VOL. 17, NO. 19, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

MATERIALS SELECTION METHODS APPLIED TO A SPORTS APPLICATION

Cristian Barrios Molano, Bladimir Ramon Valencia and Rafael Bolivar Leon
Mechanical Engineering Program, Engineering and Architectural Faculty, Pamplona University, Colombia
E-Mail: rbolivarl@unipamplona.edu.co

ABSTRACT

For the design engineer, the material selection stage is crucial by the selected material must fulfill the properties specified in the design and other requirements such as economic, weight, and manufacturing constraints. For this reason, the use of robust materials selection methodologies becomes essential. This article compared 14 materials selection, taking into account seven criteria: the Ashby, characteristic magnitudes, and the database methods obtained the highest score. These three methods were applied to materials selection for a Skateboard table. The design properties Skateboard table were defined based on a bibliographic review. ANSYS Granta Selector Software was used to determine some material properties and calculate commercial laminated materials' properties in cases that do not have references. The Ashby methodology selected Stiffness-limited design at a minimum mass material index. Mass, thickness, and cost characteristic magnitudes were calculated by the method of characteristic magnitudes. The Matweb online database was used to apply the selection by database method. The best material selected by the Ashby methodology from 4169 was longitudinal Bamboo. The characteristic magnitudes method selected a laminated material consisting of 5 maple sheets and 2 outer bamboo sheets from 5 materials. Database method did not obtain any material, but it resulted in a list of 90 possible materials starting from 155,000. Ashby's method was the best one for this application since all design properties could be included.

Keywords: material selection, materials selection methods comparison, ashby´s method, characteristic magnitudes method, skateboard selection.

INTRODUCTION

For the materials engineer or designer of mechanical elements, the material selection is a tremendous critical stage during the design and manufacturing processes. The selected material must meet both the design and manufacturing parameters and the economic restrictions of the product. For this reason, it is necessary to identify the different material selection methods to give reliability and security to the component during its useful life. About 14 different material selection methods have been reported in the literature, which was divided into three groups: rapid review, optimization, and multi-criteria decision-making processes (MCDM) [1]-[4].

RAPID REVIEW METHODS

Traditional Method

The traditional method is based on the most suitable material selection depending on the engineer's experience in designing, building, and maintaining mechanical elements. The reliability of this method lies in various factors: the experience of who selects it, the historical response of the used material, the good behaviour of the material during its service life, and the tests of similar components during their design process and manufacturing [2], [3], [5].

Cost Per Unit Property Method

This method establishes material cost as an objective to minimize; it also filters or eliminates high-cost materials compared to the value defined at the beginning. The result of this selection process is a trade-off between cost and performance. In some cases, it is possible to estimate the cost together with the most critical requirements for the materials. The method's limitation is that cost is the only critical property and ignores other properties [1].

Characteristics Magnitude Method

It analyzes component functions of the design with the help of two questions that guide the selection process: What are the objectives to be optimized in the materials? What restrictions must the component satisfy? This method requires a limited number of materials to be evaluated [6].

Ashby´S Method

This method optimizes the selection process by selecting the material that best suits the desired application according to its function. It is based on charts that relate the properties of the materials defined by the component design and is used at any stage of material selection, helping determine the material that meets the design and fabrication properties specifications [7]-[11].

Database Method

This method is based on information collected from web pages or internet platforms, books, handbooks, standards, manufacturer resumes, material property platforms, and research that characterizes materials and defines their properties. One of its advantages is that this information is generally available and relatively easy to access. It is essential to highlight that for the implementation of this method. It needs knowledge of the more important properties and a list of possible materials that can be selected that meet the design requirements [12].

Questionnaire Method

This method classifies the performance requirements into two main categories rigid and soft. Rigid or go-no-go requirements are associated with those that the material must fulfill, considered fundamental properties, and used for the initial selection of materials by eliminating unsuitable groups. Soft or relative requirements are subject to trade-offs in which items other than the basic properties were considered to improve the probability of achieving an optimal design solution [13][14].

Artificial Intelligence Methods

Artificial intelligence is applied to complex problems in which software processes extensive and scattered knowledge focused on a specific solution. With technological advances, two analytical approaches can be described to select computer-aided engineering materials; taking into account the properties or the design to be carried out, different materials within their families or groups can be classified by minimization procedures and engineering judgment factors [15]. This method includes Knowledge-based systems and Case-based reasoning [1].

Optimization method

This group of methods has an optimization approach to material selection.

Mathematic Programming

This method integrates the interrelated activities between product design, material selection, and cost estimation. Considering the variety of materials, these are reduced to a certain number using design limitations and performance requirements. It uses a cost-benefit analysis optimization technique for cost estimation, and the optimal combination of design and material is selected [13][16].

