e-ISSN: 2355-620X
DOI: 10.12928/jrkpf.v10i1.224

Spreadsheet to analyze the comparative of elasticities properties of aluminum alloy materials

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Abstract

Physics learning contains mathematical processes with various equations to interpret concepts or phenomena in the quantitative concept. Each material with different values owns material mechanical properties such as elasticity. Spreadsheets can help mathematical processes become more effective and efficient. The output of spreadsheets can be interpreted as graphs or diagrams that make it easier to understand concepts and compare the elasticity of each material. The material studied in this study is an aluminum alloy in terms of its elemental content. Spreadsheet analysis presents the values of the elasticity properties of each material in graphical form. The elasticity properties studied are the modulus of elasticity (Young modulus), yield strength (Yield strength), and maximum strength (Ultimate strength).

Keywords: spreadsheets, aluminum alloys, elasticity.

Received September 21, 2022, Revision April 11, 2022, Accepted for publication on April 18, 2022.
https://doi.org/10.12928/jrkpf.v10i1.224

I. Introduction

The materials on Earth can be learned through physics in high school and college. Various reviews of the material have been developed by scientists to date. One of them is the material's elasticity, which is included in the mechanical properties of the material [1]. A material's elasticity is the material's ability to return to its original shape when the external force exerted on the object is removed [2], [3]. It is not elastic if a material does not return to its original shape when the external force is released. Modulus of elasticity (Modulus Young), yield strength (Yield Strength), and maximum strength (Ultimate Strength) are part of elasticity [4]. The ratio of tensile stress and strain applied by a material is called Modulus Young or modulus of elasticity in units of pascal (Pa) and is symbolized by E. Universally, the size or resistance of a material experiencing elasticity in terms of one axis when given a force on the object can express in Young's Modulus or modulus of elasticity in units of pascal (Pa). At the same time, the lowest stress of a material begins to change the shape of the material permanently if the external load exerted is called the graduated strength or Yield Strength in units of pascal (Pa). The voltage at this point is also called the elasticity limit. A material will experience a constant extension of about 0.2% of its original length when the load pulling it is released. Then, the maximum stress that can be achieved by a material when given a load or force is called the maximum strength or Ultimate Strength. At this point, a material cannot increase stress again and causes fracture in the material [5], [6].

We can use a spreadsheet to compare the elastic properties of several materials. Spreadsheets that are operated through Microsoft Excel can help in the process of calculation, projection, analysis, and presentation of data in the learning process. Spreadsheet facilities can also implement numerical analysis in graphical form [7], [8]. Using spreadsheets can strengthen concepts mathematically, enhance students' visual representations through mathematical equations, and explore combinations of simple formulas [9]. Numerical analysis results are more easily understood by students when presented with visual representations, so they strengthen mathematical abilities and enhance understanding of physics concepts [10], [11].

One of the materials that is often used is Aluminum. Pure Aluminum (Al) is one of the non-ferrous metals. The aluminum crystal structure cube centering side (FCC) has an atom radius of 0.1431 nm. Aluminum is easily formed and is abundantly available in the Earth's crust beyond iron reserves (Fe). Aluminum is often used because it has several beneficial properties, such as corrosion resistance, good conductance of heat, and light density of around 2.7 gr/cm^3, and is easily fabricated. However, Aluminum has low strength and mechanical properties, so it needs to be alloyed with other materials so that its mechanical properties can be improved. Like several studies that have been done, various elements can be added to aluminum alloys to produce better materials. Some of these elements are copper (Cu), silicon (Si), zinc (Zn), manganese (Mn), magnesium (Mg), and so on [12]–[17].

Aluminum alloys have great benefits in the industrial field. Aluminum alloy is a metal structural material that is most widely used after iron and steel. Its need in the industry is also increasing every day. Aluminum alloys have advantages such as high corrosion resistance, low weight due to low density, low cost due to easy processing, and excellent electrical and thermal conductivity [18], [19]. Pure Aluminum has an elastic modulus of around ± 70 GPa, yield strength of ± 95 mPa, and maximum strength of ± 110 mPa [20].

