

Stability of Physically-Loaded Helical Springs used In Smart Fork Lift



Suresh Kumar, M.L.Aggarwal, Lakhwinder Singh

Abstract: In the following section, the behavior of helical compression springs is considered in smart fork lift (established in previous work). We have used commonly used cylindrical and conical shape helical spring as storage devices in which stability defined in term of load-gains, deflections and evaluation of spring-rates. Springs' rates of both springs were compared on a common platform. Initially both springs (helical-conical) was prepared from the coiled wires. These prepared springs also known as coil springs which regain its original form and position when distorted by the loaded in smart fork-lift apparatus. These coils springs here developed by the applying the heat treatment and quenching processes on the galvanized spring steel material by using the threaded shape fixtures. This prescribed work focused on effect of physically-loaded gains by cylindrical and conical shaped helical spring in smart fork lift. Here, springs worked as mechanical devices to bear the lifting load which differed here greatly in strength and in size depending on changing its parameters. Both the cylindrical and conical shape was made of helically coiled wires with constant clearance between the active coils and able to absorbed external counter-acting loads applied against each other in their axis. One direction deformation in axially format was considered.

Keywords: Heat treatment, helical-conical springs, Quenching process, spring -rate, smart fork lift.

I. INTRODUCTION

P.S.Valsange (2012) showed the review of fundamental stress distribution, characteristic of helical coil springs. He found the major factors that affect the strength of springs are design parameters, material selection, raw material defect, Spring geometry and surface imperfection. He also showed the presence of any impurity, inclusion in raw material reduces the strength and fatigue life of coil spring Factors affecting strength of coil spring. He also considered designing coil spring using FEA with Von Mises stress result of no-defect model and Von Mises stress result of inclusion model [1]. Amitesh, V. C. Kale and K. V. Chandratre (2019) focused on comparative evaluation of spring rate 'K' of cylindrical and conical helical compression spring.

They found from analytical calculation and experimental validation that spring rate „K“ is higher for conical helical compression spring than that for cylindrical helical compression spring. Load Vs Deflection was taken smooth response for conical v/s cylindrical spring. This paper analyses how tapering of a straight helical compression improves spring rate 'K'. The cylindrical and conical springs have been manufactured from hard drawn carbon steel ASTM A227 of wire diameter 3.5 mm and 4mm [2]. Rufus Ogbuka Chime and Samuel I.Ukwuaba (2016) focused on accuracy of the simulation model They included design, model and simulate compressive spring , to select materials for spring and also to detailed factor of safety in design process. They were taken two types of heat treatment of springs: low- heat treatment of pre strengthened materials and high-temperature heat treatment to strengthen annealed materials.. They also considered dimensional factors, applying computers to design, analysis of the spring /geometry and mesh, compress spring statistics, constraint reactions, structural results, modeling and simulation of spring [3]. Niranjan Singh (2013) mainly discussed the fatigue stress analysis of springs used in automobiles with concept of spring design, physical properties of spring materials. He used numerical and experimental methods for the analysis of springs but Finite Element Method is the best for its analysis and calculating the fatigue stress, life cycle and shear stress springs. The literature review also discussed stress distribution analysis, maximum displacement and different mode of failure. Almost in all of the above cases, fatigue stress, shear stress, maximum displacement calculation, play significant role in the design of mechanical springs [4]. Pratik Sharma and Ganesh Kondhalkar(2018) considered on design and development of conical spring for the performance enhancement of the mirror assembly. The material selection for the spring is again the crucial point to be focus which is carried out by the MCDM techniques like WPM. Various calculations provide important information regarding maximum deflection and stress introducing in the spring as well as spring index and spring rate of the existing spring. Paper focus on the efficient and effective design of the sub-assemblies considerably reduces the weight and size of the main assembly, while working condition the main assembly and sub-assemblies should not fail in accordance with proper functioning of it [5]. Rajkumar V. Patil, P. Ravinder Reddy and P. Laxminarayana (2014) discussed the buckling behavior of cylindrical helical springs subjected to axial load and comparison of cylindrical and conical helical springs for their buckling load and deflection.

