Drawing the Tensile Curve for Pure Metals and Alloys Depending On Crystal Structure and Acoustic Impedance

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Abstract. A new method to predict the stress-strain relation of the pure metals and alloys has been presented in this paper by using the acoustic impedance property. The method involves developing new algorithms that were programmed in a MATLAB code. Also, it compromises the experimental measurement of some physical properties, such as longitudinal wave velocity, density, and crystal structure. The study considered 19-samples, which have been put in three different groups depending on the crystal structure (seven FCC samples, six BCC samples, and six HCB samples). The samples' crystal structure was examined using the X-ray diffraction method before the samples' density, and longitudinal wave velocity were experimentally measured. To evaluate the validity of the developed model, a comparison between its prediction for the stress-strain relation and the corresponding curves in the literature was done. The results, also, verified the existence of a relation between pressure transmission coefficient (PrTr) and each of the $\sigma_u$, $\sigma_y$, and modulus of elasticity ($E$) properties for the metals in the same crystal structure group.

1. Introduction

The tensile tests play an important role in the detection of the mechanical properties of the specimens for many companies that use it in their works. These companies face some difficulties in test long tubes or big size specimens unless conducting many mechanical works before conducting tensile tests, time and rise the production cost. In fact, there are two factors that have the most influence on tensile resistance. The first one is crystal structure\cite{1-5} and the mechanical properties represented by the modulus of elasticity and density ($\rho$)\cite{6}. This study gives a new view through linking among crystal structure, acoustic impedance, and tensile strength. The importance of this vision is that it can be used to test the tensile strength of complex shapes such as pipeline, curvature beams, or complex shape of plates…etc. The drawing of tensile strength depends on three essential points. These three-point are: first, modulus of elasticity, which represents the slope of the elastic line (within the elastic region), second, yield strength point ($\sigma_y$), and finally the ultimate strength point ($\sigma_u$). This research gives a new idea through estimate $E$, $\sigma_y$, and $\sigma_u$, for pure metal and alloys, by using the acoustic impedance of these metals and alloys. From another side, for many materials, there is a miss-match of values of $E$ calculated from tensile tests and those calculated from the non-destructive test (NDT). Where most of NDTs utilize equation (1) to calculate the value of $E$\cite{7-13}, where CL is the longitudinal velocity of wave and $v$ is the Poisson's ratio

$$E = \frac{C_L^2 \rho (1 + v)(1 - 2v)}{(1 - v)}$$

(1)
For example, this equation gives correct values of $E$ for normal material such as Fe, Al, and Cu…etc, but, this equation gives incorrect values of $E$ for refractory metals such as Niobium titanium and tantalum[14]. The advantage of this study is dependence on a new method to calculate values of $E$ for the metals and alloys.

There are four steps to draw the tensile curve for pure metals and alloys. Firstly, sorting the metals and alloys based on their crystal structure. Secondly calculation pressure transmission coefficient ($PrTr$) through measure $CL$ and $\rho$. Thirdly, deriving a mathematical relationship between $PrTr$ and each of $E$, $\sigma_y$, and $\sigma_u$ severally. Finally, programming a MATLAB code to help in drawing the tensile strength curve for each metal and alloy.

2. Theoretical Part

The pressure of the transmitted wave between any connected materials depends on the acoustic impedance ($Z$) of these bodies

$$PrTr = \frac{2Z_2}{Z_1 + Z_2}$$  \hspace{1cm} (2)

$Z_1$ in equation (2) represents the acoustic impedance of magnesium ($Z_1 = Z_{Mg} = 9.9761 \times 10^6 \frac{Kg}{m^2s}$), while $Z_2$ represents the acoustic impedance of the metal or alloy that has needed test it ($Z_{SP}$), which is needed to find the values of $E$, $\sigma_y$, and $\sigma_u$ for it. This research chose Mg to be $Z_1$ because the magnesium metal has one of the lowest values of $E$ among the solid metals. Therefore equation (2) becomes:

$$PrTr = \frac{(39.9Z_{SP})}{(1.5 + Z_{SP})(Z_{SP} + 9.97612)}$$  \hspace{1cm} (3)

The relationship between $E$, $\sigma_y$, and $\sigma_u$ with $PrTr$ is a disciplined relationship in case these metals or alloys were sorted according to their crystal structures. The values of $PrTr$ in all the figure 1,2, and 3 were evaluated from equation (3), while the $\sigma_y$ and $\sigma_u$ values in all these figures were collected from references[15-17].

