



Effect of Load variation and thickness on deflection and operating stress of wave spring

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ABSTRACT

Wave springs are used for load bearing into assemblies. When force applied to the spring, load is gradual or abrupt. Typically wave spring will occupy an extremely small space after compressions. In this paper effect of change in thickness of wave spring on the deflection of spring and on operating stress is studied. This study leads towards the impact of thickness change under different load condition. The result reveals that after increasing the thickness from 0.1181 to 0.23622 inch, drastically decrement noticed in the deflection as well as operating stress for different loading condition in wave spring. Study shows the deflection for two different spring materials (nickel and beryllium copper) considering different parameters that help to choose best spring material.

Keywords: wave spring thickness, Deflection, working stress, Load on wave spring, etc.

1. INTRODUCTION

Spring is made up of elastic material as after getting compressed it stored the energy. Generally springs are made of steel. The spring constant of a spring can be defined as the change in the force it exerts, divided by the change in deflection, so spring rate is described by unit N/m. in case of torsion spring, when it is twisted about its axis by an angle, it produces a torque proportional to the angle and spring's rate having unit Nm/rad. wave springs replaced helical springs because wave springs required less height compare to coil spring for the similar load application. Wave springs were first discovered by Smalley industries of USA in 1990's. They manufacture wave spring of many types. Small springs can be wound from pre-

hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Some non-ferrous metals are also used including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current. Common spring materials include stainless steel, alloy steels, carbon steels, non-ferrous materials and some super-alloys which exist in the market with preparatory designations and nomenclature. Each spring material has diverse compositions, individual properties and also for a particular type of spring, more than one feasible alternative spring materials may be available in the market.

1.1 Wave spring:

Among the many types of springs, wave springs have attracted considerable attention this kind of long and reliable source of long lasting durability and considerable effectiveness than rest of the springs. Wave springs are used to reduce the height of the spring and to produce the same end effect end that of a coil spring. Wave springs operate as load bearing devices. They take up play and compensate for dimensional variations within assemblies. A virtually unlimited range of forces can be produced whereby loads build either gradually or abruptly to reach a predetermined working height. This establishes a precise spring rate in which load is proportional to deflection. Functional requirements are necessary for both dynamic and static spring applications. Special performance characteristics are individually built into each spring to satisfy a variety of precise operating conditions. Typically, a wave spring will occupy an

extremely small area for the amount of work it performs. The use of this product is demanded, but not limited to tight axial and radial space constraints.

1.2 Wave spring types:

Gap type wave spring has gap between two ends. Continued deflection causes the gap ends to move closer together while the outer dia. presses against the bore [fig. 1(a)]. Overlap type has overlapping ends and ends are free to move circumferentially during compression [fig. 1(b)]. Crest-to-Crest wave spring has more numbers of turn. No need to use key between springs because the spring is integrally

formed. Crest springs replaced helical spring because crest springs can develop similar forces so occupy less the axial space and solid height [fig. 1(c)]. Nested Wave Springs are pre-stacked in parallel from one continuous filament of flat wire used for higher load. Nested springs result in a spring rate that increases proportionally to the number of turns [fig. 1(d)]. Wavo wave spring has round-section and used for high load application and give accurate spring rate [fig. 1(e)]. In linear wave spring forces act linearly or radially depending on the installed position and axial pressure is obtained by laying the spring flat in a straight line [fig. 1(f)].



Fig. 1(a) Gap type wave spring



Fig. 1(b) Overlap type wave spring



Fig. 1(c) Crest-to-Crest wave spring



Fig. 1(d) Nested wave spring



Fig. 1(e) Wavo wave spring



Fig. 1(f) Linear wave spring

1.3 Spring materials and their properties:

For manufacturing of spring the material is selected by considering many parameters like spring is made of a material which having elasticity for storage of energy after compression, higher yield strength, etc. Also material must be compatible with the environment and withstand effects of temperature and

corrosion without an excessive loss in performance because corrosion and temperature decrease spring reliability. Engineer must analyze about the compression rate of the spring and tensile strength for fatigue frailer and life cycle of the spring. According to the requirements of the material different materials with their properties are shown in table 1.