Revised Manuscript Received on December 30, 2019.

* Correspondence Author

Suresh Kumar, PhD student, Department of Mechanical Engineering, YMCA University of Science & Technology, Faridabad-121006, Haryana, India

M.L.Aggarwal, Professor, Department of Mechanical Engineering, YMCA University of Science & Technology, Faridabad-121006, Haryana, India

Lakhwinder Singh, Professor, Department of Mechanical Engineering, YMCA University of Science & Technology, Faridabad-121006, Haryana, India

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](http://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

They found that for their same deflections, the difference between the corresponding loads on them has been significant. The conical helical springs are more useful than cylindrical for greater axial deflections without buckling. They also used specifications of cylindrical springs made ASTM A313 type 304 (Stainless Steel), theoretical analysis for cylindrical helical compression Springs, slenderness ratio versus critical deflection, buckling of conical spring with shear deformation of its differential Element [6]. Pinjarla Poornamohan and Lakshmana Kishore(2012) To validate the strength of design, they done structural analysis and modal analysis on the shock absorber. And they did also analysis by varying spring material Spring Steel and Beryllium Copper. The shock absorber design was modified by reducing the diameter of spring by 2mm and structural, modal analysis was done on the shock absorber By reducing the diameter, the weight of the spring reduced by comparing the results for both materials, the stress value obtained less for Spring Steel than Beryllium Copper [9].

1.1 Problem statement: The smart fork lift device (established in previous work) was used for the estimation of stability in terms of spring-rates by applying differ loads on it.

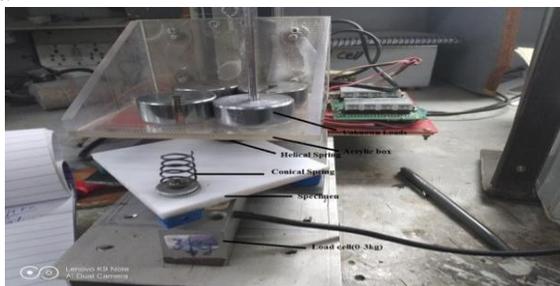


Figure 1 (smart fork lift with specimen)

To preparing of cylindrical and conical shaped helical spring with the help of fixtures which also developed on the advanced lathe machines initially.

After using heat treatment and quenching processes, then in both springs following parameters were obtained as Wire Diameter (d), Outer Diameter (D_o), Pitch (p), Free Length (L_f), Total no. of Coils(N^t), and No. of Active Coil(N). Although, different load-gains were applied that obtained in smart fork lift. Finally evaluation of spring-rates was considered to check the stability of which one springs will be more with the observation data and representation of data values in term of graphs.

2. Parts /tools / equipments used

The following things are considered in this section as:

2.1 Round bar billets (Mild Steel-2pieces): Mild steel contains approximately 0.05–0.30% carbon making (malleable and ductile), so it was available in galvanized form. Mild steel has a relatively low tensile strength, but it is cheap and easy to form. Mainly combination of iron ore and coal, initially the coal and iron ore are extracted from the earth then they are melted together in a blast furnace The chemical composition of mild steel mainly of Fe (98.5-99.26%). The other elements included as C (0.3max.), Si (0.22), Mn(0.60-0.8%), P(0.04%), S (0.04%) etc. (as prescribed by the seller) Two rods of MS were taken as fixture manufacturing of spring, one for helical spring and other for conical spring in this work. The

dimensions as diameter of each rod =12.0mm, length = 113.0mm = L_c and length = helical spring (L_c) = 72mm). (Tolerance considered upto ± 0.2 mm max. in dimensions)

2.2 Drill-Machine (230V/2200rpm) with drill-bit (2.0mm): Drill machine was used to drill the mild steel with the hole of 2.0mm in the centre-face both side of spring tool. Drilling process here used as cutting process with the drill bit to cut a hole of circular cross-section in solid materials of mild steel. The drill bit is usually a rotary cutting tool, often multi-point. This drill machine fitted on table and having 3-D movement on main workplace.



