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INVESTIGATION OF MODULUS OF RESILIENCE / RESILIENCE OF GRAPHENE SHEET

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Modulus of Resilience of Graphene is estimated for loadings when force is applied along the width and when it is applied along the length. Resilience is measured as area obtained under Stress- Strain curve within elastic limit. So Stress- Strain graphs are plotted in both the loading cases. And Resilience is obtained from these graphs. During the calculations two lengths viz. 56.608 Ǻ and 238.740 Ǻ are taken. It is found that Resilience decreases with Width at constant length. It is also found that when force is applied along length of the sheet, variation of Ur with width is marginally small. For loading along width, the decrease in Ur with width is justified as area under the stress- Strain curve decreases, resulting in decrease of Ur .

Keyword(s): Single layer Graphene, Modulus of Resilience, elastic limit

1 Introduction

Resilience of a nano material Graphene is defined as ability to absorb energy and librate that energy when it returns to its original shape. Resilience is the unique characteristic of any material. This is measured in the terms of Elastic Energy absorbed by that material when load is applied but this absorbed energy releases when load is removed. Resilience or Modulus of Resilience is measured in Energy Strain/ volume. This modulus of Resilience can be calculated by estimating the area under the Stress vs Strain curve upto elastic limit.

Graphene sheet having Resilience = 206.6 N/M[1]. Joule /meter cube is the SI unit of Resilience[2]. Modulus of resilience is defined as-

This is general form of resilience $U_r = \int_0^{\varepsilon el} \sigma d\varepsilon = \int_0^{\varepsilon y} \sigma d\varepsilon$ (1)

This is Triangular form. $U_r = 1/2\ \sigma_{el}\varepsilon_{el} = \sigma_{el}^2/2E = S_{ty}^2/2E$ (2)

Here- σ_{el} is stress at elastic limit. ε_{el} is strain at elastic limit, δ_{ty} is tensile yield strength,E is elastic modulus

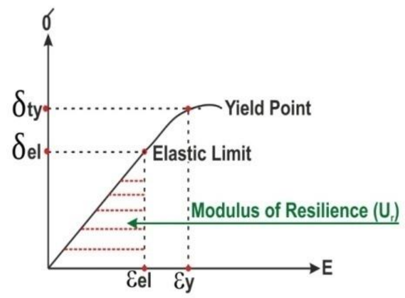


Fig.1- plot in between stress - Strain

The mechanical properties of sheet of Graphene has been observed. The possibilities of this material are really and practically endless. Carbon based substance abundantly utilized in analytical & industries area and carbon based materials showed number of modern utilities in comparison to noble metals. It stated that several challenges are still in Graphene research. Many properties of Graphene sheet are not completely understood and properties of Graphene can be changes with respect to number of layers which really needed for further investigations. If we mixed Graphene with plastic which increases its conductivity, therefore in upcoming days satellites, aeroplanes and cars etc can also be made by using Graphene. Since Graphene is optically transparent as well as good conductor, therefore Graphene is suitable for Touch screen, solar cells and light panels.This new alltrope (Graphene) of carbon which is in between diamond & Graphite are showing interest to young Researchers due to its unique properties- high surface area, high conductivity, mobility, high Y, stiffness etc& number of applications in technology [3], ,[4],[5],[6],[7].Organic material chemists are working on new synthetic ways to generate high quality Graphene. Engineers are trying to design novice devices & apparatus to utilize unique properties of Graphene. Since we know that C play an important & crucial role in our human life and this material (C) is found in excess in our universe (it is vith abundant elements). Graphene nano materials have great potential which attracts the new scientist and researchers very rapidly because of plethora of applications and properties. Resilience introduced in mechanics[8] and graphene fracture behavior is shown in perfectly[9].

2 Methodology

To analyse the Resilience of single layer of graphene sheet. We need area under stress Vs strain curve within elastic limit.. So to find out the stresses and strains. We have chosen various lengths and widths as well as young's modulus of different samples.

We have consider two cases (loading 1 and 2), One in which load is applied along the width (w) called loading -1.

