance in the space of normalised performance indices [8]. This identifies "similar" materials; their applications become potential applications for the virtual material. This suggestion must of course be cross checked using the performance indices relevant for this potential application for the definition of the distance.
- The "Matching design requirements" strategy. This strategy makes use of a database of applications, each application being associated with a list of relevant performance indices, and a set of materials currently used. The performance index and/or property values of materials currently used a given application field is compared with the

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TABLE I The virtual materials considered in this work

Material and relative density	Density (kg/m)^3	Young's Modulus (GPa)	Plastic collapse limit (MPa)	Crushing- rupture strength (MPa)	Fracture toughness, MPa·m$^{1/2}$ (1–10 mm)	Thermal conductivity (W/(m·K))
AISI 1040, (0.05)	0.39	0.53	1.99	4.31	0.24–0.76	0.13
AISI 1040, (0.1)	0.785	2.12	5.62	12.18	0.68–2.16	0.52
AISI 1040, (0.2)	1.57	8.48	15.9	34.45	1.93–6.11	2.08
AISI 1040, (0.25)	1.96	13.25	22.2	48.14	2.70–8.83	3.25
AISI 1040, (0.3)	2.36	19.08	29.2	63.3	3.55–11.22	4.68
IMI 318, (0.05)	0.22	0.29	3.52	7.70	0.43–1.37	0.02
IMI 318, (0.1)	0.44	1.15	9.96	21.79	1.22–3.86	0.07
IMI 318, (0.2)	0.89	4.6	29.17	61.63	3.45–10.9	0.29
IMI 318, (0.25)	1.11	7.2	39.38	86.13	4.8–15.3	0.45
IMI 318, (0.3)	1.33	10.35	51.76	113.21	6.35–20.1	0.65
Al-12%Si foam, (0.2)	0.48–0.52	4.7–5.3	5–10	5–20	1.8–2.3	7–14

performance index of the new material. The partial gain or loss of utilizing the virtual material in an application field is measured, for all relevant performance indices or properties, by the difference between its performance index value and the average value for the materials currently used in this application. "Effective" technical gain is the average of the partial gains per relevant property or performance index, after normalisation by the average values for the materials currently used [8].

2. Properties of the virtual materials

The property profiles of hypothetical steel and titanium foams were calculated using the property correlations set out below [1]. They are based on micro-mechanical modelling of each property. Each model has been calibrated by fitting it to data for existing aluminium foams. They describe "low density" foams with relative density (ρ/ρ_s, where ρ is the cellular metal density and ρ_s the solid metal density) less than 0.3.

Young's modulus E that is calculated as:

$$E = E_s \cdot (\rho/\rho_s)^2, \tag{1}$$

where E_s is the Young's Modulus of the solid metal.

The plastic collapse limit σ_{pl} (stress at onset of plastic collapse of cells) is given by

$$\sigma_{pl} = 0.4 \cdot \sigma_y \cdot (\rho/\rho_s)^{3/2}, \tag{2}$$

where σ_y is the yield stress of the solid metal.

The densification strain ε_s at which densification starts is:

$$\varepsilon_s = 1 - 2 \cdot (\rho/\rho_s). \tag{3}$$

The crushing or rupture strength $\sigma_f{}^*$ is calculated as:

$$\sigma_f^* = 0.65 \cdot \sigma_f \cdot (\rho/\rho_s)^{3/2}, \tag{4}$$

where σ_f is tensile or compressive strength, or modulus of rupture of the solid metal.

The fracture toughness K_{1C} is calculated as:

$$K_{1C} = \sigma_f^* \cdot \sqrt{\pi \ell}, \tag{5}$$

where ℓ is the characteristic foam cell size. In our calculation we assume that l varies over the range 1–10 mm.

The thermal conductivity λ is calculated as:

$$\lambda = \lambda_s \cdot (\rho/\rho_s)^2, \tag{6}$$

where λ_s is the thermal conductivity of the solid metal.