When Aluminum is mixed with other materials, there will be changes in mechanical properties. The study of the elastic properties of aluminum alloys has been widely used. Li et al. [21] compare the dynamic properties of two single-layer spherical shells made from different aluminum alloys, exhibiting varying degrees of elasticity and viscoelasticity. Zhu et al. [22] investigate the elastic properties of bulk Al2O3 oxide in conjunction with the A97075 Al alloy utilized in aircraft structural components. Cerbu and Teodorescu-Draghicescu [23] discuss the simulation of aluminum alloy behavior in tensile tests by modeling the nonlinear behavior of elastic-plastic materials within the plastic range. Utilizing hardness and monotonic tensile properties, Li et al. [24] develop effective approximations for calculating strain-controlled fatigue parameters and cyclic deformation of wrought aluminum alloys.

Based on previous research studies, there is limited information reporting on the analysis of the elastic properties of aluminum alloys using spreadsheets. Therefore, this study aims to analyze changes and differences in the elastic properties of aluminum alloys using spreadsheets.

II. Methods

The material used in this study is several types of aluminum alloys which will be compared with pure Aluminum. The content of aluminum alloys is presented in Table 1. Each material has different elasticity properties. Adding other ingredients to pure Aluminum will change the material's mechanical properties. In this study, the elasticity properties to be studied are modulus of elasticity, yield strength, and maximum strength presented in Table 2.

The elasticity properties related to stress and strain can be assessed through the Ramberg Osgood equation written in equation (1) [25]–[27]. This equation expresses the total strain relationship on the stress-strain curve,

$$\varepsilon_t = \frac{\sigma}{E} + \left(\frac{\sigma}{K}\right)^{\frac{1}{n}}. \tag{1}$$

The physical symbol represents the total strain, σ represents the stress in the elastic area, E represents the material's modulus of elasticity, K is the strength coefficient, and n subscript is the strain hardening coefficient. The value of n can be obtained through

$$n = \frac{Ln\left(\frac{\varepsilon_{us}}{0.2}\right)}{Ln\left(\frac{F_{tu}}{F_{ty}}\right)}, \tag{2}$$

ε_{us} expresses plastic strain at the end of a regular extension (maximum strain load F_{tu}), F_{ty} is the yield strength (ultimate strength) of a material, and F_{tu} is the maximum strength (yield strength) of a material. The amount of value ε_{us} derived from $\varepsilon_{us} = 100\left(\varepsilon_r - \frac{F_{tu}}{E}\right)$.

Table 1. The Content of Aluminum Alloy types

Name of materials	Contains
Aluminum 6061-T6 [28], [29]	Si (0.6); Mg (0.98); Fe (0.19); Cu (0.18); Cr (0.05); Zn (0.10); Ti (0.08); other elements (0.15) and Al (*balance*)
Aluminum 6061-T4 [30]	Al (95.8-98.6); Cr (0.04-0.35); Cu (0.15-0.4); Fe (≤0.7); Mg (0.8-1.2); Mn (≤0.15); Si (0.3-0.8); Ti (≤0.15); Zn (≤0.25); other elements (≤0.15 each ≤0.05)
Al Si 12-6C [31]	Al (86.0); Si (12.8); Fe (0.1); Mg (0.1); other elements (1.0)
Aluminum 2017-T4 [30]	Al (91.5-95.5); Cr (≤0.1); Cu (3.5-4.5); Fe (≤0.7); Mg (0.4-0.8); Mn (0.4-1); Si (0.2-0.8); Ti (≤0.15); Zn (≤0.25); other element (≤0.15 each ≤0.05)
Aluminum 2219-T31 [30], [32]	Al (91.5-93.8); Cu (5.8-6.8); Fe (≤0.3); Mg (≤0.02); Mn (0.2-0.4); Ti (0.02-0.1); Si (≤0.2); V (0.05-0.15); Xn (≤0.1); Zr (0.1-0.25); other element (≤0.15 each ≤0.05)