Computer-Aided Materials Selection Systems

It refers to the software containing material properties databases with algorithms for design, computer-aided design (CAD), and sometimes even computer-aided manufacturing (CAM). Its advantage is the homogenization and exchange of data. The approaches must be clear to define an objective, but when there are conflicts in the design objectives, such as weight and minimum costs, it is hard to implement [5][1].

Algorithms

It includes the simultaneous manipulation of the composition of the materials and their internal morphological distribution to obtain the required properties. It consists of combinatorial optimization of genetic algorithms with a property analytical model basis of the microstructure-property ratio[1],[17].[18].

Multi-Criteria Decision Making (MCDM)

These methods decide on the multiple alternatives based on the decision criteria where the best option is chosen. There are about 11 different methods; however, the most used are taken for this investigation. [3], [19]–[21][22].

Multi-Attribute Utility Analysis (MAUA)

It models are mathematical tools that help compare and evaluate alternatives in decision-making when complex possibilities are involved. An inverse utility function is used to identify the degree to which the individual attributes of an alternative achieve the desired level [3], [20].

Goal Programming (GP)

It is a modification of linear programming. Linear programming deals with a single objective to minimize or maximize depending on the constraint. On the other hand, goal programming is an efficient method of managing a decision on multiple or contradictory objectives. The goal programming model can consider non-homogeneous units [1].

The Technique of Ranking Preferences by Similarity to the Ideal Solution (TOPSIS)

This method performs a prioritization of order by similarity with an ideal solution. The basic principles that give orientation and solution to the application of the method take into account the relation between distances. The selected solution must fulfill the shortest distance between an ideal alternative and the furthest from the negative one. [23] [3][22].

VIKOR Method

This method was developed to solve multi-criteria decision-making problems and is applied to conflict resolution. It focuses on classifying and selecting a set of alternatives in the presence of conflicting criteria. [3][23],[21].This work adds a point of view on the constant technical debate on material method selection. It condenses and summarizes 14 different methodologies, which are hierarchy by seven different criteria to choose 3 of them. The chosen methodologies are applied to material selection for a skateboard table, thus showing different results for the same purpose and determining the most optimal.

MATERIAL AND METHODS

The methodology begins with a bibliographical review of the material selection methods. Subsequently, methods analysis is carried out according to the proposed ranking criteria. On the other hand, mechanical and other properties for the component design are collected, defined by inverse engineering, or calculated using ANSYS Granta Selector software. Three methods selected from comparison and ranking are applied using the defined properties valued previously, ANSYS Granta Selector software, and the online Matweb database. Finally, the results obtained by the different material selection methods are analyzed, discussed, and compared to identify the best method for the application.

ARPN Journal of Engineering and Applied Sciences

RESULTS AND DISCUSSIONS

Ranking Criteria

For this stage, seven criteria comparison were defined for the 14 material selection methods as follow:

Manufacturing Processes (MP)

It includes parameters or technological properties of the material necessary for its manufacturing process, according to geometry, process temperatures, and ease of forming.

Versatility (V)

This criterion defines if the method can be applied to any design stage or only to one of them. The design stages are the initial, intermediate, and detailed ones. When making any design, it is essential to clarify which method can be applied from the beginning or at what stage it can be used most effectively.

Publications (P)

The available high-quality information regarding the methods gives a way to rank them. This parameter identifies which methods are commonly studied or implemented and which only be known to exist.

Mathematical Complexity (MC)

This parameter refers to each method's mathematical level, from low to high complexity. The last one implies the implementation of special functions and differential equations. Depending on the application to solve problems, the more straightforward methods, the lower the mathematical difficulty.

General Software (GS)

It refers to computer software used when applying each method's work. It allows specialized mathematical or statistical software to speed up its application.

Material Selection Software (MSS)

This parameter refers to software tools related to the method directly. It is crucial to keep in mind that methods with these tools facilitate the application for engineers of any level.

Material Selection Software Cost (SC)

This parameter identifies if the material selection software cost must be purchased or if it is free.

Methodology for Ranking

For the hierarchy methodology, numerical values were defined for each parameter on a scale of 1 to 3, where 3 is maximum and defines the easiest method to use, and 1 is minimum and means the most complex method to apply (Table-1). Once each parameter was assessed, they were summed, giving the values for each criterion that can be seen in Table-2 and Figure-1.

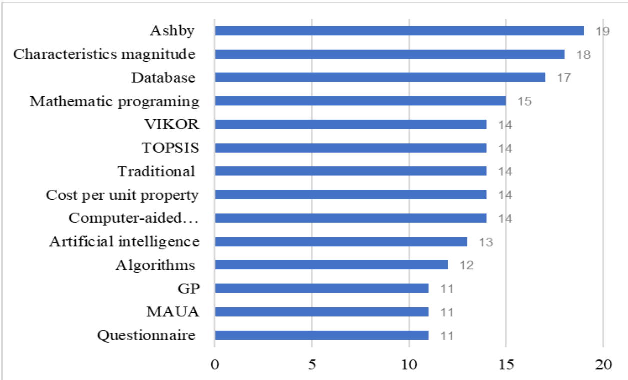

Figure-1. Hierarchy results for the investigated methods.

