AME 486

Project 8

Henry Glover
Raul Torres Jr.
3/28/2025

#1

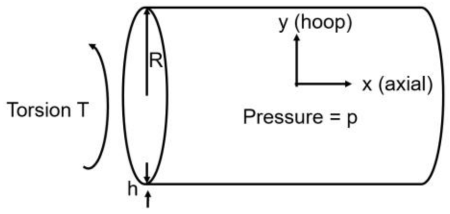
- Benefits of using composites materials that are optimized
    - Weight savings are beneficial if composites are optimized
        - If strength properties are not much better than other materials such as aluminum, there is no point of the weight savings
        - Look at [0/±45/±90]s
            - Very common, three-ply composite that is not completely correct
            - Restricts the materials ability to effectively carry loads in multiple directions
    - You have to consider cost
        - Cost, weight, and strength are the three parameters that must be accounted for
        - Optimizer is used to help achieve this
            - Optimizer works like this –
                - Fewer plies = less material = less cost = less thickness = less weight = sometimes less than optimal strength performance (need to look for this)
    - The ply optimizer can also dictate ply angles
    - Remember: The optimizer is a simple math tool and does not consider
            - What the application of the laminate is
            - Critical or noncritical application
            - What the actual loading conditions are (only experimental inputs)
            - Environmental conditions

#1 Cont.

- A generalized reduced gradient optimizer is used -
  - One of the most robust optimization methods available
  - Works with unconstrainted, linearly constrained, or nonlinear constrained problems
  - Used in conjunction with Newtons method
  - The optimizer runs through several inequalities to get the most “optimized” configuration
    - Still needs existing knowledge to produced feasible results
    - The results may not be an appropriate design
      - Materials may be incompatible
      - Limit stacking angle-plies next to each other
  - Resolving and running multiple trials with different initial conditions can lead to interesting laminate stacking sequences that are more optimal
  - The optimizer is a helpful tool
    - Can help diagnose problems in current designs
    - Can make the manufacturing process more efficient and less wasteful (physical waste and money)
    - Can help new companies/engineers/teams design and understand where and when to use composites early in the design process
  - Material selection, stacking sequence, and total laminate thickness are advantages of optimization
  - New composite materials at the lamina level can be design to reflect an optimal design
    - Changes in elastic moduli, shear moduli, and in the Poisson's ratio
    - These need to be physically achievable

#2

- Pressure Vessel
  - Radius = 20 in
  - Pressure = 800 Psi
  - Torque = 10,000 lb
- Consider stresses [psi]
  - (Nxx) Axial = $(\frac{pr}{(2t)})$ = 8000
  - (Nyy) Hoop = $(\frac{pr}{t})$ = 16000
  - In-plane shear stress (Nxy) = $(\frac{T}{2AH})$ = 3.98
    - T – disappears
- Ply properties
  - Thickness = 0.009 in
  - E11 = 12 Msi
  - E22 = 1 Msi
  - v12 = 0.3
  - G12 = 0.75 Msi
- Design parameters
  - Axial global strain < 1.2%
  - Global hoop strain < 1.2 pct (failure strain)
  - Shear strain < 2%



$\sigma_{xy} = T/(2\,A\,h)$

T = torque applied
h = thickness of cylinder
A = area enclosed by circle = πR^2

$$\begin{Bmatrix} N_{xx} \\ N_{yy} \\ N_{xy} \\ M_{xx} \\ M_{yy} \\ M_{xy} \\ Q_x \\ Q_y \end{Bmatrix} = \int_{-h/2}^{h/2} \begin{Bmatrix} p\,R/(2\,h) \\ p\,R/(h) \\ T/(2Ah) \\ \sigma_{xx}\,z \\ \sigma_{yy}\,z \\ \sigma_{xy}\,z \\ \sigma_{xz} \\ \sigma_{yz} \end{Bmatrix} dz = \begin{Bmatrix} p\,R/2 \\ p\,R \\ T/2A \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{Bmatrix}$$

#2 Cont. A

- What is the minimum number of plies
  - Given Ply properties and thickness
  - Calculated Hoop and Axial and inputted it to the code

	MID	Material Name	Thickness	E11	E22	v12	G12
1	1	Given Unidirectional	0.009	12,000,000	1,000,000	0.30	750,000
2	1	AS4/8552 Plain Weave Fabric	0.0079	9,280,000	9,300,000	0.03	830,000
3	1	IM7/8552 Unidirectional	0.0078	22,300,000	1,460,000	0.27	860,000
4	1	T700SC-12K-50C/#2510 Plain Weave	0.0088	8.10E+06	8.10E+06	0.04	580000