The cost of new metal foams is difficult to estimate, since technologies for foaming steel and titanium differ from those for the aluminium or nickel. To illustrate the method we have assumed that the cost of foamed steel and titanium is 4–5 times greater than that of the solid materials. This is certainly an optimistic estimate, but its feasibility will depend on the processes made available for this production (and on the amount of materials produced). Some of the applications suggested may never become economically viable, but the ones which are eliminated here for economical reasons are very unlikely to come back on stage except for a totally new process which would decrease very substantially their cost.

The calculated properties of the virtual materials based on AISI 1040 steels and TA6V titanium alloys are given in the Table I with the corresponding data for an aluminium foam of relative density 0.2.

3. Results of applying the methodology

The "Search through function" strategy was applied to compare the functionality of steel and titanium foams with

(a). all the materials in the database,
(b). all the metals in the database, and
(c). he foams in the database.

The results appear in Table II. We qualify the ability of material to perform a function as:

– "bad" if the value of normalized performance index value lies in the range 0.0–0.2;
– "poor"—0.2–0.4 range;
– "average"—0.4–0.6 range;

TABLE II Strategy 1: Promising functions of low-density (0.05–0.25)

		Normalized Performance index for steel foam/aluminium (0.2) foam		
		Comparison with		
Performance Index	Function	All materials	Metals	Foams
	Steel foam			
Stiffness				
[Young's Modulus]/[Density]	Stiff light tie	(0.59–0.71)/0.74	(0.14–0.43)/0.50	(0.75–0.90)/0.93
[Young's Modulus]$^{1/2}$/[Density]	Stiff light column or plate	(0.67–0.67)/0.81	(0.56–0.56)/0.80	(0.70–0.70)/0.90
[Young's Modulus] $^{1/3}$/[Density]	Stiff light beam	(0.63–0.53)/0.73	(0.82–0.64)/0.98	(0.60–0.46)/0.72
[Young's Modulus]/([Price]*[Density])	Stiff cheap tie	(0.58–0.68)/0.63	(0.63– 0.76)/0.69	(0.77– 0.91)/0.84
[Young's Modulus]$^{1/2}$/([Price]*[Density])	Stiff cheap column or plate	(0.70–0.70)/0.68	(0.84–0.84)/0.81	(0.86–0.86)/0.79
[Young's Modulus] $^{1/3}$/([Price]*[Density])	Stiff cheap beam	(0.75–0.71)/0.70	(0.91–0.86)/0.85	(0.74–0.64)/0.6
Strength				
[Plastic collapse limit]/[Density]	Strong light tie	(0.43–0.50)/0.52	(0.37–0.47)/0.50	(0.69–0.80)/0.83
[Plastic collapse limit]$^{1/2}$/[Density]	Strong light column or plate	(0.55–0.49)/0.69	(0.65–0.56)/0.74	(0.50–0.41)/0.63