Table 2. Elasticity Properties of Aluminum Alloy

Materials	Elasticity Modulus (*Modulus Young*) (GPa)	Yield Strength (*Yield Strength*) (MPa)	Ultimate Strange (*Ultimate Strength*) (MPa)
Pure Aluminum	70.0	95	110
Aluminum 6061-T6	68.9	276	310
Aluminum 6061-T4	68.9	145	241
Al Si 12-6C	25.6	110	190
Aluminum 2017-T4	72.4	276	427
Aluminum 2219-T31	73.1	248	359

III. Results and discussion

Equations (2) and (3), as well as referring to Table 2, produce n values for each aluminum alloy presented in Figure 1. Then, from the value of n obtained, it was substituted into equation (1), and the tensile strength values of each alloy are obtained Aluminum is presented in Figure 2. The results of the data obtained are interpreted visually into graphical form so that it is easier to read the results of the data and to distinguish the tensile strength of each aluminum alloy. Graph interpretation is presented in Figure 3.

The analysis shows that each aluminum alloy has different elasticity properties. Aluminum 2017-T4 has the highest stress strength compared to Aluminum and other aluminum alloys but has the same yield strength value as Aluminum 6061-T6. Whereas Aluminum 2219-T31 has the highest modulus of elasticity among the six aluminum alloys, which is 73.1 GPa, while Aluminum 2017-T4 has the second highest modulus of elasticity value of 72.4 GPa. Pure Aluminum has the lowest stress strength, and this is consistent with the previous statement that pure Aluminum has low strength and mechanical properties, so alloys from other materials are needed so that their mechanical properties can be improved [12], [19].

Various aluminum alloys which have different contents produce different elasticity properties. Students can analyze and compare the elasticity properties of various other materials through spreadsheets. Examine the effect of the elements possessed by aluminum alloys on their elasticity properties.

C8 =(LN((100*(C5/100-C3/C2))/0,2))/(LN(C3/C4))

	B	C	D	E
1	material =	Aluminium		
2	E =	70000	mPa	(Young Modulus)
3	Ftu=	110	mPa	(Ultimate strength)
4	Fty=	95	mPa	(Yield strength)
5	ε max =	10	%	(strain at rupture)

Bahan	$n = \dfrac{Ln\left(\frac{\varepsilon_{us}}{0,2}\right)}{Ln\left(\frac{F_{tu}}{F_{ty}}\right)}$
Al	26,58
Al 6061-T6	33,28
Al 6061-T4	7,63
Al Si12-6C	7,02
Al 2017-T4	8,83
Al 2219-T31	10,44

Figure 1. The result of the calculation of the n value on each aluminum alloy

C25 =B25/$C$4+0,002*(B25/$C$6)^$C$20

	Al Si 12-6C		Aluminum 2017-T4		Aluminum 2219-T31	
20	n =	7,02	n =	8,825351	n =	10,43993
23	s (MPa)	ε	s (MPa)	ε	s (MPa)	ε
24	0,0	0,00000	0,0	0,00000	0,0	0,00000
25	22,0	0,00086	55,2	0,00076	49,6	0,00068
26	44,0	0,00172	110,4	0,00153	99,2	0,00136
27	66,0	0,00263	165,6	0,00231	148,8	0,00205
28	88,0	0,00386	220,8	0,00333	198,4	0,00291
29	93,5	0,00429	234,6	0,00372	210,8	0,00325
30	99,0	0,00482	248,4	0,00422	223,2	0,00372
31	104,5	0,00548	262,2	0,00489	235,6	0,00439
32	110,0	0,00630	276,0	0,00581	248,0	0,00539
33	118,0	0,00788	291,1	0,00722	259,1	0,00670
34	126,0	0,01011	306,2	0,00923	270,2	0,00859
35	134,0	0,01322	321,3	0,01209	281,3	0,01130
36	142,0	0,01755	336,4	0,01612	292,4	0,01516
37	150,0	0,02349	351,5	0,02175	303,5	0,02062
38	158,0	0,03155	366,6	0,02956	314,6	0,02827
39	166,0	0,04238	381,7	0,04025	325,7	0,03887
40	174,0	0,05674	396,8	0,05474	336,8	0,05344
41	182,0	0,07557	411,9	0,07418	347,9	0,07327
42	190,0	0,10000	427,0	0,10000	359,0	0,10000