Table-1. Hierarchy criteria values.

Criteria	Value	
Manufacturing processes (MP)	1	No
	3	Yes
Versatility (V)	1	Restricted to one stage
	3	Any stage
Publications (P)	1	Articles comparing or referencing
	2	Articles explaining the application
	3	All of the above plus articles describing different applications
Mathematical Complexity (MC)	1	Special functions
	2	Derivatives, summations, integrals
	3	Low complexity, intuitive
General Software (GS)	1	No
	3	Yes
Material Selection Software (MSS)	1	No
	3	Yes
Material Selection Software Cost (SC)	1	No
	3	Yes

Table-2. Hierarchy results for the investigated methods.

Method	MP	V	P	MC	GS	MSS	SC	Total
Ashby´s Method	3	3	3	2	3	3	2	19
Characteristics magnitude method	1	3	3	2	3	3	3	18
Database Method	1	3	1	3	3	3	3	17
Mathematic programming	1	3	1	2	3	3	2	15
Computer-aided materials selection systems	1	1	2	2	3	2	3	14
Cost per unit property method	1	3	2	3	3	1	1	14
Traditional Method	1	3	2	3	3	1	1	14
TOPSIS	1	3	1	1	3	3	2	14
VIKOR	1	3	1	1	3	3	2	14
Artificial intelligence methods	1	1	1	2	3	3	2	13
Algorithms	1	1	1	1	3	3	2	12
Questionnaire method	1	1	1	3	3	1	1	11
MAUA	1	3	1	1	3	1	1	11
GP	1	1	2	2	3	1	1	11

As can be seen in Figure-1, the three best methods are the follow Ashby (19), characteristic magnitudes (18), and database (17). These methods obtained a high value by their versatility to be applied in any design stage, the most significant amount of published information, and lower level of mathematical complexity, almost intuitive.

Skateboard layout properties

Skateboard properties were defined from the literature or calculated by reverse engineering. Commercial material type and laminates distribution was determined (Table-3). Commercial materials' properties were determined (Table-4) using the search tool of ANSYS Granta Selector software or by bibliographic review [24], [25].

Table-3. Composite materials commercially used for skateboard tables [24], [25].

Make model	Materials, distribution of laminates and codification	
Almost, Ivy League Impact Light Max Geronzi 8.25	7 Maple Canadian wood laminates with impact support.	7MS
Almost, Blur Resin Multi 7.75	7 Maple Canadian wood laminates with epoxy resin.	7MR
Almost, PB&J FP Strawberry 7.625	7 Maple Canadian wood laminates with epoxy resin	
Powell Peralta, Ripper Natural Olive 8.75	7 Maple Canadian wood laminates	7M
Globe Blazer	Maple Canadian wood laminates with epoxy resin	MR
Jucker Hawaii, New Hoku	Maple, Bamboo, and Fiber Glass	MBG
Jucker Hawaii, Longboard Makaha	5 Maple Canadian wood laminates and two outer Bamboo laminates	5M2B
Mindless, Longboards Maverick	6 Maple Canadian wood laminates and one inner Bamboo laminate	6M1B

The synthesizer tool of ANSYS Granta Selector (Table-5) was applied to obtain laminated composite properties in cases where no information exists. The thickness of Maple wood laminate was 2 mm; for Bamboo, 1.5 mm, and for epoxy resins, 0.45 mm. Figure-2 shows the synthesizer tool, and table 5 shows the results obtained for the composite materials.

ARPN Journal of Engineering and Applied Sciences

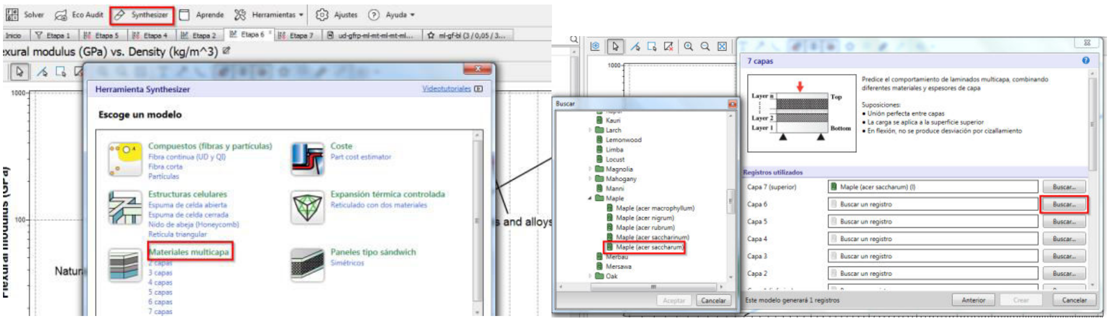

Figure-2. Synthesizer tool of ANSYS Granta Selector.

