

FEA ANALYSIS AND VALIDATION OF HELICAL COMPRESSION SPRING USED IN MEDICAL SURGICAL TOOLS USING COMPOSITE MATERIAL

Abstract

The Medical Sector has exhibited a growing interest in utilizing composite materials to replace ferrous metals due to their high strength-to-weight ratio. This study introduces a novel approach to designing helical compression springs by employing Finite Element Analysis (FEA) with the use of composite materials. The investigation includes both experimental and FEA analyses of the springs, and the results are compared against traditional steel springs.

The findings of the study demonstrate that by using composite springs, a significant reduction in weight can be achieved. Consequently, these composite material springs can serve as effective replacements for the heavier steel springs. The study also explores the correlation between design parameters and compressive stress, with a primary focus on reducing product weight while maintaining its strength.

Keywords: FEA Analysis, Helical Compression Spring, Medical Surgical Tools, Composite Material.

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I. INTRODUCTION OF HELICAL COMPRESSION SPRING

According to A.M. Whal, a mechanical spring can be described as an elastic body that deflects or distorts under load, absorbing energy, and returns to its original shape when released after being distorted. Whal classifies springs into four main functions: shock absorption, force application, structural support, and load control [5].

Considering the diverse properties and functions of springs, it is essential to use specific techniques for analyzing each type. In this proposal, our focus will be solely on the helical compression spring . These springs are the most common type and find widespread use in various devices due to their advantageous characteristics, including nearly linear rate (especially after the initial 20% deflection), versatility in materials for construction, and ease of manufacturing. As a result, helical compression springs have been in use for an extended period [5]

1. Objectives of Spring:

- Springs serve various purposes, including providing cushioning to absorb or control energy arising from shocks and vibrations. For instance, car springs or railway buffers are utilized to effectively manage energy, while springs-supports and vibration dampers play a similar role [12].
- Another essential function of springs is motion control. They ensure continuous contact between two elements, such as in the case of cams and their followers. Additionally, springs are crucial in generating the necessary pressure within friction devices like brakes or clutches. Furthermore, they help restore machine parts to their original positions when external forces are withdrawn, as seen in the case of governors or valves.
- Springs are also valuable in force measurement applications, as demonstrated by their use in spring balances and gauges.
- Additionally, springs play a significant role in storing energy, which finds practical applications in clocks or starters [11].

2. Use Of Helical Compression Spring in Surgical Tools:

- Surgical Staple Guns
- Peristaltic Pump
- Catheters
- Endoscopic Devices
- Surgical tools and Orthopedic Tools

3. Commonly Used Spring Materials: When designing springs, a crucial aspect to consider is the selection of the appropriate spring material. There are several common spring materials available, each with its specific characteristics [12].

- **Hard-drawn wire:** This cost-effective spring steel is cold drawn and ideal for low-stress applications and static loads. However, it is unsuitable for sub-zero temperatures and temperatures exceeding 1200°C.

- **Oil-tempered wire:** A versatile spring steel, cold drawn, quenched, and tempered, suitable for general purposes. Nonetheless, it should not be used under conditions of fatigue or sudden loads, at sub-zero temperatures, or temperatures exceeding 1800°C.
- **Chrome Vanadium:** An alloy spring steel suitable for high-stress conditions and temperatures up to 2200°C. It boasts excellent fatigue resistance and can endure long periods of shock and impact loads.
- **Chrome Silicon:** This material is well-suited for highly stressed springs, offering excellent service life and resilience to shock loading at temperatures up to 2500°C.
- **Music wire:** Most commonly used for small springs, it is exceptionally tough with high tensile strength, making it capable of withstanding repeated loading at high stresses. However, it is not suitable for use in sub-zero temperatures or temperatures above 1200°C.
- **Stainless steel:** A widely utilized alloy for spring materials due to its various favorable properties.
- **Phosphor Bronze / Spring Brass:** Known for good corrosion resistance and electrical conductivity, it is commonly employed for contacts in electrical switches. Spring brass, in particular, can be used in sub-zero temperatures.

II. LITERATURE REVIEW

1. **Goedland et al (2016).** Laparoscopic surgery is a minimally invasive procedure performed through a small incision in the abdomen. This approach allows for complete operations to be conducted. Throughout the surgery, cutting and stapling functions are commonly required, for which specialized staplers have been developed. Recently, the demographic of surgeons has evolved, with more women and older individuals joining the field.

However, current laparoscopic surgical staplers pose challenges for our client, a young female surgeon. The main issues she encounters are the limited accommodation of a wide range of hand sizes, grip strengths, and various usage orientations by the existing devices. To address these problems, we propose an innovative in-line handle design concept.

Our concept aims to incorporate standard grip dimensions, reduced grip force via battery assistance, and the top placement of the clamping trigger to facilitate more natural wrist angles during use in different orientations. To achieve this, a complete redesign of the current devices is necessary. Therefore, the input and feedback from practicing surgeons are vital aspects of our development process.