[Plastic collapse limit] $^{2/3}$/[Density]	Strong light beam	(0.43–0.43)/0.58	(0.52–0.52)/0.63	(0.44–0.44)/0.75
[Plastic collapse limit]/([Price]*[Density])	Strong cheap tie	(0.63–0.68)/0.62	(0.67–0.72)/0.65	(0.74–0.83)/0.71
[Plastic collapse limit]$^{1/2}$/([Price]*[Density])	Strong cheap column or plate	(0.81–0.78)/0.75	(0.87–0.84)/0.80	(0.74–0.68)/0.61
[Plastic collapse limit] $^{2/3}$/([Price]*[Density])	Strong cheap beam		(0.79–0.79)/0.75	
Shock absorption				
[Plastic collapse limit]*[Densification Strain]/[Density]	Light shock absorber	(0.60–0.62)/0.66	(0.68–0.71)/0.78	(0.77–0.81)/0.88
Damage tolerance				
[Fracture Toughness]/[Density]	Light tough body	(0.60–0.69)/0.75	(0.15–0.35)/0.48	(0.66–0.83)/0.94
Thermal				
[Thermal Conductivity]* [Plastic collapse limit] ^{2}/[Density]	Light heat exchanger	(0.39–0.58)/0.58	(–0.17–0.25)/0.27	(0.58–0.85)/0.86
	Titanium foam			
Stiffness				
[Young's Modulus]/[Density]	Stiff light tie	(0.58–0.70)/0.74	(0.13–0.42)/0.50	(0.74–0.89)/0.93
[Young's Modulus]$^{1/2}$/[Density]	Stiff light column or plate	(0.71–0.71)/0.81	(0.64–0.63)/0.80	(0.76–0.76)/0.90
[Young's Modulus] $^{1/3}$/[Density]	Stiff light beam	(0.71–0.60)/0.73	(0.94–0.76)/0.98	(0.69–0.55)/0.72
[Young's Modulus]/([Price]*[Density])	Stiff cheap tie	(0.30–0.40)/0.63	(0.27– 0.41)/0.69	(0.39–0.53)/0.84
[Young's Modulus]$^{1/2}$/([Price]*[Density])	Stiff cheap column or plate	(0.45–0.45)/0.68	(0.50–0.50)/0.81	(0.06–0.06)/0.79
[Young's Modulus] $^{1/3}$/([Price]*[Density])	Stiff cheap beam	(0.51–0.48)/0.70	(0.58–0.54)/0.85	(0.00–(–0.09))/0.6
Strength				
[Plastic collapse limit]/[Density]	Strong light tie	(0.52–0.59)/0.52	(0.51–0.61)/0.50	(0.85–0.95)/0.83
[Plastic collapse limit]$^{1/2}$/[Density]	Strong light column or plate	(0.73–0.65)/0.69	(0.84–0.75)/0.74	(0.76–0.64)/0.63
[Plastic collapse limit] $^{2/3}$/[Density]	Strong light beam	(0.57–0.56)/0.58	(0.69–0.69)/0.63	(0.71–0.71)/0.75
[Plastic collapse limit]/([Price]*[Density])	Strong cheap tie	(0.44–0.49)/0.62	(0.47–0.52)/0.65	(0.36–0.45)/0.71
[Plastic collapse limit]$^{1/2}$/([Price]*[Density])	Strong cheap column or plate	(0.57–0.54)/0.75	(0.61–0.58)/0.80	(0.20–0.14)/0.61
[Plastic collapse limit] $^{2/3}$/([Price]*[Density])	Strong cheap beam		(0.56–0.56)/0.75	
Shock absorption				
[Plastic collapse limit]*[Densification Strain]/[Density]	Light shock absorber	(0.70–0.72)/0.66	(0.85–0.88)/0.78	(0.96–0.99)/0.88
Damage tolerance				
[Fracture Toughness]/[Density]	Light tough body	(0.73–0.83)/0.75	(0.44–0.64)/0.48	(0.91–1.07)/0.94
Thermal				
[Thermal Conductivity]* [Plastic collapse limit] ^{2}/[Density]	Light heat exchanger	(0.39–0.57)/0.58	(−0.19–0.24)/0.27	(0.57–0.84)/0.86