Table 1- loading-1, At w = 19.894 Å

S.N.	L(Å)	Y(TPa)	ΔL(Å)	STRAIN(ΔL/L)	STRESS=Y.STRAIN
1-	56.608	2.57065	1.00	0.01766	0.0453
	56.608	2.57065	1.10	0.01943	0.0499
	56.608	2.57065	1.20	0.02119	0.0544
	56.608	2.57065	1.30	0.02296	0.0590
	56.608	2.57065	1.40	0.02473	0.0635
2-	118.139	2.58394	2.10	0.01777	0.0459
	118.139	2.58394	2.30	0.01946	0.0502
	118.139	2.58394	2.50	0.02116	0.0546
	118.139	2.58394	2.70	0.02285	0.0590
	118.139	2.58394	2.90	0.02454	0.0634
3-	177.209	2.58826	3.10	0.01749	0.0452
	177.209	2.58826	3.40	0.01918	0.0496
	177.209	2.58826	3.80	0.02144	0.0554
	177.209	2.58826	4.00	0.02257	0.0584
	177.209	2.58826	4.30	0.02426	0.0627
4-	238.740	2.59025	4.20	0.01759	0.0455
	238.740	2.59025	4.60	0.01926	0.0498
	238.740	2.59025	5.20	0.02178	0.0564

	238.740	2.59025	5.40	0.02261	0.0585
	238.740	2.59025	5.80	0.02471	0.0640
5-	297.810	2.59130	5.20	0.01746	0.0452
	297.810	2.59130	5.70	0.01913	0.0495
	297.810	2.59130	6.30	0.02115	0.0548
	297.810	2.59130	6.80	0.02283	0.0591
	297.810	2.59130	7.30	0.02451	0.0635

Table 2- At w = 41.209 Å

S.N.	L(Å)	Y(TPa)	ΔL(Å)	STRAIN(ΔL/L)	STRESS=Y.STRAIN
1-	56.608	2.57065	1.00	0.01766	0.0436
	56.608	2.57065	1.10	0.01943	0.0480
	56.608	2.57065	1.20	0.02119	0.0523
	56.608	2.57065	1.30	0.02296	0.0567
	56.608	2.57065	1.40	0.02473	0.0611
2-	118.139	2.58394	2.10	0.01777	0.0459
	118.139	2.58394	2.30	0.01946	0.0503
	118.139	2.58394	2.50	0.02116	0.0546
	118.139	2.58394	2.70	0.02285	0.0590
	118.139	2.58394	2.90	0.02454	0.0634
3-	177.209	2.58826	3.10	0.01749	0.0452
	177.209	2.58826	3.40	0.01918	0.0496
	177.209	2.58826	3.80	0.02144	0.0555
	177.209	2.58826	4.00	0.02257	0.0584
	177.209	2.58826	4.30	0.02426	0.0628
4-	238.740	2.59025	4.20	0.01759	0.0455
	238.740	2.59025	4.60	0.01926	0.0499
	238.740	2.59025	5.20	0.02178	0.0564
	238.740	2.59025	5.40	0.02261	0.0585
	238.740	2.59025	5.80	0.02429	0.0629
5-	297.810	2.59130	5.20	0.01746	0.0452
	297.810	2.59130	5.70	0.01913	0.0495
	297.810	2.59130	6.30	0.02115	0.0548
	297.810	2.59130	6.80	0.02283	0.0591
	297.810	2.59130	7.30	0.02451	0.0635

Table 3- load is applied along the length (l) called loading-2 At w = 24.612 Å

S.N.	L(Å)	Y(TPa)	ΔL(Å)	STRAIN(ΔL/L)	STRESS=Y.STRAIN
1-	53.998	2.37659	1.00	0.01851	0.0440
	53.998	2.37659	1.10	0.02037	0.0484
	53.998	2.37659	1.20	0.02222	0.0528
	53.998	2.37659	1.30	0.02407	0.0572
	53.998	2.37659	1.40	0.02592	0.0616
2-	113.680	2.38598	2.10	0.01847	0.0440
	113.680	2.38598	2.30	0.02023	0.0482
	113.680	2.38598	2.50	0.02199	0.0524
	113.680	2.38598	2.70	0.02375	0.0566
	113.680	2.38598	2.90	0.02551	0.0608
3-	173.362	2.38904	3.10	0.01788	0.0427
	173.362	2.38904	3.40	0.01961	0.0468
	173.362	2.38904	3.80	0.02191	0.0523
	173.362	2.38904	4.00	0.02307	0.0551
	173.362	2.38904	4.30	0.02480	0.0592
4-	233.044	2.39045	4.20	0.01802	0.0430
	233.044	2.39045	4.60	0.01973	0.0471
	233.044	2.39045	5.20	0.02231	0.0533
	233.044	2.39045	5.40	0.02317	0.0553
	233.044	2.39045	5.80	0.02488	0.0594
5-	292.726	2.39128	5.20	0.01776	0.0424
	292.726	2.39128	5.70	0.01947	0.0465
	292.726	2.39128	6.30	0.02152	0.0514
	292.726	2.39128	6.80	0.02322	0.0555
	292.726	2.39128	7.30	0.02493	0.0596