2. **Mansour, (2015)** Tactile displays have gained significant attention in the field of human-computer interaction, particularly for applications where the sense of touch is lost, such as in laparoscopic surgeries where surgeons need to feel the tissue hardness. In this research, a novel multi-modal tactile display device capable of showing both the surface shape and stiffness of an object is introduced.

The design of this device centers around the use of two springs made of Shape Memory Alloys (SMA), one for displaying shape and the other for stiffness. Design

parameters are carefully selected, taking into account the spatial resolution of the human finger and the elasticity range of soft tissue. The Finite Element Method (FEM) is employed to simulate the device's behavior and study the impact of design parameters on the resulting stiffness.

3. **Mahshidet et al (2012)** Mechanical torque devices (MTDs) are widely recommended for delivering precise torque to dental implant screws. Among them, spring-style mechanical torque devices (S-S MTDs) have gained popularity. However, there have been recent concerns about the accuracy of these devices, as it directly affects the joint stability and survival rate of fixed implant-supported prosthesis.

The impact of steam sterilization on the accuracy of MTDs remains poorly understood, as there is limited information available on this subject. Therefore, the objective of this study is to evaluate the effect of steam sterilization on the accuracy of spring-style mechanical torque devices used for dental implants. The study aims to assess whether the accuracy remains within $\pm 10\%$ of the target torque after the sterilization process.

4. **Ling Chen, (2022)** Composite helical springs (CHSs) find widespread applications in the transportation and aerospace sectors, including automobile suspension, railway bogies, and aircraft engine systems. A notable trend in these industries involves replacing traditional metal helical springs with CHSs due to their ability to conserve energy during service and reduce emissions during manufacturing. The numerous advantages of CHSs, such as their lightweight nature, high specific strength, high specific modulus, corrosion resistance, fatigue resistance, and excellent strain energy storage capacity, make them highly promising for further development.
5. **M.-S. Scholz, et al (2011)**. This review focuses on the utilization of fiber-reinforced composite materials in biomedical applications. The advancements in polymer composite materials have significantly contributed to technological progress in modern orthopedic medicine and prosthetic devices. Compared to monolithic materials, composites exhibit superior strength-to-weight characteristics and demonstrate excellent biocompatibility. As a result, they are highly advantageous for various hard and soft tissue applications, as well as in prosthesis design.

A notable breakthrough is the development of specifically designed carbon fiber sports prostheses, enabling lower-limb amputees to actively participate in competitive sports. Furthermore, ongoing developments are expected to introduce sensory feedback systems, porous composite materials for tissue engineering, and functional coatings for metallic implants in the next generation of orthopedic medicine.

6. **S Ramakrishna, (2001)** This paper provides an overview of the diverse biomedical applications of polymer-composite materials, as documented in the literature over the past three decades. To offer comprehensive insights to readers, the paper also includes general information on tissue structure and function, types and purposes of implants/medical devices, and other materials commonly used in the field.

The paper delves into different types of polymer composites currently employed or under investigation for various biomedical applications. Furthermore, it emphasizes the specific advantages of utilizing polymer-composite biomaterials in selected applications

7. **Anil Antony Sequeira, (2016).** In the automobile sector, rapid innovation and tough competition drive the reengineering of old products with new composite materials. Particularly in the suspension area of vehicles, continuous innovations take place. The automobile industry is significantly interested in Fiber Reinforced Material (FRP) components due to their high strength-to-low weight ratio, which makes them a viable alternative to steel components.
8. **Mali et al (2022)** The automotive industry has increasingly shown interest in replacing ferrous metals with composite materials due to their high strength-to-weight ratio. This study introduces a novel approach to designing helical compression springs using workbench software. The composite materials employed in the study are E-glass/Epoxy and Carbon fiber/Epoxy.