Table-4. Commercial materials properties obtained by de ANSYS Granta Selector.

Properties	M-L	M-T	B-L	B-T	EG	E
Density kg/m^3	710	710	700	700	1,7e3	2,3e3
Young's Modulus GPa	13,9	2,2	17,5	1,7	40	1
Specific modulus MN.m/kg	19,7	3,1	25,5	2,5	22,7	0,9
Yield strength MPa	55,5	3,2	39,9	7,8	700	40
Tensile strength MPa	101,1	5,4	240	37,5	700	54,5
Elongation %	2,18	0,7	3,20	5	2,5	52,5
Compressive strength MPa	54	10,1	80	70	620	73,2
Flexural modulus GPa	25,3	2,0	19,5	1,9	40	1
Flexural strength MPa	109	5,4	120	37,5	600	69,8
Fatigue strength 10e7 cycle MPa	32,6	1,6	34,3	10,7	280	21,8
Fracture toughness MPa.m^0,5	6,4	0,5	6,35	0,6	44,8	2,6
Water resistance	Limit use				Excellent	

M- Maple, B-Bamboo, EG-Epoxy+Glass Fiber, E-Epoxy resin, L- Longitudinal T-transversal

Calculated properties of different materials such as 7 Maple Canadian wood laminates (7M); 6 Maple Canadian wood laminates and 1 inner Bamboo laminate (6M1B); 5 Maple Canadian wood laminates and 2 outer Bamboo laminates (5M2B); 5 Maple Canadian wood laminates with 2 Glass Fiber and 1 Carbon Fiber (5M2G1C); and 5 Maple Canadian wood laminates with 2 Glass Fiber (3M2G) can be observed on Table-5. Table-6 shows the lowest values of material properties for the skateboard table found in the bibliographic review or the synthesized tool's calculated ones.

Table-5. Laminate materials properties calculated by Synthesizer tool of ANSYS Granta selector.

Properties	7M	6M1B	5M 2B	5M2G 1C	3M2G
Density Kg/m3	707	705	703	781	763
Young´s Modulus GPa	8,86	9,06	9,28	15,50	8,79
Yield strength MPa	12,9	13,20	13,6	22,60	12,8
Flexural modulus GPa	12,1	12,70	13,4	28,40	15
Flexural strength MPa	16,5	16,29	17	62,70	38,9
Cost COP/kg e3	5,65	5,65	5,65	24	6,8
Thickness mm	14	13,5	13	10,84	6,9

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table-6. Minimum properties collected or calculated for the Skateboard table.

Property	Value	Bibliographic reference
Force (F)	785 N	[26][27][28][29]
Maximum deflection	0,021 m	[27]
Large (L)	0,75 m	[26][28][29]
Wide (W)	0,18 m	[26][28][29]
Thickness (T)	0,008 m	[27][29]
Flexural modulus	12,08 GPa	[27],*
Density	781 kg/m^3	*
Wheelbase	0,80 m	[26]
Young´s Modulus	8,79 GPa	*
Flexural strength	16,29 MPa	[27],*
Yield strength	12,8 MPa	[26][27][29],*
Security factor	2.6	[27]
Fracture toughness	6,35 MPa.m^0,5	[29]

*Calculated from commercial materials using the ANSYS Selector Synthesizer tool

Application of the Selected Methods

Ashby´s method

Ashby´s method requires a list of properties or requirements, defined as function, constraint, and objectives [30], as seen in Table-7.

Table-7. Requirements for Ashby´s method.

Type	Properties	Sign	Value
Function	**Flexural modulus**	≥	**12,08 GPa**
Constraint	Density	≤	781 kg/m^3
	Young's Modulus	≥	8,79 GPa
	Flexural strength	≥	16,29 MPa
	Yield strength	≥	12,8 MPa
	Fracture toughness	≥	6,35 MPa.m^0,5
	Water resistance	≥	Acceptable
Objective	Density Kg/m^3		Minimize
	Cost		Minimize Us/Kg

The limit tool of the ANSYS Granta Selector software at level 3 was used to screen out the materials that did not fulfill the requirements of Table-7. Of 4169 initial materials, 1610 fulfill the requirements as Figure-3 shows, where are plotted the Function Vs. Objective properties.