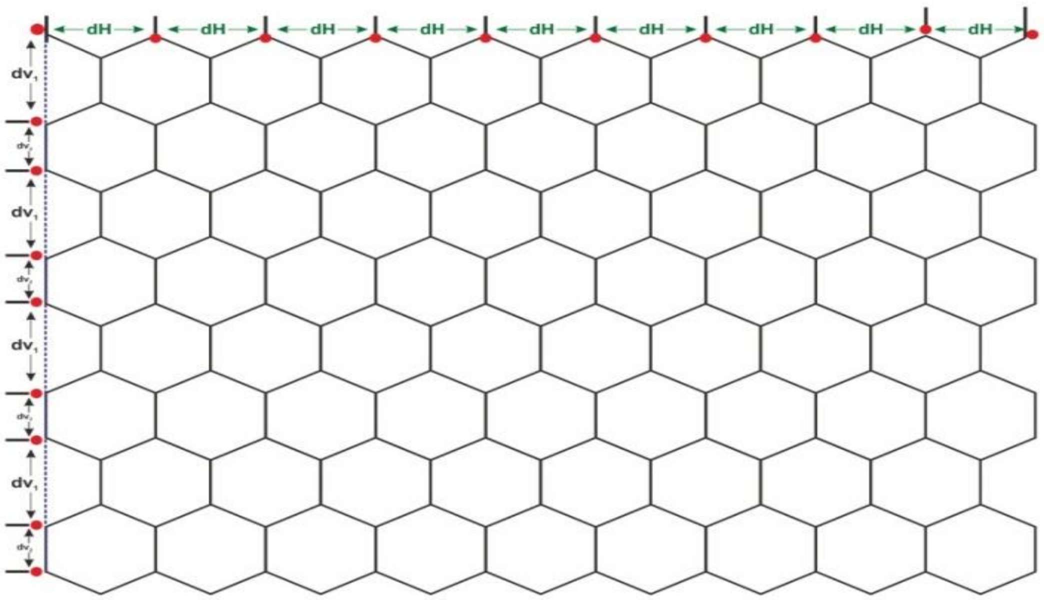


Fig. 2- Single layer of Graphene sheet with marking of dH, dv_1 and dv_2

To analyze the effect of size and shape of Graphene sheet on Resilience, we have taken case-1 which is loading 1.

In this load is applied along the width (w) . Pictorial representation is shown in figure 3-

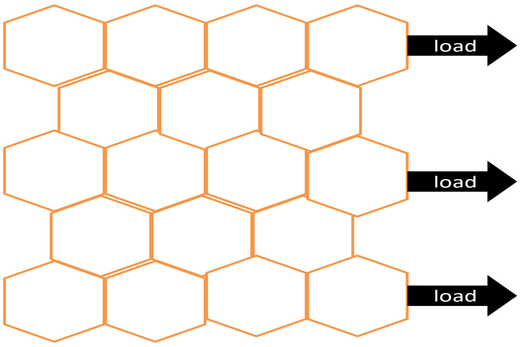


Fig.3- Graphene sheet, Load applied along the width (w) (at width 19.894 Å and 41.209 Å) in loading-1

In this case of loading-2, in which load is applied along the length (l). Pictorial representation of loading -2 is shown in figure 4

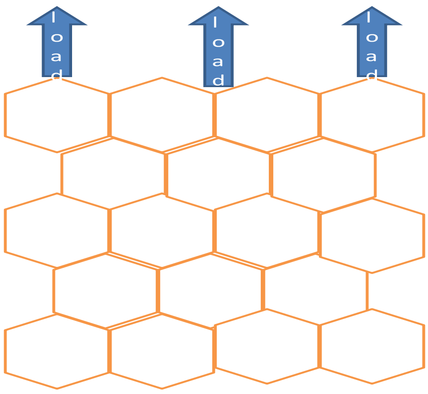


Fig.4- Graphene sheet, Load applied along the length (l) (at width (w) = 24.612 Å) in loading-2

