Fabrication and experimentation of FRP helical spring

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Abstract. In present scenario, the automobile industry sector is showing increased interest in reducing the unsprung weight of the automobile & hence increasing the fuel Efficiency. One of the feasible sub systems of a vehicle where weight reduction may be attempted is vehicle-suspension system. Usage of composite material is a proven way to lower the component weight without any compromise in strength. The composite materials are having high specific strength, more elastic strain energy storage capacity in comparison with those of steel. Therefore, helical coil spring made of steel is replaceable by composite cylindrical helical coil spring. This research aims at preparing a re-usable mandrel (mould) of Mild steel, developing a setup for fabrication, fabrication of FRP helical spring using continuous glass fibers and Epoxy Resin (Polymer). Experimentation has been conducted on fabricated FRP helical spring to determine its strength parameters & for failure analysis. It is found that spring stiffness (K) of Glass/Epoxy helical-spring is greater than steel-coil spring with reduced weight.

1. Introduction
Springs are mainly designed to absorb as well as to store energy and then release it. In designing the springs strain energy of the material is a key factor. The materials, which have lower modulus and densities, will be having greater capability of specific strain energy. Therefore, the composite materials are strong components for this kind of applications. Replacement of steel material by composite materials makes significant weight reduction. Nevertheless, with introduction of new materials, design related and processing problems will also arise. The key reason is FRP composites are anisotropic materials. Hence, they are unique compared to traditional materials. Therefore, the application of composite in the manufacture of springs is not much popular. The automobile manufacturers are putting enormous effort to reduce the weight of vehicles to achieve fuel economy.

According to Mallick (1997) Fiber reinforced polymers have been extensively employed in vital applications, mainly because of its weight savings, high damping factor, non-corrosive property, lower maintenance and tooling cost, which in turn impact on favourable manufacturing costs. Erol Sancatkar et al in 1999 designed and fabricated a composite spring for a Light weight solar vehicle. A new rectangular c/s wire helical springs by Kotaro in 2001 is contrived which joins by twisted part the first and second coil part. The free vibration problem in uni directional composite helical spring is theoretically modelled as a continuous system by considering the rotary inertia, shear and axial deformation effects (Yildrim - 2001). Gulur et al in 2006 fabricated a low cost mono-composite leaf spring with bonded end joints using Epoxy/Glass fiber. (Mahdi et al. (2006)) have fabricated springs in elliptical configuration by using woven roving composites and investigated on controlling the
failure by utilizing strength in principal direction. Faruk in 2009 have investigated the behaviour of arbitrary shaped composite coil springs. Abdul et al. in year 2010 investigated both experimentally and numerically the influence of ellipticity ratio on the performances of woven wrapped composite elliptical springs. T S Manjunatha et al in 2012 fabricated helical spring using glass woven mat/Epoxy resin and compared with helical spring made of Steel.

2. Material selection and fabrication process

2.1 Materials

The continuous E-glass fibers have been chosen for the spring design due to their high extensibility, toughness. Epoxy resin has been selected as base material. The properties of materials opted for fabrication is given in Table 1.

| Properties     | E - Glass Fiber | Epoxy Resin |
|----------------|-----------------|-------------|
| Density        | 2.50 g/cm³      | 1.31 g/cm³  |
| Young’s Modulus| 72.40 GPa       | 3.4 GPa     |
| Shear Modulus  | 30.00 GPa       | 1.60 GPa    |
| Elongation     | 4.80 %          | 2.00 %      |

2.2 Fabrication method

The fabrication process adopted in present work is “Spring Winding Technique”. In this, a mandrel (Figure 1) is prepared by Mild Steel material. The mandrel, which has the shape of required spring profile, is fixed on a lathe. Mould releasing agent like Silicone gel is applied to the surface of mandrel. The measured quantity of resin & corresponding hardener is blended. The fibers after passing through the Epoxy resin bath are wounded on the mandrel. The process of winding fiber on the mandrel is continued until required dimension of spring is obtained. After completion, a rubber tape is wound on the mandrel. The mandrel is then kept for curing at atmospheric temperature for about 48 hours. After necessary curing the spring is carefully removed from the mandrel. The dimensions of cured FRP spring is \( l = 175 \text{ mm}, D_o = 97 \text{ mm}, D_i = 75 \text{ mm}, d = 12 \text{ mm}, b = 12 \text{ mm}, t = 12 \text{ mm}, n = 7 \). Fabricated composite FRP springs are as shown in Figure 2.
3. Experimental Methods
The prime parameters of spring like spring stiffness, maximum compression, failure load, and physical dimensions are determined by testing the spring on UTM. All the Experiments were carried by following their ASTM standards and test results are tabulated in Table 2. Figure 3 shows the testing of FRP-Spring on UTM.

![Testing of FRP spring on UTM](image)

**Figure 3.** Testing of FRP spring on UTM

| Table 2. Mechanical Properties of Fabricated Composite FRP Helical Springs |
|---------------------------------------------------------------|
| **Properties** | **Values** |
| Spring Constant | 9.95 N/mm |
| Max Compression | 56 mm |
| Load at Max. compression | 550.00 N |
| Shear stress | 81.76 N/mm² |
| Fiber volume fraction | 60 % |
| Weight of the spring | 424 g |

4. Results and discussion
Key objective of the work is to fabricate a composite FRP helical springs for light weight vehicle suspension like solar powered Vehicles and to study their mechanical & strength parameters. The springs of Glass/Epoxy material combination has been fabricated using reusable mandrel & tests were carried out. The average values of the test results were analysed.

4.1 Load bearing Capacity of composite FRP Helical Springs
Load - deflection curves for the composite helical springs is in Figure 4. A linear curve has been obtained for the spring. The values of the load and deflection of spring is given in Table 3.
Table 3. Average value of Load and deflection

| Deflection of spring (mm) | Load (N) |
|---------------------------|----------|
| 5                         | 100      |
| 10                        | 140      |
| 15                        | 180      |
| 20                        | 225      |
| 25                        | 275      |
| 30                        | 320      |
| 35                        | 360      |
| 40                        | 400      |
| 45                        | 445      |
| 50                        | 500      |
| 56                        | 560      |

Figure 4. Graph of load-deflection of FRP helical spring

4.2 Spring stiffness of composite FRP Helical Spring

Spring constant is defined as the force that is required to compress spring by 1 millimetre. Spring rates depend on the number of coils in the spring, rigidity modulus of material and dimensions of the spring taken. Stiffness of the present fabricated spring is obtained as per JIS B2704 standards & its value is 9.95 N/mm

5. Conclusion

The following conclusions can be drawn based on the fabrication process carried out & from the observed experimental results:

- The re-usable mandrel fabricated using Mild Steel is easy to fabricate & very convenient for the fabrication of composite helical spring.
- The “Spring Winding” setup developed for the fabrication of helical spring is simple & cost efficient.
The weight of composite FRP helical spring is 40% less than Steel spring. In the other hand, the cost of Composite spring is greater but it can be compensated by amount of fuel saved by using this FRP spring.

The stiffness of the FRP spring with Continuous glass fibers is greater compared to Steel helical spring of same dimension. To increase the stiffness of spring its dimension can be increased in turn it increases the weight of the spring.

By using two FRP spring of continuous glass fiber which can withstand app. 1120 N load can be efficiently used for light vehicles Eg. Solar vehicles etc.

The stresses developed within FRP coil springs are less. Hence, we can expect high fatigue life from these springs in comparison with Steel coil springs.

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