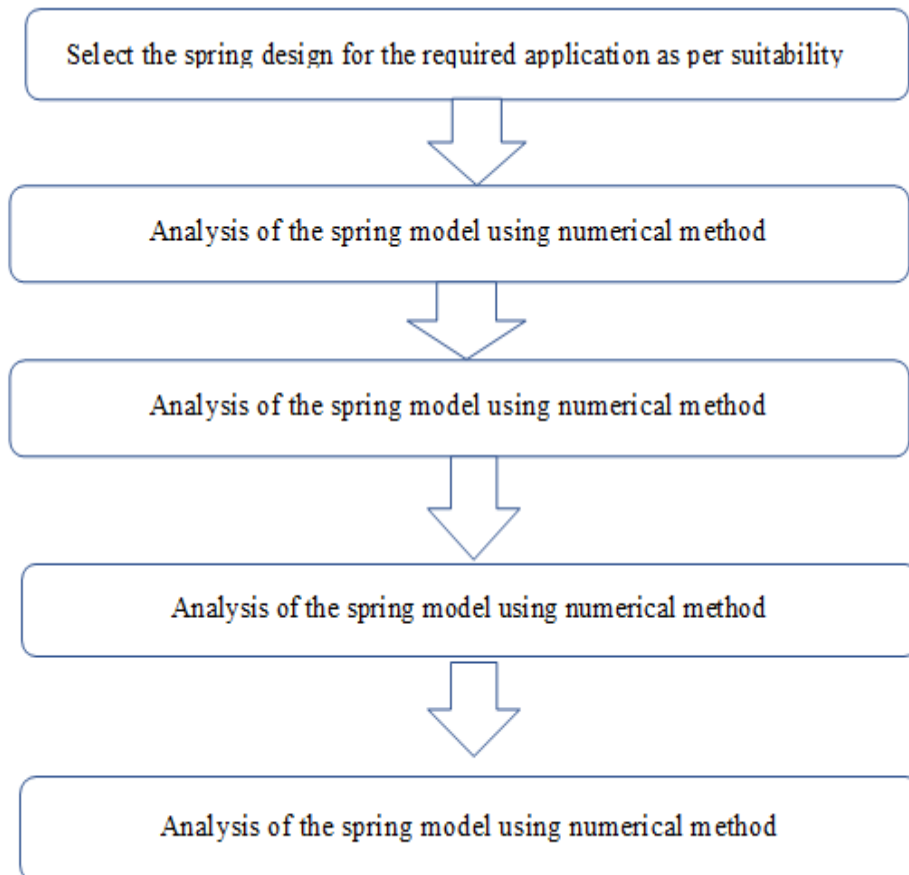
The analysis of the springs is carried out using Finite Element Analysis (FEA), and the results are compared with those of steel springs. The findings demonstrate that the composite springs achieve weight reduction without compromising strength. This indicates that composite material springs can effectively replace heavy steel springs.

9. **Mehdi Bakhshesh1, (2012).** Highly efficient springs with a substantial capacity for storing potential energy play a crucial role in various industries. Among them, helical springs have found widespread use in car suspension systems. This research focuses on studying a steel helical spring used in light vehicle suspension systems, subjecting it to uniform loading. The study involves a comparison between Finite Element Analysis (FEA) and analytical solutions to understand the spring's behavior.
10. **Chatterjee et al (2020)** In recent times, fiber-reinforced composite materials have garnered significant commercial attention in modern orthopedic medicine due to their exceptional strength and biocompatibility. These materials have also made remarkable technical advancements in the field of cosmetic dentistry. As researchers continue to explore new frontiers, their focus lies in enhancing current prosthetic technologies by incorporating sensory feedback systems. The aim is to create prostheses with value-added capabilities that can provide more natural and responsive functionalities, thus improving the overall user experience. This cutting-edge approach is set to revolutionize the field of prosthetics and offer better solutions to individuals in need of such devices. Upper and lower limb prostheses.
11. **Gupta et al (2016)** Composite materials offer vast opportunities and applications across various industries, including automotive, aerospace, wind energy, electrical, sports, domestic use, civil construction, and medical chemical sectors. Their potential is particularly noteworthy in structures exposed primarily to compressive loads.

With their unique combination of properties, composite materials provide excellent structural integrity and strength, making them highly suitable for withstanding compressive forces. As a result, they are widely utilized in a wide range of applications,

enabling significant advancements and innovations in different industries. The versatility and strength of composites make them a valuable choice for developing efficient and reliable structures in various fields.

III. METHODOLOGIES



- 1. Research Gap:** In medical sector almost in every operation cutting and stapling is needed throughout the surgery, for that multiple specialized staplers have been designed for this purpose. Even peristaltic pumps are also used during surgery, and in both equipment helical compression spring is used, and till now hard drawn wire, Bronze, Nickel, Crome and silver material is used for the spring. Since in this research we are going to to use composite material for spring to reduction of weight of equipment's/tools with enhancing its strength. Input from practicing surgeons is an important aspect of our development process. Further discussion with surgeons and optimization of our design will be performed in order to develop a device best suited to their needs.
- 2. Problem Definition:** Current surgical staplers fail to accommodate a large range in hand sizes, grip strengths, and use orientations. these are the main problems our client, a young female surgeon and also high force is required to operate with these devices. In Currant surgical equipment's uses steel spring which is having high weight and low strength compared with composite spring.

IV. OBJECTIVES OF THE PROJECT WORK

- To determine the most suitable design for a compression spring that best fits the given application.
- To conduct a comprehensive analysis of the spring using both experimental methods and Finite Element Analysis (FEA) techniques.
- To identify and assess various factors and influences that the spring may encounter during its operation, which could potentially impact its longevity.
- To pinpoint critical parameters or factors that require further investigation and research.
- To propose recommendations for enhancing the spring's lifespan through improvements in design, material selection, and manufacturing processes

V. CONCLUSION

By utilizing FEA analysis and validation techniques, manufacturers and researchers can confidently adopt composite helical compression springs in medical surgical tools, thereby contributing to advancements in healthcare technology. The continued exploration and application of composite materials in medical devices hold promising potential to revolutionize the medical industry, enhancing patient outcomes and surgical procedures while advancing the field of medical engineering.

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