Figure 2 (drill-machine with drill-bit)

This drill bit made of stainless steel material as used in my work. This Forces the cutting edge against the work-piece, cutting off chips from the work piece means the hole is drilled in work piece. It includes drill chuck with locking key, pulley- based driven, vertical stand with heavy base. The pulley and drill bit rotating in same direction about a vertical axis.

2.3 Spring steel wire (A227 GR-II): Spring steel wire also available in galvanized material form with carbon-content was used so that we can apply heat treatment on it. We used dimensions as diameter of wire equal to 1.0mm and length of wire equal to 1.25m (proximate). Extra wire length was taken for experimental failure purpose if happened. It also accessible in small scale spring manufacturing springs shop in city.



Figure 3 (steel wire A227 GR-II)

The commercial achievability of two classes of round cold-drawn steel spring and hard-drawn steel spring wire having properties and quality for the manufacture of mechanical springs that are not subject to high stress or requiring high fatigue properties and wire forms. Hard drawn carbon steel ASTM A227 GR-II was taken here which widely used among the spring steels for static application. It is commercially available in standard form and wire size. The chemical composition of hard drawn carbon steel ASTMA227 mentioned in table 8.3.3

Table 1 (Composition of Spring steel wire (A227 GR-II)

Carbon(C):	0.60-0.85%,	Phosphorous (P):	0.04%max.
Manganese (Mn):	0.30-0.85 % (max),	Sulphur (S):	0.05%max.
Silicon(Si)	0.15-0.35%	Colour/Dia.	Blacky-grey/1.0mm

2.4 Muffle furnace (230 V/AC 1100 deg C): A muffle furnace having temperature range upto 1100°C with an externally heated chamber and the walls of which radiantly heat the contents of the chamber, so that the material being heated has no contact with the flame. A muffle furnace operated at 230 volt in which the subject material actually isolated from the fuel and all of the products of combustion, including gases and flying ash. The inner coating material of muffle oven was glass wool. The internal ceramic chamber of the furnace which is also known as muffle is wrapped up in vast layers of insulation so as to prevent heat loss and achieve high temperatures. Muffle furnace regulator initially set at 650°C for tempering purposes and then 860°C secondly for tempering purposes.

2.5 Infrared thermometer (Digital/leaser type): An infrared thermometer leaser was used in which infers temperature from a portion of the thermal radiation sometimes called black-body radiation emitted by the object being measured. For the accuracy of temperature parameter we applied this in between the working of muffle furnace. Infrared Temperature sensor which just emitted red ray on the particular point or target cross-section, then we obtained the value of temperature shows on its screen. Infrared thermometers usually used a lens to focus infrared light from one object onto a detector called a thermopile. The thermopile absorbs the infrared radiation and turns it into heat.



Figure 4 (Infrared temperature sensor)

The two springs were treated with the help Infrared temperature sensor in various stages to check the accurate working of muffle furnace.

2.6 Clamping wire (Galvanized Mild steel): Spring steel wire in galvanized material form with carbon-content was used so that we can apply heat treatment on it. The wire also purchased from the nearby city commercial material shop (Address as: shop no 48-49, gate no.1, behind jama-musjid, Delhi) just Rs. 30. We used dimensions as diameter of wire equal to 1.0mm and length of wire equal to 0.5m (proximate). Extra wire length was taken for experimental failure purpose if happened. It also available in small scale spring manufacturing spring shops in city.

2.7 Fixture-cum-spring tool making: Mild steel rods were used to making the fixture-cum-spring tool which easily available in the workshop of local engineering college as advance institute of engineering and technology,

palwal(Haryana). These are also called spring manufacturing tools which removed the fixtures, clamping devices and wrapping wires as applied in previous making of smart intelligent helical springs. They are made on advance lathe machine



Figure 5 (Fixture- cum-spring tools)

To manufacturing of cylindrical and conical shaped helical spring the present work, two fixture-cum-spring tools were made with the help of lathe machine such that the springs have been coiled on this tools-periphery in which teeth's are provided and coil spring of hard drawn carbon steel ASTM A227 wire. The specifications of cylindrical tool-Fixture and conical tool-fixture springs that have been used for evaluation are as given below.