for Resilience loading 1 at w =19.894

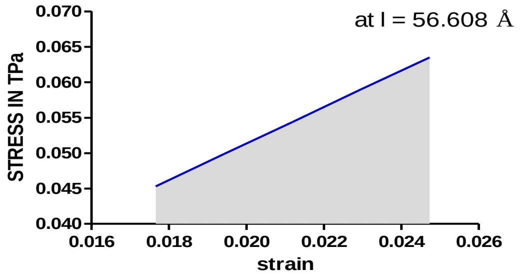


fig- stress vs strain at w = 19.894 Å

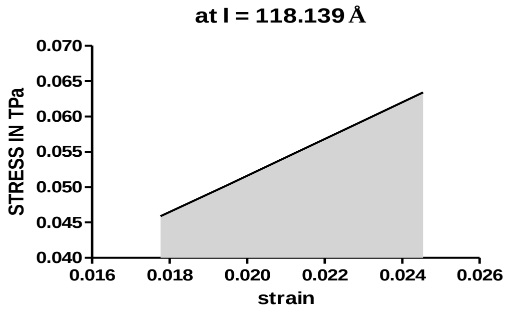


fig- stress vs strain at w= 19.894 Å

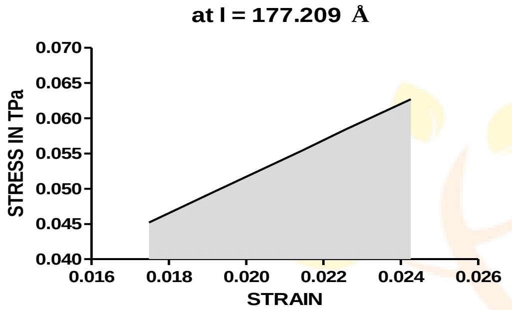


FIG- STRESS VS STRAIN LOADING-1

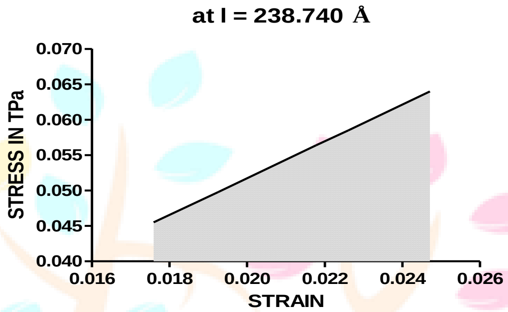


FIG- STRESS VS STRAIN LOADING-1

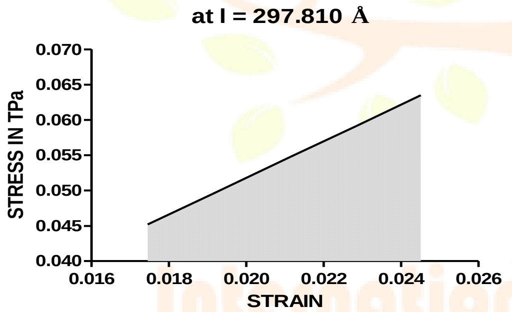


FIG-STRESS VS STRAIN LOADING-1

Fig. 5- Stress Vs Strain (area Between Stress and Strain is calculated as Resilience) At w = 19.894 Å