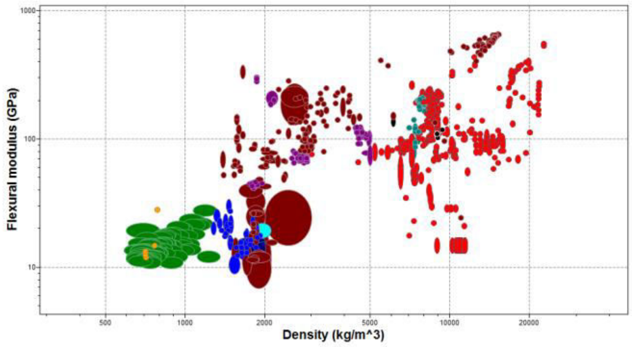

Figure-3. Materials fulfill the requirements in table 5.

The Stiffness-limited design at minimum mass material index was used to select the best material from the 1610 ones. This index considers the function (flexural modulus) and the objective (density) properties, and the ANSYS Granta Selector includes a tool to choose it depending on the individual case (Figure-4).

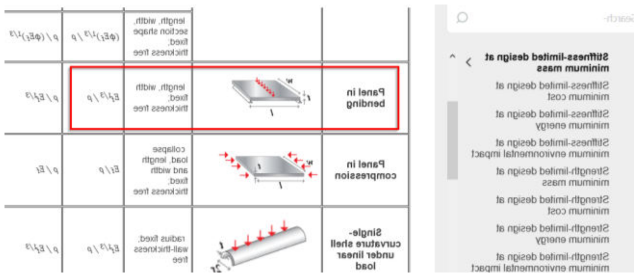

Figure-4. Material index selected by ANSYS Granta Selector.

The selected material index is:

$$M = \frac{E_f^{1/3}}{\rho} \quad (1)$$

Where,
E_f = Flexural modulus
$\rho = Density$

By plotting the Material Index (y-axis) Vs. Costs (x-axis), the most suitable materials can be obtained placed on the lower part of the violet curve (Figure-5). The selected material is Bamboo (longitudinal).

VOL. 17, NO. 19, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

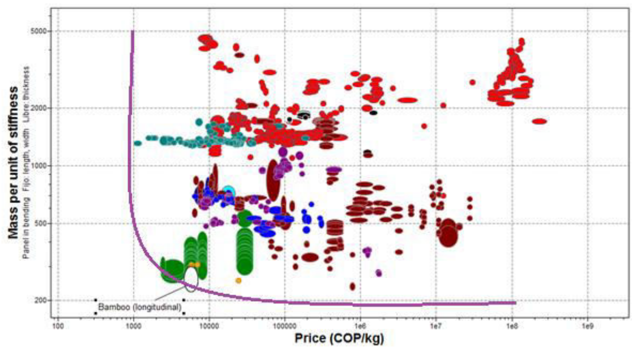

Figure-5. Ahsby's Chart of Material index Vs Objective to select the best material by ANSYS Granta Selector.

Characteristics magnitude method

This method calculates the characteristic magnitudes dependent on the component's function and objective properties. In this case, the magnitudes selected were mass, thickness, and cost. This method considers a similar proposal to Ashby's one about the material index. However, unlike Ashby, this method requires pre-selected materials and previous knowing their properties. Between them must be selected the most optimal. For this reason, it defined five materials from the commercial materials used (Table-5). The mathematical procedure to determine the magnitudes characteristics is shown below:

$$S = \frac{F}{\delta} = \frac{C_1 EI}{L^3} \quad (2)$$

$$I = \frac{wt^3}{12} \quad (3)$$

Where,

S : Modulus
F : Force
δ : Deflexion
I : Inertia moment for a sheet
L : Large
w : Wide
t : Thickness
C_1 : 48 (charge distribution constant)
E : Flexural modulus

Equation (1) and (2) is obtained:

$$\frac{F}{\delta} = \frac{C_1 E}{L^3}\left(\frac{wt^3}{12}\right) \Rightarrow t^3 = \frac{FL^3 12}{\delta C_1 E}$$

$$t = \left(\frac{FL^3 12}{\delta C_1 E}\right)^{1/3} \quad (4)$$

For each constraint as mass, thickness, and cost, a special function is defined as $\Gamma_{M/RF}, \Gamma_{esp/RF}, \Gamma_{C/RF}$ respectively. The function includes two parts, the first one depends on the specific application, and the second one depends on the material properties. The second part is called the characteristic magnitude, and it is calculated as follows:

For the thickness,

$$t = \left(\frac{12FL^3}{\delta C_1}\right)^{1/3} \left[\frac{1}{E}\right]^{1/3} \quad (5)$$