– "good"—0.6–0.8 range;
– "excellent"—0.8–1.0 range;
– "new champion" if normalized performance index value is bigger than 1.0;
– "new minimum" if normalized performance index value is smaller than 0.

As expected, steel foams show good specific stiffness, but they are less good than aluminium foam. However, steel foams are stiffer per unit price, making them potentially interesting for civil building and construction where significant amounts of material are consumed. Steel foams are "average to good" in terms of specific strength and, as with stiffness, less good than aluminium foams. Measured by strength per unit cost, on the other hand, steel foams are again an attractive proposition.

The energy-absorbing properties of steel foams are comparable with those of aluminium, and their lower cost makes them potential competitors. The specific

TABLE III Materials close to low-density (0.2)

			Performance gain of (0.2) steel foam		
N	Close materials	*D*	$E^{1/2}/\rho$	$\sigma_y^{1/2}/\rho$	K_{1C}/ρ
		Comparison with all materials			
1	"High Cr" white cast iron (BS grade 3A)	0.0147	0.0075	0.0063	0.011
2	"Low alloy" white cast iron (BS grade 1A)	0.0172	0.0019	0.0155	0.0071
3	Zirconia (Y_2O_3 stabilised)	0.0344	0.0044	0.0255	0.0227
		Comparison with metals			
1	"Low alloy" white cast iron (BS grade 1A)	0.0236	0.0032	0.0179	0.0149
2	"High Cr" white cast iron (BS grade 3D)	0.0273	0.0127	0.0073	0.0231
3	Ni-Cr white cast iron (BS grade 2A)	0.0293	0.0228	0.0146	0.0111
		Comparison with foams			
1	Aluminium-SiC foam (0.16)	0.0823	−0.0808	0.0034	−0.0154
2	Polycarbonate foam: structural (0.84–0.86)	0.2424	0.0273	−0.2385	0.0334
3	Polyethylene foam PE80	0.25	01678	−00323	01823
			$E^{1/2}/(C_m\rho)$	$\sigma_y^{1/2}/(C_m\rho)$	$K_{1C}/(C_m\rho)$
		Comparison with all materials			
1	Polyester –SiO_2 composite	0.0205	−00017	−00157	00131
2	Duralcan Al-20SiC (p) cast (F3S20S)	0.0223	00217	00044	00032
3	Rapidly solidified aluminium alloy (8009)	0.0276	00275	00011	−00013
		Comparison with metals			
1	Zinc-Aluminium general casting Alloy. ZA-12	0.0306	0.0051	−0.0138	−0.0268
2	Wrought martensitic stainless steel. 420S29	0.0356	0.0146	0.0094	−0.0311
3	Rapidly solidified aluminium alloy (8009)	0.0367	0.0366	0.0012	−0.0017
		Comparison with foams			
1	Aluminium foam (0.5)	0.1396	0.075	0.0814	0.0851
2	Aluminium foam (1.0)	0.1457	0.1099	0.084	0.0458
3	Aluminium-SiC foam (0.54)	0.1907	0.1464	0.0901	0.0825
			$E^{1/2}/\rho$	$\sigma_y^{1/2}\rho$	K_{1C}/ρ
		Comprasion with all materials			
1	Ti-10%TiC(p). MMC powder product	0.0214	0.0024	−0.0173	−0.0125
2	Al-Carbon Steel Reinforced high strength wire	0.0292	−0.0021	0.0231	−0.0177
3	Ti-10%SiC(p)	0.0317	−0.0214	0.0012	0.0233
		Comparison with metals			
1	AISI 4340 steel ("oil quenched", tempered at 205 °C)	0.0806	0.0741	0.0315	0.0028
2	"Medium carbon" spring steel, BS5216 ND3	0.0832	0.0751	0.0277	−0.0228
3	Unalloyed titanium, CP4, annealed	0.084	0.015	0.0546	−0.062
		Comparison with foams			
1	Aluminium foam (1.0)	0.1161	−0.0968	0.0403	0.0497
2	Aluminium-SiC foam (0.54)	0.1319	−0.0551	0.0521	0.0108
3	Aluminium foam (0.5)	0.1803	−0.1367	0.0354	0.0112
			$E^{1/2}/(C_m\rho)$	$\sigma_y^{1/2}/(C_m\rho)$	$K_{1C}/(C_m\rho)$
		Comparison with all materials			
1	Al-12%SiC(p)	0.0165	−0.0065	0.0082	0.0128
2	Al(2124)-20%SiC(p) MMC powder product	0.0209	−0.0131	0.0005	0.0162
3	Al-17%SiC(p),powder product, T351 (AMC217-xa)	0.0222	−0.0096	−0.0031	0.0198
		Comparison with metals			
1	Beryllium (50–127 micron fibres)	0.0821	−0.0599	−0.022	0.0516
2	Silver-copper eutectic alloy hard (cold worked)	0.0864	0.0499	0.0467	−0.053
3	Silver-copper-nickel electrical contact alloy, hard	0.0866	0.0505	0.0549	−0.0439

Table Continued on next page.

TABLE III Continued.