For Conical,
Diameter of Round rod = 12.00mm,
Total Length of conical tool-fixture =113.00mm,
Unthreaded length = 42.75mm,
Threaded length = 113.00-72.50 = 40.50mm,
Angle of teeth cutting on lath M/C = 2.5°

For Helical,
Diameter of Round rod = 12.00mm,
Total Length of helical tool-fixture =88.50mm,
Unthreaded length = 42.75mm,
Threaded length = 88.00-42.75 = 45.25mm,
Angle of teeth cutting on lath M/C = 2.5°

3 Manufacturing of helical and conical shaped helical springs

The following Steps are considered as:-

STEP-I

3.1 Tempering of spring steel wire: Tempering here involved in which heating the spring steel wire upto 650 deg C for 10minutes, and then slowly cooled inside the furnace by just switch-off and half opening the gate of it for 12 hours at room temperature. Wire had temperature slightly above the room temperature after 12 hours then air cooled for 2 hours in outside atmosphere inside the room (normalizing). It must be precise temperature below the critical point of spring steel wire in but cooling vacuum or inert atmospheres.



Figure 6 (Tempering of wire)

STEP-II

3.2 Wrapping of steel wire and applying clamping on tool-fixtures: These are also called spring manufacturing tools as a fixtures and clamping wire applied on tool-fixtures such that spring cannot backed in strength during the wrapping.



Figure 7 (wrapping steel wire)

STEP-III

3.3 Heating the Steel wire at 860 deg C (solid phase critical heating): Solid phase critical heating applied such that heating the steel wire at specified temperature of 860 deg C for the duration 25minutes. The muffle furnace used again for this purpose and preset the temperature on the regulator of it whereas tong used as a gripping of parts from inside of furnace.



Figure 8 (Muffle furnace operating at 860 deg C)

STEP-IV

3.4 Quenching process (oil-based): Quenched steel generally cannot be used directly, must be used after tempering. Quench oil serves two primary functions firstly as to facilitate hardening of steel by controlling heat transfer during quenching and secondly it enhances wetting of steel. Castrol quenching oil used as cooling medium. Quenching and tempering are processes applied here to strengthen and harden materials of steel specimens of helical/conical.



Figure 9 (After quenching)

The process of quenching or quench hardening involves heating the material and then rapidly cooling it to set the components into place as quickly as possible.

STEP-V

3.5 Separation of spring from tool-fixture: By removing oil and clamping wire, then separate the springs from the tool- fixtures as shown in figure 10. It can be seen in combined figures the separately the helical coiled spring and

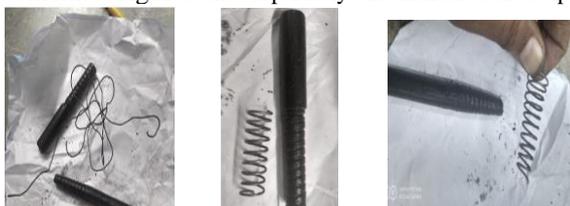


Figure 10 (Separation of spring)

Conical coiled springs with fixture-cum-spring tools. The followings parameters had obtained for the cylindrical and conical springs as shown in table no.2.

STEP-VI

3.6 Specimens formation (for loading-gains, spring rate and deflections): The acrylic material was used as the spring holder in the form of specimen. The Initial specimen was considered as the same free length for helical/ conical springs. The four supports also applied as the acrylic-base so that accurate readings can be obtained.