The values of $\sigma_y$ and $\sigma_u$ for FCC metals (Face Center Cubic metals) were grouped then the relations between them and their $PrTr$ values were drawn as shown in figure 1.

![Relationship of $\sigma_y$ and $\sigma_u$ with $PrTr$ for FCC metals.](image)

Figure 1. Relationship of $\sigma_y$ and $\sigma_u$ with $PrTr$ for FCC metals.
The equation (4) and (5) were constructed by utilizing the curve fitting technique for the two curves in figure 1. Equation (4) and (5) refer to the uniform (polynomial) relationship between the \( \sigma_y \) and \( \sigma_u \) with PrTr, where the increase in values of \( \sigma_y \) and \( \sigma_u \) for FCC is associated with decreasing of values of PrTr.

\[
\sigma_{y_{FCC}} = 4274.76 - 48701.1 \times PrTr + 241443 \times (PrTr^2) - 635316 \times (PrTr^3) \\
+ 953657 \times (PrTr^4) - 818338 \times (PrTr^5) + 373112 \times (PrTr^6) \\
- 70012.1 \times (PrTr^7) 
\]

(4)

\[
\sigma_{u_{FCC}} = 40151 - 419670 \times PrTr + 1840250 \times (PrTr^2) - 4300940 \times (PrTr^3) \\
+ 5788240 \times (PrTr^4) - 4502280 \times (PrTr^5) + 1881010 \times (PrTr^6) \\
- 326639 \times (PrTr^7)
\]

(5)

The same behavior (the disciplined relationship between \( \sigma_y \) and \( \sigma_u \) with PrTr) for FCC metal was repeated with BCC metal too, as shown in figure 2. The equation (5) and equation (6) indicate the mathematical expression for the curves shown in figure 2.

\[
\sigma_{y_{BCC}} = 127772 - (1588710 \times PrTr) + (8242590 \times PrTr^2) - (23016300 \times PrTr^3) \\
+ (37392900 \times PrTr^4) - (35434900 \times PrTr^5) + (18188700 \times PrTr^6) \\
- (3912140 \times PrTr^7)
\]

(6)

\[
\sigma_{u_{BCC}} = -2336.06 + 15257.1 \times PrTr - 6856.14 \times (PrTr^2) - 71417.21 \times (PrTr^3) + 120448 \times (PrTr^4) - 55118.3 \times (PrTr^5) 
\]

(7)

![Figure 2](image.png)

**Figure 2.** Relationship between \( \sigma_y \) and \( \sigma_u \) with PrTr for body center cubic metals.

The curve of \( \sigma_y \) for HCP metals in figure 3 was divided into two portions A1 and A2, in order to find suitable curve fitting as shown in equation (8) (a and b). The portion A1 is for PrTr<1.11 and PrTr>1.11 is for portion A2.

For section A1:
\[
\sigma_y(A1)_{HCP} = 87005.7 - 388401 \times PrTr + 647564 \times PrTr^2 - 476290 \times PrTr^3 \\
+ 130272 \times PrTr^4
\]

Section A2:
\[
\sigma_y(A2)_{HCP} = 8658.89 - 25203.4 \times (PrTr) + 27714.7 \times (PrTr^2) - 13444.7 \times (PrTr^3) \\
+ 2420.17 \times (PrTr^4)
\]

Equation (9) clarifies the relationship between \(\sigma_u\) and PrTr, as shown in figure 3, for hexagonal closest packed (HCP) metals:
\[
\sigma_u_{HCP} = 20576.01 - 81541.201 \times (PrTr) + 127710 \times (PrTr^2) - 96409.6 \times (PrTr^3) + 34862.6 \times (PrTr^4) - 4817.61 \times (PrTr^5)
\]