The characteristic magnitude for thickness is:

$$\Gamma esp_{/RF} = \left[\frac{1}{E}\right]^{1/3} \quad (6)$$

For the mass,

$$\rho = \frac{m}{v} \Rightarrow m = \rho Lwt \quad (7)$$

Where,

ρ : Density
m : Mass
v : Volume

Equation (4) in (7):

$$m = \rho Lw \left(\frac{12FL^3}{\delta C_1 E}\right)^{1/3} \quad (8)$$

$$\Rightarrow \; m = Lw \left(\frac{12FL^3}{\delta C_1}\right)^{1/3} \left[\frac{\rho}{E^{1/3}}\right] \quad (9)$$

The characteristic magnitude for mass is:

$$\Gamma_{M/RF} = \frac{\rho}{E^{1/3}} \quad (10)$$

For the cost,

$$C = C_u m \quad (11)$$

Equation (8) in (11) is obtained:

$$C = Lw \left(\frac{12FL^3}{\delta C_1}\right)^{1/3} \left[\frac{C_u \rho}{E^{1/3}}\right] \quad (12)$$

Where,

C_u: Cost by unit

The characteristic magnitude for cost is:

$$\Gamma_{C/RF} = \frac{C_u \rho}{E^{1/3}} \quad (13)$$

Value forthe characteristic magnitudes of mass, thickness, and cost was calculated for each material previously defined in Table-3, using equations (6), (10), and (13). Their value and relative percentage are shown in Table-8 and Figure-5.

Table-8. Characteristic magnitudes of mass, thickness, and cost.

Materials	Mass magnitude $\Gamma_{M/RF} = \frac{\rho}{E^{1/3}}$		Thickness magnitude $\Gamma_{esp/RF} = \left[\frac{1}{E}\right]^{1/3}$		Cost magnitude $\Gamma_{C/RF} = \frac{C_u \rho}{E^{1/3}}$	
	Value	%	Value	%	Value	%
7M	308,12	120	0,4358	133	1,7E6	14
6M1B	302,17	118	0,4286	131	1,7E6	12
5M2B	295,97	116	0,421	128	1,6E6	10
5M2G1C	255,98	10	0,3277	10	6,1E6	367
3M2G	309,38	121	0,4054	124	2,1E6	126

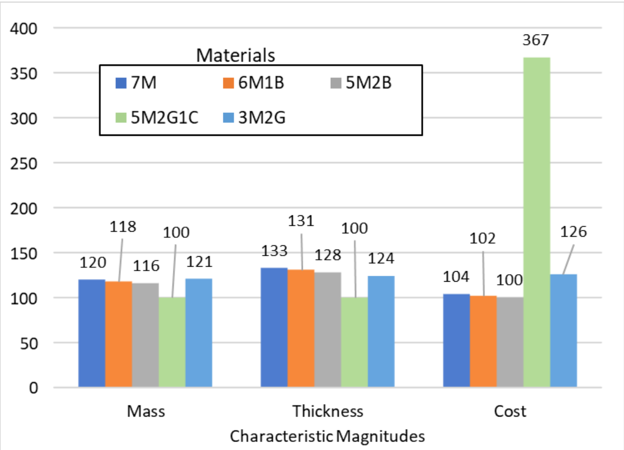

Figure-6. Characteristic magnitudes for investigated materials.

It can be seen in Figure-7 that for mass and thickness magnitudes, the best material is M4, but it exhibits the highest relative cost, whit a quite broad difference from the others. Materials M1, M2, and M3 do not have significant mass and thickness magnitude differences between them. If the objective is to minimize mass, M3 (5 maple laminates and 2 outer bamboo laminates) is the best material. M3 is the second material that shows the lower value of mass magnitude characteristic and cost magnitude is the lowest. On the other hand, the difference in thickness magnitude compared to the others is insignificant.

Database method

Online MatWeb [12] database was used for this method. It is a free access database with 155,000 materials with their respective properties. The filter option of the online database was applied, taking into account flexural modulus (bending modulus), flexural strength (bending stress), and Young's modulus (elasticity modulus) properties. Once the filter was applied, only 90 materials fulfilled the requirements. Most of the materials obtained are composite materials. However, subsequent filters could not be used, and essential properties such as density or cost were neglected.

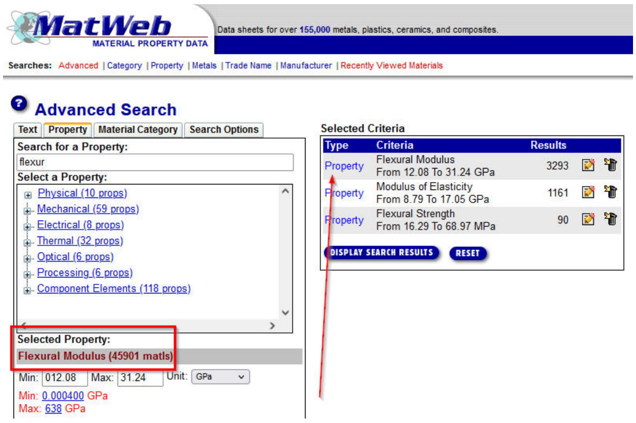

Figure-7. Matweb Online database filter.