Nxx	16000	0.01565399	exx	0.012
Nyy	8000	0.013667566	eyy	0.012
Nxy	3.98	1.42144E-05	gxy	0.02

#2 Cont. A

- What is the minimum number of plies
  - PLY optimizer says 10 plies
  - 9 in the 30 degree
  - 1 in the 60 degree
  - Within the 1.2 % for hoop and axial
  - Shear is way below the target

0.009954867	exx	0.012
0.0092911	eyy	0.012
8.73931E-06	gxy	0.02

Output	Output	Output		Sum=1	Binary		
Angle	Material	Plies	Plies Temp	Sum	AMID	MatID	Plies
NONE	NONE	NONE	0	1	1	1	0
					0	2	0
					0	3	0
					0	4	0
NONE	NONE	NONE	0	1	1	1	0
					0	2	0
					0	3	0
					0	4	0
NONE	NONE	NONE	0	1	1	1	0
					0	2	0
					0	3	0
					0	4	0
30	Given Unidirectional	9	9	1	1	1	9
					0	2	9
					0	3	9
					0	4	9
NONE	NONE	NONE	0	1	1	1	0
					0	2	0
					0	3	0
					0	4	0
60	Given Unidirectional	1	1	1	1	1	1
					0	2	1
					0	3	1
					0	4	1
NONE	NONE	NONE	0	1	1	1	0
					0	2	0
					0	3	0
					0	4	0
					1	1	0

#2 Cont. B

- The strains along the fiber are calculated and shown below using the other Excel sheet
- The properties are inputted from the given problem
- The ply's are set symmetrically

Laminate

Enter layer information in bold coloumns from top (layer 1) to bottom (max 30)

LAYER #	Mat. ID	Material Name	Thickness	Angle (°)
1	6	User Defined	0.009	-30
2	6	User Defined	0.009	30
3	6	User Defined	0.009	-30
4	6	User Defined	0.009	30
5	6	User Defined	0.009	60
6	6	User Defined	0.009	30
7	6	User Defined	0.009	-30
8	6	User Defined	0.009	30
9	6	User Defined	0.009	-30
10	6	User Defined	0.009	30

6
User Defined
1.200E+07
1.000E+06
0.3
7.500E+05

N_x	16000
N_y	8000
N_xy	3.98

#2 Cont. B

- The global strains match that of what was calculated in the first Excel sheet
  - Uses the ABD matrix formulation
- Within the 1.2 % for hoop and axial (Green)
- Results make sense in both Excel sheets

	628710.6423	187410.2645	43192.19898	-224.4332494	-1.4779E-12	-1.1937E+03
	187410.2645	229718.199	43192.19898	-1.47793E-12	224.4332494	-361.2315755
ABD Matrix:	43192.19898	43192.19898	227706.2343	-1193.687588	-361.231576	-2.38742E-12
	-224.4332494	-1.47793E-12	-1193.687588	456.6980715	126.5019285	1.166189372
	-1.47793E-12	224.4332494	-361.2315755	126.5019285	122.7413964	1.166189372
	-1.1937E+03	-361.2315755	-2.38742E-12	1.166189372	1.166189372	153.7017081

	2.1276E-06	-1.70453E-06	-7.56077E-08	6.61103E-08	2.70736E-06	1.24964E-05
	-1.70453E-06	5.91219E-06	-8.15612E-07	9.6557E-07	-1.4213E-05	7.5759E-07
Inverted	-7.56077E-08	-8.15612E-07	4.62438E-06	1.10097E-05	3.77887E-06	-2.61626E-06
ABD Matrix:	6.61103E-08	9.6557E-07	1.10097E-05	0.003092916	-0.00315707	3.26949E-06
	2.70736E-06	-1.42132E-05	3.77887E-06	-0.003157071	0.011438832	-7.52146E-05
	1.24964E-05	7.5759E-07	-2.61626E-06	3.26949E-06	-7.5215E-05	0.006605486