For Resilience loading-1 at 41.209

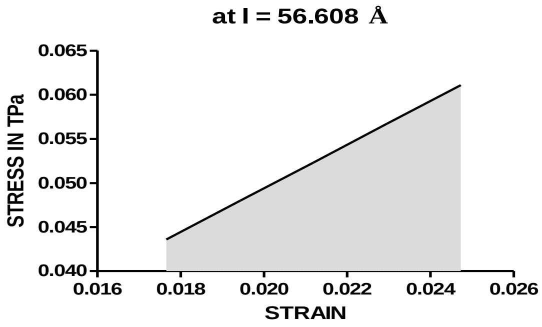


FIG- STRESS VS STRAIN LOADING-1

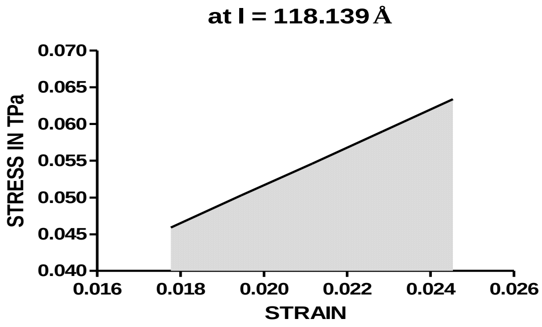


FIG-STRESS VS STRAIN LOADING-1

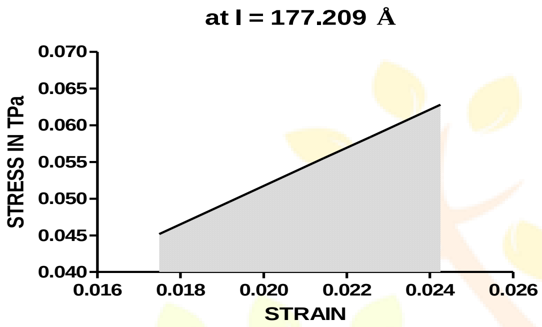


FIG- STRESS VS STRAIN LOADING-1

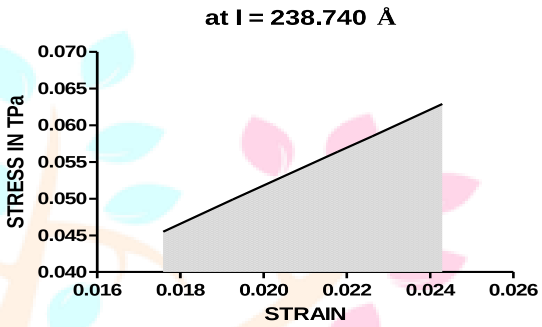


FIG- STRESS VS STRAIN LOADING-1

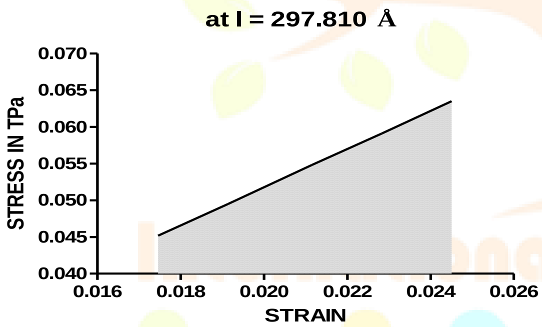


FIG-STRESS VS STRAIN LOADING-1

Fig. 6- Stress Vs Strain (area Between Stress and Strain is calculated as Resilience) At w = 41.209 Å