**Figure 3.** Relationship between \(\sigma_y\) and \(\sigma_u\) with PrTr for HCP metal.

The values of \(C_1, \rho, \sigma_{y\text{ASTM}}\) and \(\sigma_{u\text{ASTM}}\) in table 1 were collected from sources[15, 18, 19] according to ASTM, while \(\sigma_{y\text{cal}}\) and \(\sigma_{u\text{cal}}\). in table 1, represent the values of \(\sigma_y\) and \(\sigma_u\) evaluated from the suggested method in this study (equations (4),(6),(8) and equations (5),(7),(8)).

\(Cg1\) in equation (10) represents the convergence between \(\sigma_{y\text{ASTM}}\) and \(\sigma_{y\text{cal}}\), while \(Cg2\) indicates the convergence between \(\sigma_{u\text{ASTM}}\) and \(\sigma_{u\text{cal}}\). The results of these two equations (10 and 11) were listed in table 1 also.

\[
Cg1 = 100 - \sqrt{\left[\frac{(\sigma_{y\text{ASTM}} - \sigma_{y\text{cal}})}{\sigma_{y\text{ASTM}}}\right] \times 100}^2
\]

\[
Cg2 = 100 - \sqrt{\left[\frac{(\sigma_{u\text{ASTM}} - \sigma_{u\text{cal}})}{\sigma_{u\text{ASTM}}}\right] \times 100}^2
\]

The column \(E_{cal}\) in table 1 were evaluated from equation (8) in the sources [14, 20].
## Table 1. Sorting Mechanical properties according to their crystal structure [15-17].

| Crystal Structure | Metal Name | Cl. Name [ASTM] | \( \rho \) (kg/m\(^3\)) | \( Z \) (Kg/m\(^2\) s) \( \times 10^6 \) | PrTr | \( \sigma_{ASTM} \) MPa | \( \sigma_{cal} \) MPa | Cg1. % | \( \sigma_{ASTM} \) MPa | \( \sigma_{cal} \) MPa | Cg2. % | \( E_{cal} \) GPa | Cg3. % |
|-------------------|------------|-----------------|--------------------------|-------------------------------|------|------------------|--------------|------|------------------|--------------|------|----------------|------|
| FCC               | AL         | 6320            | 2710                     | 17.127                        | 1.3535 | 12               | 14.014       | 45   | 48.787           | 91.582       | 68.136 | 90.1          |
|                   | Ge         | 5450            | 5470                     | 29.811                        | 0.9547 | 130              | 130.62       | 150  | 158.39           | 94.403       | 163.13 | 83.47         |
|                   | Thorium    | 2850            | 11720                    | 33.402                        | 0.8803 | 144              | 144.25       | 217  | 203.83           | 93.93        | 57.597 | 80            |
|                   | Ge         | 6190            | 12410                    | 76.817                        | 0.4509 | 200              | 199.91       | 99.518| 99.958           | 99.986       | 371.98 | 98.14         |
|                   | Ir         | 5380            | 22650                    | 121.85                        | 0.2989 | 234              | 233.96       | 99.967| 99.967           | 99.967       | 443.62 | 84.01         |
| BCC               | Nb         | 3480            | 8570                     | 29.82                         | 0.95   | 105              | 101.62       | 98.17 | 99.97           | 99.934       | 103.98 | 99.036        |
|                   | V          | 6000            | 6160                     | 36.96                         | 0.81   | 150              | 158.06       | 96.421| 96.421           | 96.450       | 132.36 | 99.951        |
|                   | Fe         | 5900            | 7800                     | 46.02                         | 0.69   | 131              | 141.29       | 92.138| 92.138           | 92.138       | 213.83 | 212.51        |
|                   | Ta         | 3400            | 16654                    | 56.62                         | 0.58   | 172              | 178.32       | 96.325| 96.325           | 96.325       | 173.76 | 99.960        |
|                   | Mo         | 6370            | 10220                    | 65.1                          | 0.51   | 345              | 322.79       | 93.56 | 93.56            | 93.56        | 399.67 | 99.979        |
|                   | W          | 5180            | 19300                    | 99.97                         | 0.35   | 550              | 550.51       | 99.906| 99.906           | 99.906       | 407.43 | 99.991        |
| HCP               | Mg         | 5740            | 1738                     | 9.9761                        | 1.7383 | 69               | 70.952       | 97.17 | 97.17            | 97.17        | 184.22 | 92.625        |
|                   | Be         | 12800           | 1850                     | 23.68                         | 1.1148 | 117              | 124.44       | 93.641| 93.641           | 93.641       | 378.37 | 97.078        |
|                   | Ti         | 6100            | 4450                     | 27.145                        | 1.0185 | 140              | 131.51       | 93.942| 93.942           | 93.942       | 380.2  | 97.759        |
|                   | Zr         | 4650            | 6480                     | 30.132                        | 0.9476 | 207              | 201.38       | 97.287| 97.287           | 97.287       | 378.93 | 64.726        |
|                   | Hf         | 3000            | 13310                    | 39.93                         | 0.7705 | 230              | 229.85       | 99.936| 99.936           | 99.936       | 444.97 | 56.369        |
|                   | Colt       | 5730            | 8900                     | 50.997                        | 0.6356 | 758              | 707          | 93.272| 93.272           | 93.272       | 775.78 | 94.849        |