N	Close materials	D	Performance gain of (0.2) steel foam $E^{1/2}/\rho$	$\sigma_y^{1/2}/\rho$	K_{1C}/ρ
		Comparison with foams			
1	Polyurethane microcellular foam Closed Cell (1.05)	0.2038	0.0528	−0.1967	0.0068
2	Polyurethane elastomeric foam Open Cell (0.065)	0.2354	−0.0023	−0.1722	0.1606
3	Polyurethane microcellular foam Closed Cell (0.53)	0.2479	0.0387	−0.2364	0.064

TABLE IV Promising applications Steel foams

Application	Effective Gain,% (Relative density) 0.05	0.1	0.2	0.25	0.3
		Steel foams			
Building and construction: domestic and commercial building					
Flooring			32.11		
Internal structure			29.52		
Decoration			27.81		
Roof and ceiling			14.92		
Exterior work	11.13	9.63	8.13	7.65	7.25
Commercial constructions			9.41		
Doors	3.87	2.75	1.62	1.25	0.95
Building and construction: infrastructure and general uses	5.23	5.93	6.6	6.83	7.0
Transport: ground transport					
Automobiles: interior and decoration	28.39	26.14	23.89	23.16	22.56
Automobiles: safety, bump and crash protection	12.08	13.18	12.98	9.93	–
Railway transport	7.51	8.41	9.29	9.59	9.81
Aerospace: landing devices, brakes	18.72	9.72	0.72	–	–
Marine. naval and offshore : shipbuilding, superstructure and interior	8.61	7.23	5.83	5.39	5.01
Packaging, storage and handling of goodsboxes			10.28		
Thermal applications: thermal insulation	17.24	10.29	3.34	1.09	–
Materials production: metallurgy, metallurgical equipment, casting	0.56	1.61	2.61	2.96	3.21
Mechanics movable parts transmiting force and moment	–	0.37	2.42	3.12	3.67
Mining infrastucture and equipment		1.58	3.3	3.86	4.32
Agriculture and forestry_general uses	2.41	2.83	3.23	3.37	3.47
		Titanium foams			
Building and construction: domestic and commercial building					
Flooring*			31.84		
Internal structure*			29.25		
Decoration*			27.61		
Roof and ceiling*			18.46		
Exterior work*	20.6	19.08	17.58	17.08	16.7
Commercial constructions*			9.14		
Plumbing and sewage			9.94		
General architecture*	6.76	4.94	3.14	2.54	2.08
Thermal insulation	2.7	–	–	–	–
Building and construction, infrastructure: general uses*	–	–	–	0.17	0.33
Bridges	3.79	3.33	2.89	2.75	2.63
Roads*			2.92		
Transport_ground transport					
Automobiles: interior and decoration*	23.84	18.03	19.31	18.56	17.99
Automobiles: safety, bump and crash protection	16.98	13.18	17.83	14.78	
Automobiles: body	–	3.17	6.84	7.22	1.95
Ground transport, general uses	–	–	–	0.31	0.33
Aerospace					
Landing devices: brakes	26.32	17.22	8.22	5.22	2.92
Doors and window frames	5.3	4.1	3	2.67	2.36
Marine, naval and offshore_shipbuilding:					
Superstructure and interior*	11.13	9.71	8.33	7.87	7.51
Hull	–	–	0.33	1.93	3.23
Sports equipment			9.14		
Military and army: armour	–	–	–	0.86	1.4

TABLE IV Continued.

Application	Effective Gain,% (Relative density)				
	0.05	0.1	0.2	0.25	0.3
Packaging, storage and handling of goods					
Boxes*			22.58		
Different containers*			10.11		
General packaging*			5.69		
Bottles*			4.61		
"Corrosion resistant" applications:					
Domestic food processing*			12.76		
Industrial milk processing*			8.95		
Paper processing and manufacturing			6.73		
Chemical industry equipment_vessels			6.7		
Primary production: mining, primary chemical processing			5.95		
Industrial food processing*			4.75		
Brewing*			3.85		
General chemical industry			2.67		
Industrial food processing_pickling*			2.56		
Chemical industry equipment			2.53		
"Low temperature" chemical applications	–	–	22	22.96	23.74
Thermal applications: thermal insulation	27.14	20.19	17.19	10.99	9.19
Goods: clothing and footwear	3.99	1.29	–	–	
Pipe infrastructure:					
Pumps	–	–	2.12	2.45	2.73
Valves	–	–	1.42	1.75	2.04