Figure 11 (Initial and Final specimens)

4 Experimental setup and observation data

Strain gauge measuring kit which was basically amplifier circuit (ADC type) applied here in the setup. The ADC is an electronic integrated circuit which transforms a signal from analog presented in continuous form into digital which presented in discrete form. The analog signals are directly measurable quantities or we can say the physical signal. Digital signal only have two states. For digital we refer to binary states, 0 and 1. ADC provides a link between the analog world of transducers and the digital world of signals processing and data handling. The transducer's electrical analog output serves as the analog input to the ADC.



Figure 12 (ADC based amplifier circuit and smart fork-lift loading box)

4.1 Average scale-value: The scale values had calculated with the help of acrylic box of smart fork-lift and steel slotted weights. The steel slotted weights were used and each piece having weight of 100gm. We had also used soldering roll as a weight equal to 250gm. The total weights upto 650gm had applied. Placed the slotted weight of 100gm piece one by one and soldering roll on the acrylic box of smart fork-lift until the weight reached lastly 650gm.

Table 2 (Average scale-value)

Sr No.	Weight of Acrylic box (gm)	Avg. Load-Cell Strain or GF value	Atm. Temperature (°c)	Difference value	Related value
1	unknown	17.5	25.2	nil	Nil
2	100	27	26	9.5	100/9.5=10.526
3	200	36.5	25.1	19	200/19=10.526

4	300	46	26.1	28.5	300/28.5 =10.526
5	400	55	25.9	37.5	400/37.5=10.666
6	650	80.5	25.6	63	650/63=10.317
Avg. scale value			(10.526x3+10.666+10.317)/5 =10.512		

From the above Table 8.5, we define one Average scale reading of Load cell strain equal to '10.512gm'. So for further calculations we have used this average scale value in order to estimate the total load applied on helical shaped and conical shaped springs which mounted on the common platform known as spring holder and that holder worked as Initial specimen and final specimen. The weight of acrylic box equal to 10.512x17.5=183.96gm and weight of spring holder (which having reading '3' in terms of average stain value) equal to 3x10.512=31.536gm respectively.

4.2 Stage First

The first considered initial specimen for the same free length of springs i.e. cylindrical / conical.

Table 3 (Parameters of springs-stage first)

Parameters	Cylindrical Spring	Conical Spring
Type of End	Plain end	Plain end
Wire Diameter (d)	1.0mm	1.0mm
Outer Diameter (D _o)	12mm	14.3mm(Base-end), 6.5mm(Apex-end), 12mm(Mean dia.)
Pitch (p)	3.8mm	3.8mm
Free Length (L _f)	34.8mm	34.8mm
Total no. of Coils(N ^t)	10	10
No. of Active Coil(N)	8	8

The weight of spring holder and acrylic box also found by the load cell of smart fork-lift that attached to strain measurement kit. We can see the related data in table no. 2.



Figure 13 (Initial Specimen for first stage)

Table 4 (Observation data for cylindrical spring – stage first)

Sr No.	Weight of Acrylic box (gm)	Weight of spring holder(gm)	load applied(gm)	Vertical scale reading(m m)	Avg. Load-Cell Strain or GF value	spring loaded value(helical)
1	nil	31.536	nil	nil	3	nil
2	183.96	31.536	nil	3.0	20.5	215.496
3	183.96	31.536	100	3.9	29.5	315.496
4	183.96	31.536	200	4.7	40	415.496
5	183.96	31.536	300	5.4	51	515.496
6	183.96	31.536	400	6.0	61	615.496
7	183.96	31.536	650	7.6	71	865.496

Table 5 (Observation data for conical spring – stage first)

Sr No.	Weight of Acrylic box (gm)	Weight of spring holder(gm)	load applied(gm)	Vertical scale reading (mm)	Avg. Load-Cell Strain or GF value	spring loaded value(conical)
1	nil	31.536	nil	nil	3	nil
2	183.96	31.536	nil	2.46	20.5	215.496
3	183.96	31.536	100	3.60	29.5	315.496
4	183.96	31.536	200	4.70	40	415.496
5	183.96	31.536	300	5.70	51	515.496
6	183.96	31.536	400	6.81	61	615.496
7	183.96	31.536	650	9.62	71	865.496

Here, the data was obtained in table no. 4 and 5 for Cylindrical and conical spring of wire size(d=1.0mm)

4.2 Stage second

The secondly considered final specimen for the different free length of springs i.e. cylindrical / conical. The free length of conical spring was considered as shorter than cylindrical spring. The table no. 6 showed the various parameters of second stage springs.