*(C10200)Cu(C10100)*

It is worth mentioning the elongation of pure metals and alloys is also required to complete the steps of getting the program for drawing the stress-strain curve. Figure 4 represents the relationship between the elongation values of pure metals and alloys and their PrTr values. The elongation values were gathered from sources [15, 18, 19].
Figure 4. The elongations relationships for pure metals with PrTrs.

The program below represents the equations from (3-9). Longitudinal velocity ($C_L$), density ($\rho$) and crystal structure ($Cy$) are the only input to this program to draw the tensile strength curve.

```matlab
clc
%If the crystal structure (Cy) of materials is FCC then Cy=1. Cy=2 if BCC and Cy=3 if HCP YS=\sigma_y and UTS= \sigma_u
%FCC=1, BCC=2 and HCP=3
Cy=1; % (Cy)Crystal structure
P=8890; % (P)Density
CL =5780; % (CL)Longitudinal velocity
Z= (P*CL)/10^6
PRTR=(39.9*Z)/((1.5+Z)*(Z+9.97612)) %for z<29
if Z>=50.99
E = ((-5.66211+73.0387*PRTR-275.856*(PRTR^2)+425.253*(PRTR^3)-
234.885*(PRTR^4))/P)*(10^7)
elseif Z>29 && Z<50.99
E = ((-6.86293+58.1587*(PRTR)-
102.833*((PRTR)^2)+52.8154*((PRTR)^3))*10^6)/P
elseif Z<= 29
E = (12533000.0-460076000*(PRTR)+675849000*(PRTR^2)-
493640000*(PRTR^3)+1783970000*(PRTR^4)-255258000*(PRTR^5))/P
end
sprintf('%.2f',PRTR)
if Cy == 1
YS=4274.76-48701.1*PRTR+241443*(PRTR^2)-635316*(PRTR^3)+953657*(PRTR^4)-
818338*(PRTR^5)+373112*(PRTR^6)-70012.1*(PRTR^7)
UTS=40151-419670*PRTR+1840250*(PRTR^2)-4300940*(PRTR^3)+5788240*(PRTR^4)-
4502280*(PRTR^5)+1881010*(PRTR^6)-326639*(PRTR^7)
Elong=-9733.76+107627*(PRTR)-482622*(PRTR^2)+1141490*(PRTR^3)-
1542520*(PRTR^4)+1195950*(PRTR^5)-494744*(PRTR^6)+84585.9*(PRTR^7)
elseif Cy == 2
```