Al | Al 6061-T6 | Al 6061-T4 | Al Si 12-6C | Aluminum 2017-T4 | Aluminum 2219-T31

C20 =(LN((100*(C7/100-C5/C4))/0,2))/(LN(C5/C6))

	Aluminium		Aluminum 6061-T4		Aluminium 6061-T6	
20	n =	26,58	n =	33,27829	n =	7,63
23	σ (MPa)	ε	s (MPa)	ε	s (MPa)	ε
24	0,0	0,00000	0,0	0,00000	0,0	0,00000
25	19,0	0,00027	29,0	0,00042	55,2	0,00080
26	38,0	0,00054	58,0	0,00084	110,4	0,00160
27	57,0	0,00081	87,0	0,00130	165,6	0,00240
28	76,0	0,00109	116,0	0,00205	220,8	0,00321
29	80,8	0,00118	123,3	0,00237	234,6	0,00341
30	85,5	0,00134	130,5	0,00279	248,4	0,00367
31	90,3	0,00180	137,8	0,00335	262,2	0,00417
32	95,0	0,00336	145,0	0,00410	276,0	0,00601
33	96,5	0,00441	154,6	0,00551	279,4	0,00706
34	98,0	0,00597	164,2	0,00755	282,8	0,00860
35	99,5	0,00826	173,8	0,01049	286,2	0,01085
36	101,0	0,01163	183,4	0,01467	289,6	0,01412
37	102,5	0,01653	193,0	0,02053	293,0	0,01887
38	104,0	0,02365	202,6	0,02861	296,4	0,02576
39	105,5	0,03394	212,2	0,03962	299,8	0,03572
40	107,0	0,04873	221,8	0,05444	303,2	0,05005
41	108,5	0,06989	231,4	0,07413	306,6	0,07061
42	110,0	0,10000	241,0	0,10000	310,0	0,10000

Al | Al 6061-T6 | Al 6061-T4 | Al Si 12-6C | Aluminum 2017-T4 | Aluminum 2219-T3

Figure 2. The value of aluminum alloy tensile strength

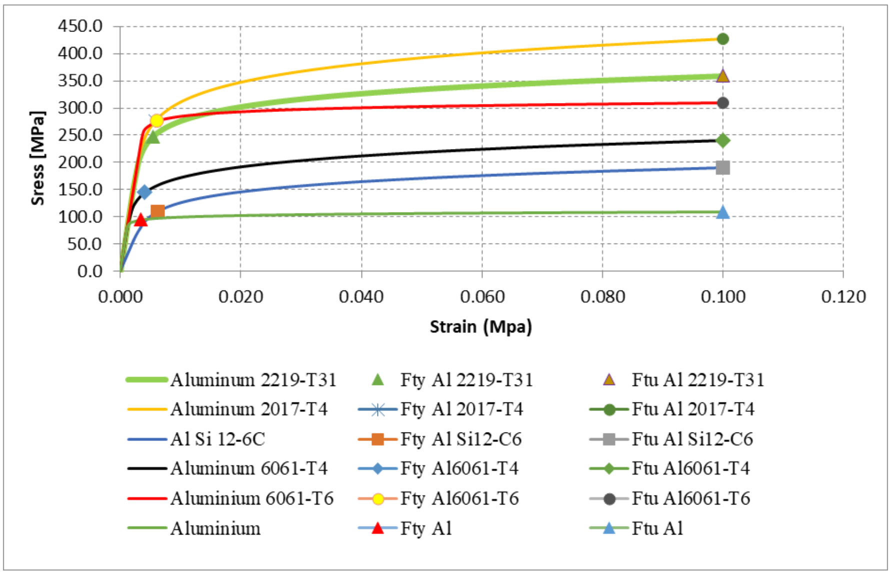

Figure 3. Tensile strength of some aluminum alloys

IV. Conclusions

Spreadsheets can be applied as an alternative to the physics learning process on material elasticity so that it is more effective and efficient. Examine the influence of the alloy material's elements on the material's mechanical properties, especially elasticity. Aluminum alloys can also be applied to materials or other alloy materials.

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