	Applied Loading		Thermal Loading		Total Loading		Strains/Curvatures
N_x	16000	N_xT	0.000E+00		1.600E+04		2.041E-02
N_y	8000	N_yT	0.000E+00		8.000E+03		2.002E-02
N_xy	3.98	N_xyT	0.000E+00	=	3.980E+00	Gives	-7.716E-03
M_x	0	M_x	0.000E+00		0.000E+00		8.826E-03
M_y	0	M_y	0.000E+00		0.000E+00		-7.037E-02
M_xy	0	M_xy	0.000E+00		0.000E+00		2.060E-01

#2 Cont. C

- The local strains match that of what was calculated in the first Excel sheet
  - Ex = 0.00208
  - Ey = 0.001817
  - Gxy = 0.0002651
  - Match The excel sheets

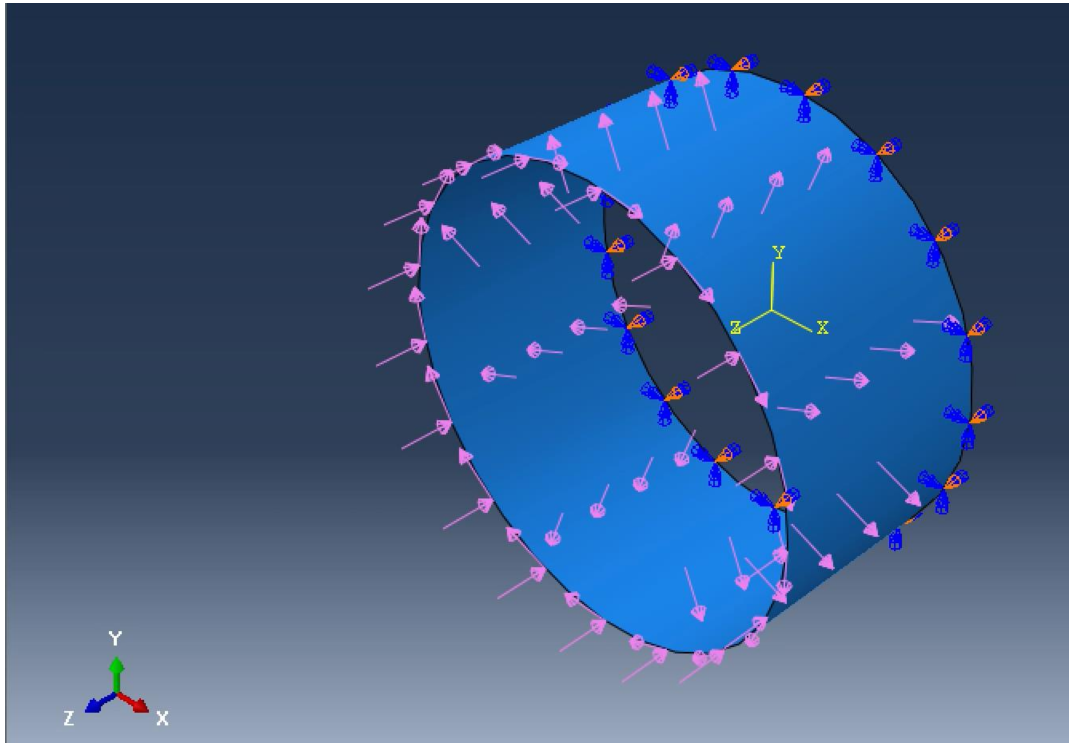
Values at the top of layers										
Total Strains										
eps_x	2.080E-02	2.072E-02	2.064E-02	2.056E-02	2.048E-02	2.041E-02	2.033E-02	2.025E-02	2.017E-02	2.009E-02
eps_y	1.686E-02	1.749E-02	1.812E-02	1.876E-02	1.939E-02	2.002E-02	2.066E-02	2.129E-02	2.192E-02	2.256E-02
gamma_xy	1.553E-03	-3.005E-04	-2.154E-03	-4.008E-03	-5.862E-03	-7.716E-03	-9.570E-03	-1.142E-02	-1.328E-02	-1.513E-02