*–Titanium foam is more expensive than any material currently used in this application.

fracture toughness of steel foams is less than that of aluminium foams of corresponding density although it may be possible to improve this by adjusting chemical composition, heat treatment and cell architecture. The thermal and electric conductivities of metal foams are clearly less good than those of dense metals. This, however, may allow the development of hybrid materials with controlled thermal and electric properties in combination with good mechanical properties.

Titanium foams offer no advantages over aluminum foams in terms of stiffness, and they are much more expensive, but their high maximum working temperature may compensate for a smaller specific stiffness. The specific strength of titanium foams is as good as or better than that of aluminium. This makes titanium foams promising in space applications where the higher material price can be justified, since any final weight saving of whole construction brings significant net gain. It is also worth noting that the superior fracture toughness of titanium foams can increase overall construction safety. The "energy absorbing" ability of titanium foams is also better than aluminium foams, suggesting potential in military and space applications. The lower thermal conductivity of titanium foams can also be a benefit in rocket construction, when heat resistant structural elements are to be assembled with elements not requiring this heat resistance, e.g. made of polymers.

The "Closest match" strategy identifies the materials that most closely resemble the virtual materials in predefined properties or performance indices. We selected the most desirable performance indices for bending loaded plates from technical ($E^{1/2}/\rho$, $\sigma_y^{1/2}/\rho$ and K_{1C}/ρ) and economic ($E^{1/2}/(C_m\rho)$, $\sigma_y^{1/2}/(C_m\rho)$ and $K_{1C}/(C_m\rho)$) points of view. The search has been made separately through all materials, all metals and all foams. The results as shown in Table III for foams having a relative density equal to 0.2. The property profile of steel foam resembles that of cast irons and it seems difficult for foams to compete with these traditional materials. On the other hand, foam sandwich structures would be certainly stiffer and could be used for the flooring in metallurgical plants, where cast irons are still widely used; the obstacles are economic. Some performance advantages of steel foams in comparison with structural polymer foams look promising in packaging applications: steel foams or foam sandwiches are less flammable, more "heat resistant," can be handled with electro-magnetic cranes and they are easily recyclable. As mentioned above, from an economic point of view steel foams are promising—in structural applications their potentially lower price makes them comparable with modern polymer and metal-based composites, strong aluminium alloys and aluminium foams. The further reduction of price could bring steel foams into the range of "low alloy steels"—materials widely used in the car industry.

The property-profile of titanium foams resembles that of other "high performance" materials: metal-based composites, strong "high carbon steels", unalloyed titanium and aluminium foams. This promises some applications where titanium and its alloys are already used—aerospace and chemical engineering, but careful technical analysis will be required to optimise design. From an economic viewpoint, it would be attractive to replace beryllium structural components by titanium foams or foam sandwiches, wherever it is technically feasible.

The "Matching design requirements" strategy returns already expected results: steel foams have promising structural applications in civil building and

infrastructure construction, shipbuilding, packaging and the specific foam application of car crash protection. Some possible applications are expected in mining and agricultural construction—cheap materials of substantial strength and stiffness are welcome in these fields. Light components in general mechanics are also possible—efforts to make a core of aluminium foam for mechanical assemblies are in progress [4].

Titanium foams find the traditional application fields of solid titanium: aerospace, chemical engineering and sports equipment. Nevertheless, one can find that in addition to car crash protection, some effective gain can be reached in shipbuilding (luxury boats hulls), car industry (car body and interior) and armour.

4. Conclusions

Steel and titanium foams, currently under development, compete with existing traditional solid materials and recently commercialized aluminium foams. As well as the proven application for crash protection application, cheap steel foams are promising materials for civil engineering and construction, packaging and shipbuilding. Titanium foams, being more efficient over solid titanium, retain conventional application fields of this material—aerospace, chemical engineering and sports equipment.

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