For Resilience loading-2 at w = 24.612

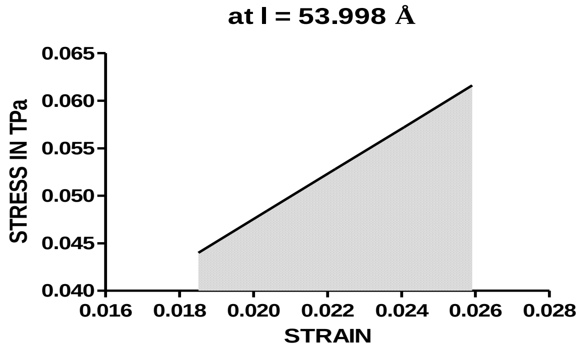


FIG- STRESS VS STRAIN LOADING-2

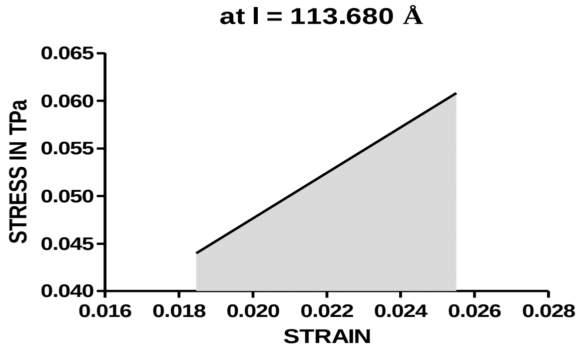


FIG- STRESS VS STRAIN LOADING-2

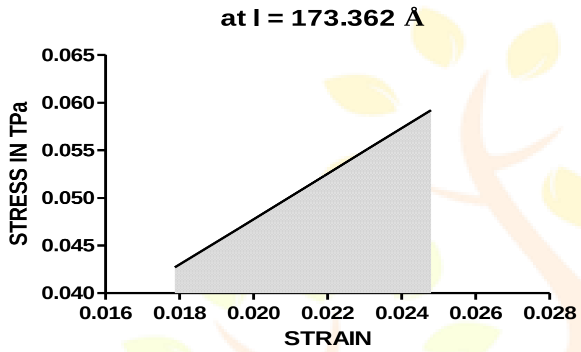


FIG- STRESS VS STRAIN LOADING-2

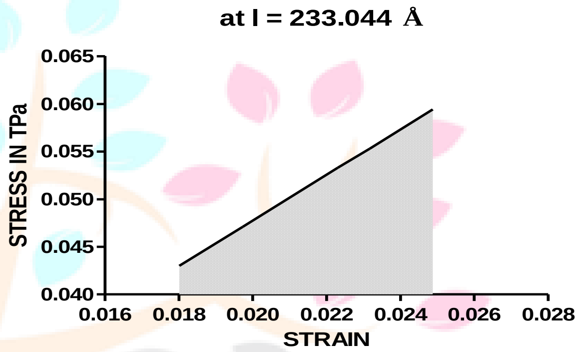


FIG- STRESS VS STRAIN LOADING-2

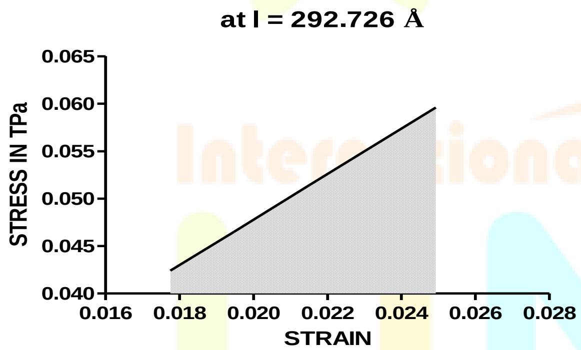
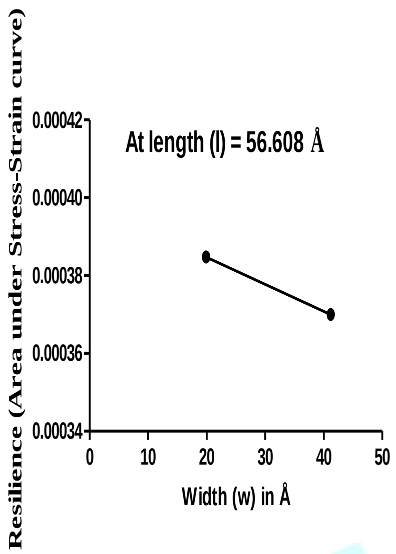


FIG STRESS VS STRAIN LOADING-2

Fig. 7- Stress Vs Strain (area Between Stress and Strain is calculated as Resilience) At w = 24.612 Å



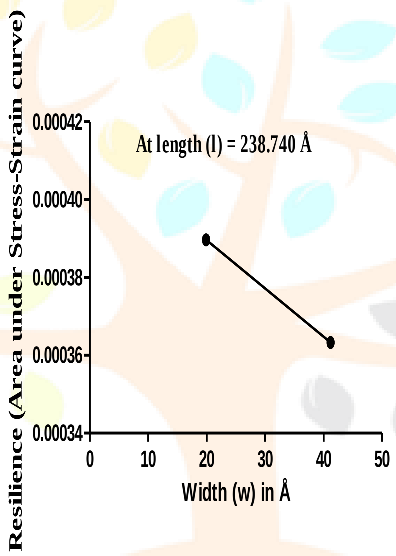


Fig. 8- Resilience Vs Width (w) At (a)- length (l) = 56.608 Å, (b) length (l) = 238.740 Å

4 Result

Modulus of Resilience (U_r) of single layer Graphene sheet is calculated using area under Stress Vs Strain curve, for different width and length of the sheet. Firstly Graphene sheet of width w= 19.894 Å, 41.209 Å and 24.612 Å is taken for different length (50Å - 300Å) .

The result is plotted in fig. 5, 6 & 7 between Stress Vs Strain for various length of Graphene sheet . Fig.8 shows curve between resilience and width for a given length of Graphene sheet. It is found from fig. 8 that as width increases keeping length constant resilience decreases. This seems justified as with increasing width, the stress for same load decreases owing to increase in width and hence resilience decreases. However from fig. 5,6 & 7 it has been found that for a given width, there is no significant change in resilience. This is more so true for case II when load is applied along the length (fig. 7).

5 Conclusions

Modulus of Resilience decreases with width of Graphene sheet for the selected case of lengths(fig.8) because as width increases, stress decreases which results in decrease of resilience. However, for a constant width, resilience doesn't change much with increasing length of Graphene sheet. This finds support as resilience is product of Stress and strain and decreasing strain (i.e. increasing length of sheet) can result in less value of resilience. In Conclusion we can say that width has negative effect on reliance and length has little effect on it. So for purposes where high resilience is needed width of the sheet should remain less.

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