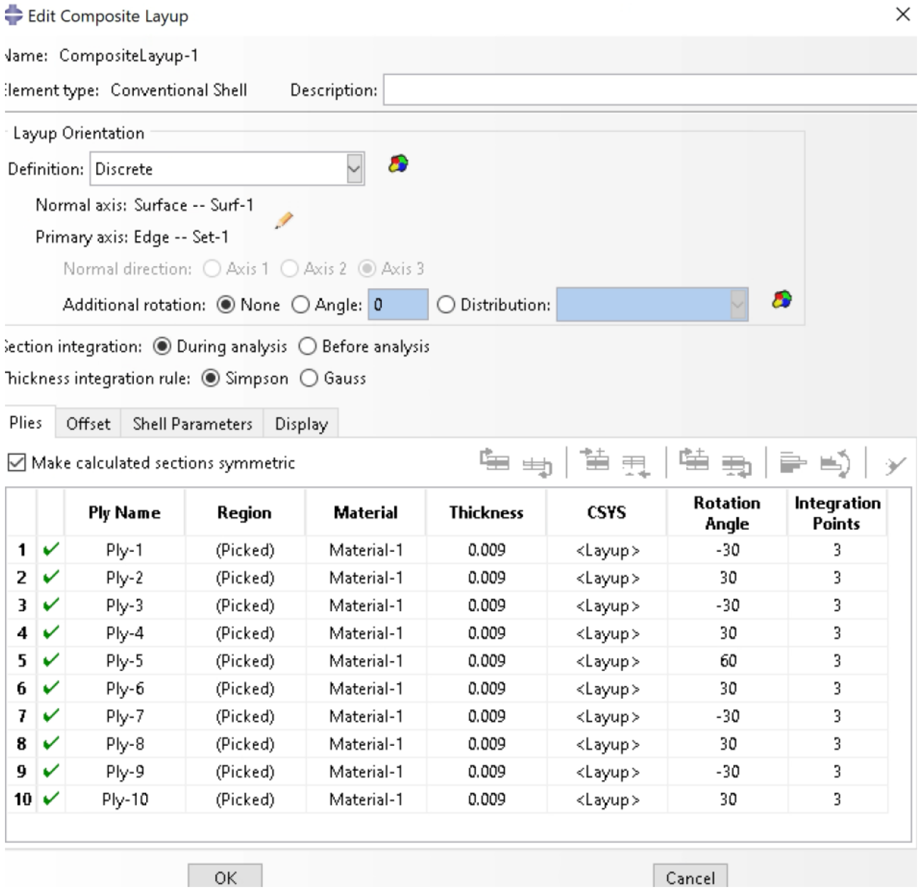
Mechanical Strains and Stresses (Locally Layer by Layer)										
eps_1	2.004E-02	1.908E-02	2.185E-02	1.767E-02	1.678E-02	1.626E-02	2.545E-02	1.486E-02	2.726E-02	1.345E-02
eps_2	1.817E-02	1.969E-02	1.747E-02	2.220E-02	2.365E-02	2.472E-02	1.608E-02	2.723E-02	1.539E-02	2.975E-02
gamma_12	2.651E-03	-3.261E-03	-4.377E-04	-3.880E-03	3.526E-03	-4.500E-03	-6.615E-03	-5.119E-03	-9.703E-03	-5.738E-03

Values at the bottom of layers										
Total Strains										
eps_x	2.072E-02	2.064E-02	2.056E-02	2.048E-02	2.041E-02	2.033E-02	2.025E-02	2.017E-02	2.009E-02	2.001E-02
eps_y	1.749E-02	1.812E-02	1.876E-02	1.939E-02	2.002E-02	2.066E-02	2.129E-02	2.192E-02	2.256E-02	2.319E-02
gamma_xy	-3.005E-04	-2.154E-03	-4.008E-03	-5.862E-03	-7.716E-03	-9.570E-03	-1.142E-02	-1.328E-02	-1.513E-02	-1.699E-02

#2 Cont.

- The Abaqus is set up
  - Ply’s are set up to found values in excel
  - Loads are set following the YouTube tutorial




Edit Composite Layup

Name: CompositeLayup-1

Element type: Conventional Shell   Description:

Layup Orientation

Definition: Discrete

Normal axis: Surface -- Surf-1

Primary axis: Edge -- Set-1

Normal direction: Axis 1 Axis 2 Axis 3

Additional rotation: None Angle: 0 Distribution:

Section integration: During analysis Before analysis

Thickness integration rule: Simpson Gauss

Plies | Offset | Shell Parameters | Display

Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✔	Ply-1	(Picked)	Material-1	0.009	<Layup>	-30	3
2	✔	Ply-2	(Picked)	Material-1	0.009	<Layup>	30	3
3	✔	Ply-3	(Picked)	Material-1	0.009	<Layup>	-30	3
4	✔	Ply-4	(Picked)	Material-1	0.009	<Layup>	30	3
5	✔	Ply-5	(Picked)	Material-1	0.009	<Layup>	60	3
6	✔	Ply-6	(Picked)	Material-1	0.009	<Layup>	30	3
7	✔	Ply-7	(Picked)	Material-1	0.009	<Layup>	-30	3
8	✔	Ply-8	(Picked)	Material-1	0.009	<Layup>	30	3
9	✔	Ply-9	(Picked)	Material-1	0.009	<Layup>	-30	3
10	✔	Ply-10	(Picked)	Material-1	0.009	<Layup>	30	3

OK   Cancel

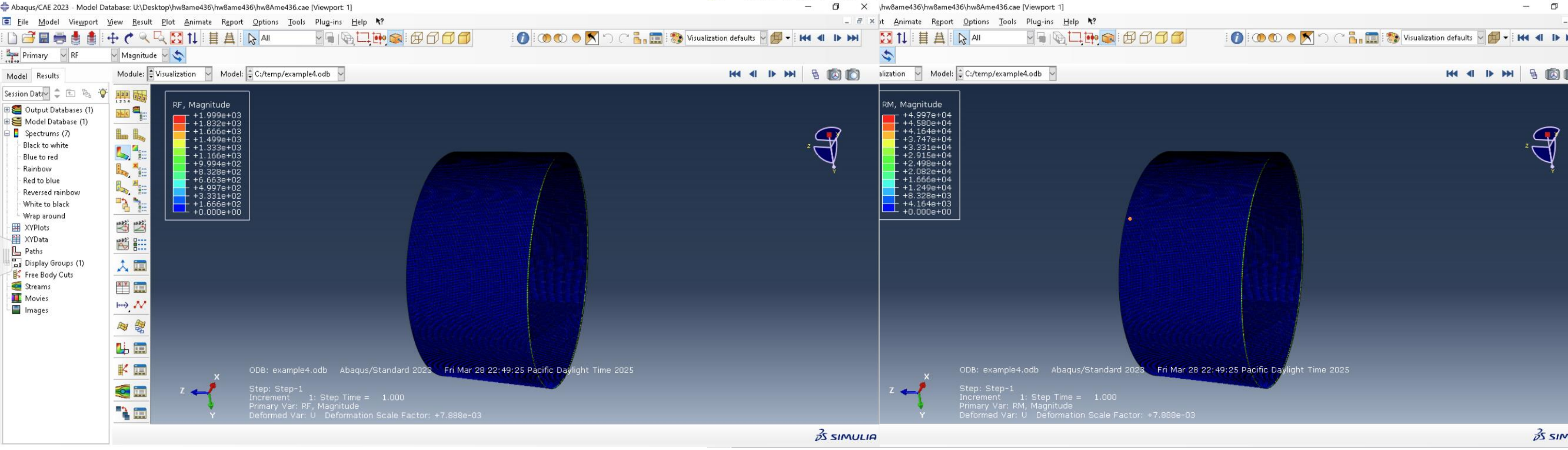
#2 Cont.

- The local strains match that of what was calculated in the first Excel sheet
  - All though the excel sheets match there seems to be an issue, which we later see in Abaqus as well
  - 18-20 plies seem to be what Abaqus is suggesting
    - Which gives us a total thickness of 0.18 in or 0.164 in
  - The strains in the Abaqus are far two large
    - This can be due to:
      - The number of plies, perhaps we had computed fewer plies than was necessary
      - Also, for Abaqus to create a "job" successfully, the values for E3, G13, and G23 were not give to use
        - Therefore, we tried to make a trial-and-error approach to try to make our strain match as close to what was computed

  - Although we followed the Youtube video very carefully and accurately, our model is Abaqus did not meet what had computed and optimized for this example

  - As you can see there is bigger magnitude for RM at the edge where the hoop stress and torque was located based on the problem

#2 Cont.



Results from Abaqus (left is the "RF" results and right is the "RM"Results

#2 Cont. F

- Density
- L = 1 m
- R = 20 in. = 0.508 m
- Thickness of Laminate = 0.09 in. = 0.002286
- Volume = 0.00728 m^3
- Mass of Al = Volume * Density = 19.66 Kg
- Mass of Composite = volume * Density = 9.24 Kg
- Composite is 2.13% lighter

$$V = \pi \cdot h \cdot (D^2 - d^2) / 4$$