Elongation vs. PrTr for different crystal structures.
YS=127772 – (1588710*PRTR)+824590*(PRTR^2) –
23016300*(PRTR^3)+37392900*(PRTR^4) –
35434900*(PRTR^5)+18188700*(PRTR^6) –39121400*(PRTR^7)
UTS= -2336.06+15257.1*(PRTR)-6856.14*(PRTR^2) –
71417.2*(PRTR^3)+120448*(PRTR^4) –55118.3*(PRTR^5)
Elong = 82696.5 –807505*(PRTR)+3198520*(PRTR^2) –6599990*(PRTR^3) +
7503080*(PRTR^4)–4465200*(PRTR^5)+1088620*(PRTR^6)
else if Cy == 3
UTS=20576.81541.2*(PRTR)+127710*(PRTR^2) –
96409.6*(PRTR^3)+34862.6*(PRTR^4) –4817.61*(PRTR^5)
Elong = 463.981–1906.27*(PRTR)+2883.43*(PRTR^2) –
1794.42*(PRTR^3)+391.038*(PRTR^4)
%for section A1
if PRTR<=1.11
YS=87005.7–388401*PRTR+647564*(PRTR^2) –476290*(PRTR^3) + 130272*(PRTR^4)
elseif PRTR>1.11
%For Section A2:
YS=8658.89–25203.4*(PRTR)+27714.7*(PRTR^2) –
13444.7*(PRTR^3)+2420.17*(PRTR^4)
end
end
if Elong> 15
EE1=YS/(E);
theta = linspace((2*pi)/(2.0), pi/6, 10);
beta = linspace((pi/(2.0)), 0, 10);
RRR = UTS-YS;
dd=Elong-EE1;
x1 = ddd*cos(beta)+EE1;
y1 = RRR*sin(theta) + YS;

theta = linspace((2*pi)/(2.0), pi/(2.0), 10);
beta = linspace((pi/(2.0)), 0, 10);
RRR = (UTS-YS);
y1 = RRR*sin(theta) + YS

else
EE1=YS/(E);
theta = linspace((2*pi)/(2.0), pi/(2.0), 10);
beta = linspace((pi/(2.0)), 0, 10);
RRR = (UTS-YS);
y1 = RRR*sin(theta) + YS

end

end

if Elong> 15
EE1=YS/(E);
theta = linspace((2*pi)/(2.0), pi/6, 10);
beta = linspace((pi/(2.0)), 0, 10);
RRR = UTS-YS;
dd=Elong-EE1;
x1 = ddd*cos(beta)+EE1;
y1 = RRR*sin(theta) + YS;
yy=[0 YS y1 ];

figure (1)
plot (xx,yy)
xlabel('Strain (%)'), ylabel('Stress (MPa)');
else

EE1=YS/(E)
theta = linspace((2*pi)/(2.0), pi/(2.0), 6)
beta = linspace((pi/(2.0)), 0, 100);
RRR = (UTS-YS);
y1 = RRR*sin(theta) + YS

OO=Elong/2
TT=OO/5
s=EE1
for k=1:6
s=s;
x1(k)=s
s=s+TT
end

yyy=[0 YS y1 UTS];

figure (2)
plot (xxx,yyy)
xlabel('Strain (%)'), ylabel('Stress (MPa)');
end
3. Experimental part
The three experimental steps of this study are:
1- Utilized the X-Ray test to verify from crystal structure for each specimen.
2- Measurement $C_L$, then $\rho$ for each test specimen to determine The $PrTr$ of these specimens, then $\sigma_y$ and $\sigma_u$ are determined by using equations (3-9).
3- The results of step-2 are compared with ASTM for $E, \sigma_y$ and $\sigma_u$.
In this study $Mg, Ni, and Nb$ were selected as the test samples for crystal structures HCP, FCC, and BCC respectively.