Comparison of material selection methods

As a final result, Table-9 can observe the results of each selected method.

Table-9. Comparison between selected method.

Type	Ashby method	Characteristic Magnitude method	Database method
Function	Flexural modulus	Flexural modulus	
Constrains	Density	Thickness	Flexural strength
	Young's Modulus	Cost	Young's Modulus
	Flexural strength	Mass	Flexural modulus
	Yield strength		
	Fracture toughness		
	Water resistance		
Number starts materials	4169	5	155000
Number final materials	1	1	90
Selected material	Bamboo (longitudinal)	5 Maple laminates and 2 outer bamboo laminates	-

Table-9 summarizes the characteristics of the three methods used. The same function property (Flexural modulus) was applied to compare the three methods. It is essential to highlight that both Ashby and characteristic magnitudes are efficient for this specific application because they handle mathematical function optimization, method index of materials for Ashby, and characteristic magnitudes for the other one. For the Ashby´s and the characteristic magnitudes method, the mathematical cost function of optimization was essential in selecting the final material among materials with similar properties. The number of starting materials is quite different and varies between 5 and 155,000 depending on the method. Although the ANSYS Granta Selector software can support both Ashby's method and the characteristic magnitudes method, such support was not made for the second one since this application methodology is not generally associated with the bibliography.

The database method relies heavily on the information available on the materials and the ability to filter with the tool used. In this case, MatWeb provides a limited number of simultaneous filters, limiting the number of materials obtained. It is expected that this method can generate better results with a database with better capabilities to apply filters. For the characteristic magnitudes, a limited number of input materials is required. This method is used when there is a shortlist of previously filtered materials. Ashby's method was the best fit for this application since it allows you to start with many materials and results in only one of your choices.

CONCLUSIONS

The ranking process obtained the three best materials selection methods from fourteen investigated: Ashby, Characteristic Magnitudes, and Database, ordered from highest to lowest.

Ashby's selection method defines a mathematical optimization equation based on objectives and functional properties that can be easily selected using ANSYS granta selector software. The characteristic magnitudes method also uses mathematical optimization equations based on the properties and objectives functional too, but they must be calculated, increasing the difficulty of applying it quickly.

The material selected according to the Ashby method among 4169 materials is longitudinal Bamboo. According to characteristic magnitudes, starting from 5 materials, a laminated material was selected made up of 5 sheets of maple and 2 outer sheets of Bamboo. For the database, it was not possible to select it.

Ashby's selection method is the one that gave the best results since it can include all the properties that the designer requires, starts from a large number of materials, uses software for a quick and intuitive selection, and applies optimization processes. The method of characteristic magnitudes only considers the defined properties to calculate the magnitudes and part of a specific and known number of materials. The database method does not manage to select the properties, and its selection must be made depending on the designer's experience.

REFERENCES

[1] A. Jahan, M. Y. Ismail, S. M. Sapuan and F. Mustapha. 2010. Material screening and choosing methods - A review. Mater. Des., 31(2): 696-705, doi: 10.1016/j.matdes.2009.08.013.

[2] A. Jahan, K. L. Edwards and M. Bahraminasab. 2016. Multi-criteria decision analysis for supporting the selection of engineering materials in product design. Butterworth-Heinemann.

[3] S. Chatterjee and S. Chakraborty. 2021. Material selection of a mechanical component based on criteria relationship evaluation and MCDM approach. Mater.

Today Proc., 44: 1621-1626, doi: 10.1016/j.matpr.2020.11.817.

[4] E. K. Arthur, E. Gikunoo, F. O. Agyemang, S. T. Azeko, A. Andrews, and A. Twenewaa. 2020. Material Selection for Water Pipes by the Multi-Objective Decision-Making Method: The Case of Alternative Materials for PVC Pipes. J. Sci. Technol., 5(1): 29-42.

[5] C. M. Aceves, A. A. Skordos and M. P. F. Sutcliffe. 2008. Design selection methodology for composite structures. Mater. Des. 29(2): 418-426, doi: 10.1016/j.matdes.2007.01.014.

[6] C. Riba Romeva, Selección de Materiales en el Proceso de Diseño de Maquinas. 2008.

[7] I. Mazínová and P. Florian. 2014. Materials Selection in Mechanical Design. In Lecture Notes in Mechanical Engineering. 16: 145-153.

[8] M. Yazdani and A. F. Payam. 2015. A comparative study on material selection of microelectromechanical systems electrostatic actuators using Ashby, VIKOR and TOPSIS. Mater. Des., 65: 328-334, doi: 10.1016/j.matdes.2014.09.004.