Table 6 (Parameters of springs-stage second)

Parameters	Cylindrical Spring	Conical Spring
Type of End	Plain end	Plain end
Wire Diameter (d)	1.0mm	1.0mm
Outer Diameter (D _o)	12mm	14.3mm(Base-end), 8.6mm(Apex-end), 13.2mm(mean dia)
Pitch (p)	6.8mm	6.8mm
Free Length (L _f)	24.39mm	19.80mm
Total no. of Coils(N ^t)	7	6
No. of Active Coil(N)	5	4



Figure 14 (Final Specimen for second stage)

Table 7 (Observation data for cylindrical spring – second first)

Sr No.	Weight of Acrylic box (gm)	Weight of spring holder(gm)	load applied(gm)	Vertical scale reading(m m)	Avg. Load-Cell Strain or GF value	spring loaded value(helical)
1	nil	31.536	nil	nil	3	nil
2	183.96	31.536	nil	2.06	20.5	215.496
3	183.96	31.536	100	3.01	29.5	315.496
4	183.96	31.536	200	4.00	40	415.496
5	183.96	31.536	300	4.92	51	515.496
6	183.96	31.536	400	5.78	61	615.496
7	183.96	31.536	650	8.30	71	865.496

Table 8 (Observation data for conical spring – stage second)

Sr No.	Weight of Acrylic box (gm)	Weight of spring holder(gm)	load applied (gm)	Vertical scale reading(mm)	Avg. Load-Cell Strain or GF value	spring loaded value(conical)
1	nil	31.536	nil	nil	3	nil
2	183.96	31.536	nil	2.06	20.5	215.496
3	183.96	31.536	100	3.01	29.5	315.496
4	183.96	31.536	200	4.00	40	415.496
5	183.96	31.536	300	4.92	51	515.496
6	183.96	31.536	400	5.78	61	615.496
7	183.96	31.536	650	8.30	71	865.496

1	nil	31.536	nil	nil	3	nil
2	183.96	31.536	nil	2.44	20.5	215.496
3	183.96	31.536	100	3.50	29.5	315.496
4	183.96	31.536	200	4.71	40	415.496
5	183.96	31.536	300	5.85	51	515.496
6	183.96	31.536	400	6.90	61	615.496
7	183.96	31.536	650	9.72	71	865.496

Here, the data was obtained in table no. 7 and 8 for Cylindrical and conical spring of wire size(d=1.0mm) but differed in numbers of turns and free lengths.

II. RESULTS AND DISCUSSION

Spring Rate Calculation for Cylindrical and conical spring of wire size(d=1.0mm)

5.1 Stage first analysis for helical spring

Spring rate evaluated here for the helical spring, we can see in table no. 9.

Table 9 (spring rate of helical spring- stage first)

Vertical scale reading(mm)	spring loaded value(conical)	Spring Rate (Kh)
2.05	215.496	105.120
2.00	315.496	105.165
3.90	415.496	106.537
4.90	515.496	105.203
5.80	615.496	106.12
8.40	865.496	103.035

The spring rate of helical had showed by linearly and regression coefficient shown the value of 0.96.

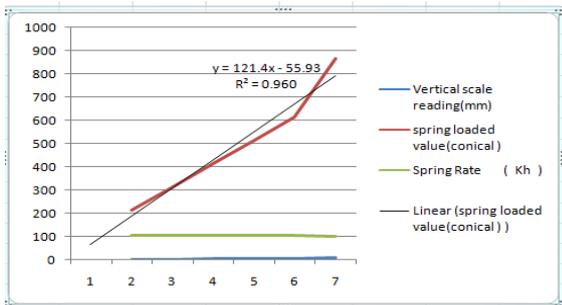


Figure 15 (Vertical scale reading or Deflection and load variation)

Stage first analysis for helical and conical springs, Spring rate evaluated here for the conical spring, we can see in table no. 10.