Step-1- XRD test
XRD 6000 SHIMDZU was used as a device of XRD testing for Mg, Ni, and HCP samples. Figure 5 illustrate the purity of these test specimen and confirm the symmetrical to the crystal structures of these samples with the crystal structure shown in table 1

![Figure 5](image-url)

**Figure 5.** (a) XRD for magnesium metal sample, (b) XRD for Nickel metal sample (c) XRD for Niobium metal sample

Step-2 Calculation $PrTr$ through measurement $C_L$ and $\rho$
Measuring the wave flight time, through employed the echo pulse technique for test samples ($Mg, Ni, and Nb$). Equation (11) and equation (12) explains how the $C_L$ was calculated, [21, 22] where $t_{TOF}$ represents the wave flight time, $L$ is the thickness of the specimen, and $t_o$ is the wedge delay of the probe that used in this study [23, 24] ($t_o = 9 \mu sec$ for the used probe)

$$t_{TOF} = \frac{2L}{C_L} + 2t_o \quad (11)$$

$$\therefore C_L = \frac{2L}{(t_{TOF} - 2t_o)} \quad (12)$$
Table 2. PrTr, $\sigma_y$, and $\sigma_u$ calculations.

| Metal name | Size of test specimen (m$^3$) | mass (Kg) $\rho$ | The Time of flight of the wave (t$_{TOF-Lc}$) | PrTr calculations $\sigma_y$ calculated (MPa) | $\sigma_u$ calculated (MPa) |
|------------|-------------------------------|-------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------|
| Ni (FCC)  | 0.05 × 0.0495 × 0.0075 = 1.856 × 10$^{-6}$ | 0.16502 × 0.0075 × 0.0075 = 1.856 × 10$^{-6}$ | (11.6 − 9) × 10$^{-6}$ = 2.6 × 10$^{-6}$ | \[ \begin{align*} C_L &= \frac{L \times 2}{t} \\ &= \frac{0.0075 \times 2}{2.6 \times 10^{-6}} \\ &= 5769 \end{align*} \] \( Z = C_L \times \rho \) = 51.38 × 10$^6$ | 147.8 \((\text{In equation (3) because it is FCC})\) | 451.17 \((\text{In equation (4) because it is FCC})\) |
| Nb (BCC) | 0.02 × 0.02 × 0.001 = 0.4 × 10$^{-6}$ | 0.00342 × 0.001 = 0.4 × 10$^{-6}$ | (9.57 − 9) × 10$^{-6}$ = 0.57 × 10$^{-6}$ | \[ \begin{align*} C_L &= \frac{L \times 2}{t} \\ &= \frac{0.01 \times 2}{0.01 \times 2} \\ &= 5708 \end{align*} \] \( Z = C_L \times \rho \) = 30.06 × 10$^6$ | 109 \((\text{In equation (5) because it is BCC})\) | 197.4 \((\text{In equation (6) because it is BCC})\) |
| Mg (HCP) | 0.1185 × 0.0915 × 0.0365 = 3.9576 × 10$^{-4}$ | 0.69 | (50 − 9) × 10$^{-6}$ = 41 × 10$^{-6}$ | \[ \begin{align*} C_L &= \frac{L \times 2}{t} \\ &= \frac{0.1185 \times 2}{0.1185 \times 2} \\ &= 5780 \end{align*} \] \( Z = C_L \times \rho \) = 10.07 × 10$^6$ | 70.22 \((\text{In equation (7) because it is HCP and PrTr} \geq 1.11)\) | 177.66 \((\text{In equation (8) because it is HCP})\) |
Figure 6. The experimental test system by using the echo pulse technique.

Figure 6 illustrates the all test system. This test system contains the Ultrasonic Pulse UP200 (OSUN) as a generator of electric pulses, the probe to create ultrasonic waves, and the oscilloscope type of DSEX1102A (100MHz). Putting ultrasonic gel on the test sample is essentially before placement the probe on this test sample. After putting the probe, the $t_{TOF}$ will appear on the oscilloscope screen.

Table 2. indicates the details of the test specimen such as dimensions of the specimen, the mass, and the density. This table also involves the calculation of $PrTr$, $\sigma_y$, and $\sigma_u$.