[9] R. A. Antunes and M. C. L. de Oliveira. 2014. Materials selection for hot stamped automotive body parts: An application of the Ashby approach based on the strain hardening exponent and stacking fault energy of materials. Mater. Des. 63: 247-256.

[10] R. A. Antunes, C. A. F. Salvador, and M. C. L. de Oliveira. 2018. Materials Selection of Optimized Titanium Alloys for Aircraft Applications. Mater. Res., 21(2), doi: 10.1590/1980-5373-mr-2017-0979.

[11] D. Deshmukh and M. Angira. 2019. Investigation on switching structure material selection for RF-MEMS shunt capacitive switches using Ashby, TOPSIS and VIKOR. Trans. Electr. Electron. Mater. 20(3): 181-188.

[12] Matweb. Data base MatWeb Material property data. https://www.matweb.com/.

[13] M. M. Farag. 2002. Quantitative methods of materials selection. Handb. Mater. Sel. pp. 1-24.

[14] K. L. Edwards. 2005. Selecting materials for optimum use in engineering components. Mater. Des. 26(5): 469-473.

[15] D. P. Hanley and E. Hobson. 1973. Computerized Materials Selection. J. Eng. Mater. Technol., 95(4): 197-201, doi: 10.1115/1.3443153.

[16] A. W. A. Hammad, K. Figueiredo, A. C. Rosa, E. Vazquez and A. Haddad. 2021. Enhancing the passive design of buildings: A mixed-integer non-linear programming approach for the selection of building materials and construction building systems. Energy Reports, 7: 8162-8175, doi: 10.1016/j.egyr.2021.04.063.

[17] X. Huang and W. Li. 23021. A new multi-material topology optimization algorithm and selection of candidate materials. Comput. Methods Appl. Mech. Eng., 386: 114114, doi: 10.1016/j.cma.2021.114114.

[18] X. Zhang. 2008. Improved genetic algorithm based on family tree used for the material selection optimization of components made of multiphase materials. Chinese J. Mech. Eng. 44(3): 220.

[19] R. Kumar, Jagadish and A. Ray. 2014. Selection of Material for Optimal Design Using Multi-criteria Decision Making. Procedia Mater. Sci., 6(no. Icmpc): 590-596, 2014, doi: 10.1016/j.mspro.2014.07.073.

[20] I. Emovon and O. S. Oghenenyerovwho. 2020. Application of MCDM method in material selection for optimal design: A review. Results Mater., 7(June): 100115, doi: 10.1016/j.rinma.2020.100115.

[21] A. Jahan, F. Mustapha, M. Y. Ismail, S. M. Sapuan, and M. Bahraminasab. 2011. A comprehensive VIKOR method for material selection. Mater. Des., 32(3): 1215-1221, doi: 10.1016/j.matdes.2010.10.015.

[22] U. Khan, R. Verma, B. K. Singh and V. Yadav. 2021. Application of Multi Criteria Decision Making tools in Selection of Concrete Mix. J. Sci. Ind. Res., 80(04): 304-309, [Online]. Available: http://nopr.niscair.res.in/bitstream/123456789/57481/1/JSIR 80%284%29 304-309.pdf.

[23] S. Opricovic and G. H. Tzeng. 2004. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. Eur. J. Oper. Res., 156(2): 445-455, doi: 10.1016/S0377-2217(03)00020-1.

[24] Fillow Magazine. 2021. Las mejores marcas de tablas de Skate 2021. https://www.fillow.net/blog/2021/09/las-mejores-marcas-de-tablas-de-skate-2021/.

ARPN Journal of Engineering and Applied Sciences

[25] Ciudad Surf. 2020. Los 5 mejores LONGBOARD de 2020. https://ciudadsurf.com/mejores-longboard-de-2020/.

[26] J. O. Ortega Ruíz. 2018. Desarrollo de un material hibrido, madera/fique-poliéster para la fabricación de tablas de skateboard. Thesis, Pamplona Univ.

[27] M. Rodríguez Gasca. 2020. Metodología de ingeniería concurrente enfocada al desarrollo de tablas de skateboard a base de biocompuesto reforzado con fibra de fique.

[28] A. Endruweit and P. Ermanni. 2002. Experimental and numerical investigations regarding the deformation-adapted design of a composite flex slalom skateboard. Sport. Eng., 5(3): 141-154, doi: 10.1046/j.1460-2687.2002.00104.x.

[29] H. Liu, T. Coote, A. Aiolos and C. Charlie. 2018. Skateboard deck materials selection. IOP Conf. Ser. Earth Environ. Sci., 128(1), doi: 10.1088/1755-1315/128/1/012170.

[30] M. F. Ashby and D. Cebon. 2005. Materials selection in mechanical design. MRS Bull. 30(12): 995.