Table 10 (spring rate of conical spring- stage first)

Vertical scale reading(mm)	spring loaded value(helical)	Spring Rate (Kc)
2.46	215.496	87.600
3.60	315.496	87.637
4.70	415.496	88.403
5.70	515.496	90.437
6.81	615.496	90.381
9.62	865.496	89.968

The spring rate of conical had showed by linearly and

regression coefficient shown the value of 0.96.

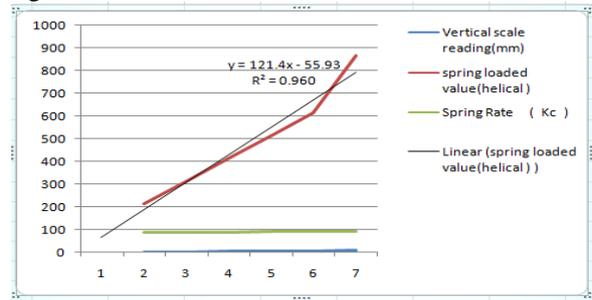


Figure 16 (Vertical scale reading or Deflection and load variation)

Combined spring rate variation of conical spring and helical springs can be seen for stage first

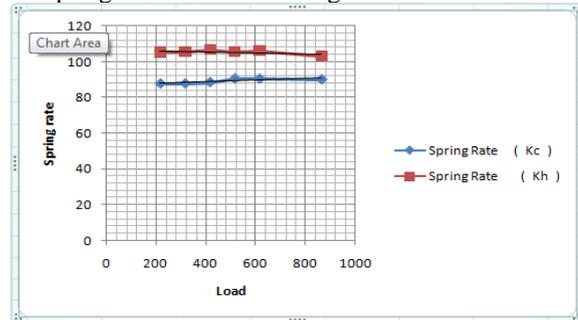


Figure 17 (spring rate variation)

Stage second analysis for helical and conical springs, Spring rate evaluated here for the helical spring, we can see in table no.11.

Table 11 (spring rate of helical spring- stage second)

Vertical scale reading(mm)	spring loaded value(helical)	Spring Rate (Kk)
2.06	215.496	104.609
3.01	315.496	104.815
4.00	415.496	103.874
4.92	515.496	104.775
5.78	615.496	106.487
8.30	865.496	104.276

The spring rate of helical had showed by in figure 18.

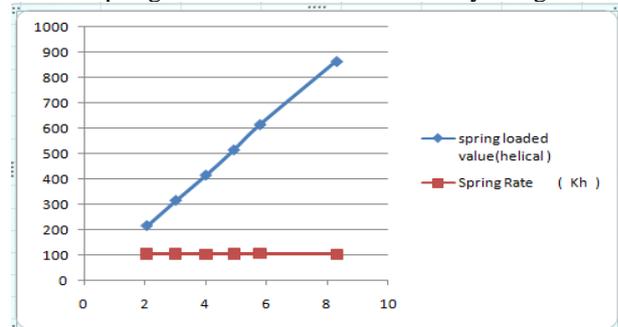


Figure 18 (Vertical scale reading or Deflection and load variation)

Spring rate evaluated here for the conical spring, we can see in table no. 12.

Table 12 (spring rate of conical spring- stage second)

Vertical scale reading(mm)	spring loaded value(conical)	Spring Rate (Kc)
2.44	215.496	88.318
3.50	315.496	90.141
4.71	415.496	88.215
5.85	515.496	88.573
6.90	615.496	89.202
9.72	865.496	89.042

The spring rate of conical had showed by in figure 19.