4. Results and Discussion

The matching between the proposing method represented by black color curves with red color curves which represent the experimental curves, for HCP materials, in figure 7 (a) is more than 93%. Also, the identity between experimental curves in green color, in figure 7 (b) with black color curves (the proposing program results) is more than 90%. These results were proved also in table 1 for the values of $E$, $\sigma_y$, and $\sigma_u$. Figure 7 (c) involves two curves stress-strain curve. The first one belongs to the alloy Al 1100-O, while the other the pure Ni, where these to materials represent the FCC group of pure material. For alloy Al 1100-O the matching was excellent (more than 90%), while for Ni was good, but not excellent. The difference between the experimental curve in blue color, in figure 7 (c), for Ni metal and the theoretical curve (black color curve) is beginning from the yield point until the ultimate point. The mismatch in this interval of the curve, (Ni curve) returns to the mathematical approximation shown in the equation below that was used to sketch the plastic deformation area:

$$EE1 = \frac{YS}{(E)}$$

$$\theta = \text{linspace}\left((2 \pi)/(2.0), \pi/6, 10\right)$$

$$\beta = \text{linspace}\left((\pi)/(2.0), 0, 10\right)$$

$$RRR = \text{UTS} - \text{YS}$$

$$\text{ddd} = \text{Elong} - EE1$$

$$x1 = \text{ddd} \times \text{cos} (\beta) + EE1$$

$$y1 = RRR \times \text{sin} (\theta) + \text{YS}$$
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Figure 7. Approaching between the proposed method results and other experimental works [11, 12, 25-27].

In fact, all equation above in this section is a part of the program shown in the theoretical part of this study, and it is just prediction from the proposed program to the metal behaviour in the plastic zone. Despite this small mismatch, however, it does not affect the main results of this program which are modulus of elasticity, yield stress, ultimate stress. In addition, according to table 1 and figure 7, the maximum error was 10% and the minimum error was 1%, therefore the average error is 5% and that might be produced from the random error or any other causes, therefore, in this study, these results were regarded as acceptable results according to the references [28] [29].

| Alloys (99.95%) | $C_L$ (m/s) | $\rho$ (kg/m³) | Crystal Structure | Figure |
|-----------------|-------------|----------------|-------------------|--------|
| Mg-0.5Zr        | 5790        | 1740           | HCP               | 12-a   |
| Cast Iron       | 4600        | 7200           | BCC               | 12-b   |
| AL1100-O        | 6350        | 2710           | FCC               | 12-c   |
| Ni 233          | 5515        | 8890           | FCC               |        |
| Ni 200          | 5810        | 8890           | FCC               |        |
| AL1199-O        | 6320        | 2710           | FCC               |        |
| AL(2014-O)      | 6310        | 2800           | FCC               |        |
Table 3 involves three properties (CL, ρ, and crystal structure) for six pure alloys that did not exist in table 1. First three of these six alloys were drawn in figure 7, while the other three were not drawn. The drawing of the last four alloys (Ni 233, Ni 200, AL1199-O, and AL2014-O) did not conduct because figure 7 will be very long, therefore these four alloys were listed in table 3 in order to be more confident in the proposed program through using the data (CL and ρ) for anyone would like to confirm from that.

5. Conclusion
The prediction of the stress-strain relation using the acoustic wave is of great importance for the industry. Companies that purchase big size parts, such as pipeline, cannot perform the ordinary tensile test unless some mechanical works are done to prepare standard test specimens. This study provides a novel MATLAB-code to predict the stress-strain relation for pure metals and alloys. The developed MATLAB-code adopts the experimentally measured wave velocity, density, and crystal structure of the metal to provide the prediction. The results confirmed a disciplined relation between the PrTrs and the mechanical properties of the metals that have the same crystal structure. Further, the results revealed that the developed algorithm is excellent in predicting the mechanical properties when compared with the ASTM. The results, also, confirmed a linear relation between the metals’ mechanical properties and the acoustic impedance, and a reverse relation with the pressure transmission coefficient. Further, the results showed that for the same acoustic impedance, HCP crystal structure metals have higher mechanical properties.

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