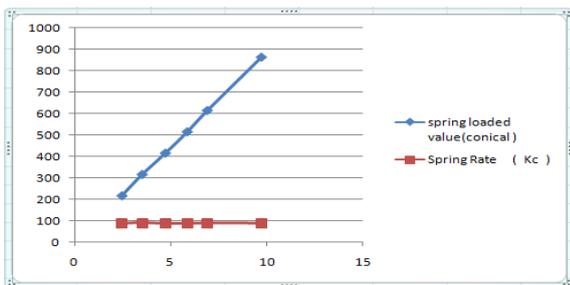


Figure 19 (Vertical scale reading or Deflection and load variation)

Combined spring rate variation of conical spring and helical springs can be seen for stage second in figure 20.

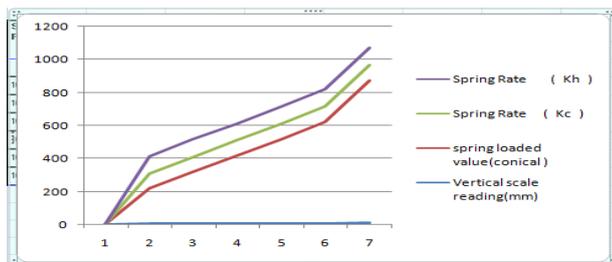


Figure 20 (spring rate variation)

III. CONCLUSIONS

It is evident from experimental results that spring rate (k) is higher for conical helical compression spring than that for cylindrical helical compression spring. So the stability of conical spring as compared to helical spring found higher, physical loaded conical can be placed in smart fork-lift.

Other points included as:-

- (i) The initial sample of the helical and conical springs showed that the conical spring taken large deflection for the same free lengths in comparison to helical spring for eight numbers of active coils.
- (ii) The final sample of the helical and conical springs showed that the conical spring taken less deflection and bear large load for the shorter free lengths in comparison to helical spring for different active coils(four numbers of active coils for conical spring and five numbers of active coils of helical spring were considered).
- (iii) Unknown Load also calculated with the help of

strain gauge kit used in fork lift for every springs

- (iv) Regression coefficient was obtained equal to 0.96. so accuracy upto 96% for both springs (as shown in first stage)

Load verses deflection response was also smooth for conical in relation with cylindrical spring. This worked is performed mainly for stability of physically loaded springs (helical or conical) in terms of spring rate (K) i which directly affects mechanical properties of a spring. This prescribed work also helped to researchers an alternative way to define the physically-loaded springs applicability in smart fork-lift.

REFERENCES

1. P.S.Valsange, 'Design Of Helical Coil Compression Spring:A Review', IJERA, 2(6), pp.513-522, Dec.2012.
2. Amitesh, V. C. Kale and K. V. Chandratre, A Comparative Evaluation Of Spring Rate, International Engineering Research Journal, Page No 2025-2029, June 2019.
3. Rufus Ogbuka Chime and Samuel I.Ukwuaba, Design, Modeling, Simulation and Analysis Compress Spring, IJESIT, 5(1), Jan 2016.
4. Niranjana Singh, General Review Of Mechanical Springs Used In Automobiles Suspension System, IJAERS, 3(1), pp.115-122, Dec.2013.
5. Pratik Sharma and Ganesh Kondhalkar, design And Analysis Of Conical Spring, IRJET, 5(7), e-ISSN:2395-0056, p-ISSN:2395-0072, July 2018.
6. Rajkumar V. Patil, P. Ravinder Reddy and P. Laxminarayana, Comparison of Cylindrical and Conical Helical Springs for their Buckling Load and Deflection.IJAST, vol.(73), pp.33-50, 2014.
7. <http://www.nptelvideos.in/helicalspring/chapter/design/conicalspring/design>
8. <https://www.google.com/helicalspring/types/applicability/pdf>.
9. Pinjarla Poornamohan and Lakshmana Kishore. design and analysis of a shock absorber,IJRET journal,vol.(01), pp.578-592,2012
10. <https://www.google.com/conicalspring/type/applicability/pdf>.