Table 1 spring material properties [6]

Material	Density (gm/cc)	Tensile Strength (MPa)	Modulus of Elasticity (GPa)	Design Stress percentage Min. Tensile (%)	Max. Operating Temp (°C)	Rockwell Hardness (HRC)	Material Cost (\$/Kg.)
High Carbon Steel (ASTM A 228)	7.85	2168.5	207	45	121	50.5	35
Beryllium Copper Alloy (ASTM B 197)	8.26	1310	128	45	204	38.5	33
Monel K500	8.44	1241	179	40	288	29	55
Chrome Silicon Alloy Steel (ASTM A 401)	7.85	1844.5	207	45	245	51.5	30
Stainless Steel (AISI 304)	7.92	1551.5	193	35	288	40	15
Inconel 600	8.47	1379	214	40	371	40	45
Nickel Alloy (ASTM A 286)	7.92	1241	200	35	510	38.5	32

2. CALCULATION

Table 2 value of K corresponding to N [7]

N	2.0 - 4.0	4.5 - 6.5	7.0-9.5	10.0+
K	3.88	2.9	2.3	2.13

$$\text{Deflection} = f = \frac{PKD_m^3 Z I.D.}{Ebt^3 N^4 O.D.}$$

$$\text{Operating stress} = S = \frac{3\pi PD_m}{4bt^2 N^2}$$

P = Load (lb.)	b = Radial Wall, in. [(O.D. - I.D.) ÷ 2]	L = Length, overall Linear (in.)
K = Multiple Wave Factor	t = Thickness of Material (in.)	H = Free height (in.)
I.D. = Inside Diameter (in.)	N = Number of Waves (per turn)	W.H. = Work Height (in.) [H-f]
O.D. = Outside Diameter (in.)	E ₁ = Modulus of Elasticity (psi) of Nickel Alloy (ASTM A 286)	E ₂ = Modulus of Elasticity (psi) of Beryllium Copper Alloy (ASTM B 197)
D _m = Mean Diameter, in. [(O.D. + I.D.) ÷ 2]	S ₁ = Operating Stress (psi) of Nickel Alloy (ASTM A 286)	S ₂ = Operating Stress (psi) of Beryllium Copper Alloy (ASTM B 197)
Z = Number of Turns	F ₁ = Deflection (in.) of Nickel Alloy (ASTM A 286)	F ₂ = Deflection (in.) of Beryllium Copper Alloy (ASTM B 197)

Table 3 calculation of operating stress and deflection @ 600lbs

P	K	ID	OD	D _m	Z	b	t	N	E ₁	E ₂	S ₁ = S ₂	F ₁	F ₂
600	3.88	3.937	4.7244	4.3307	20	0.3937	0.1181	2.5	29007548	18564830	178391.8019	4.288643	6.701004947
600	3.88	3.937	4.7244	4.3307	20	0.3937	0.2362	2.5	29007548	18564830	44597.95048	0.536080	0.837625032
600	3.88	3.937	4.7244	4.3307	20	0.3937	0.3543	2.5	29007548	18564830	19821.31132	0.158838	0.248184384
600	3.88	3.937	4.7244	4.3307	20	0.3937	0.4727	2.5	29007548	18564830	11149.48762	0.067010	0.104703129

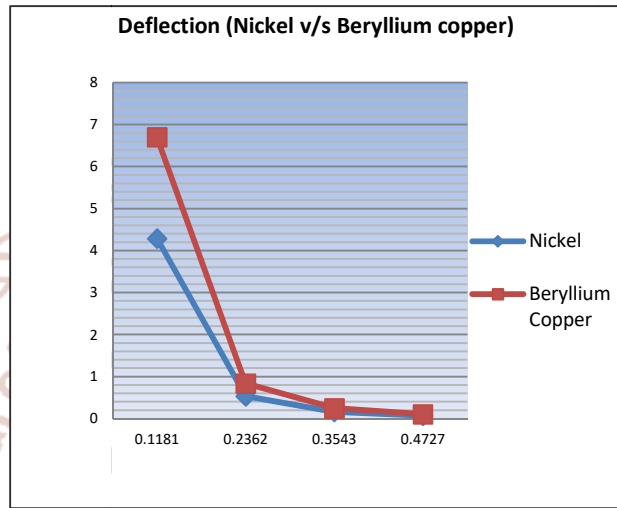
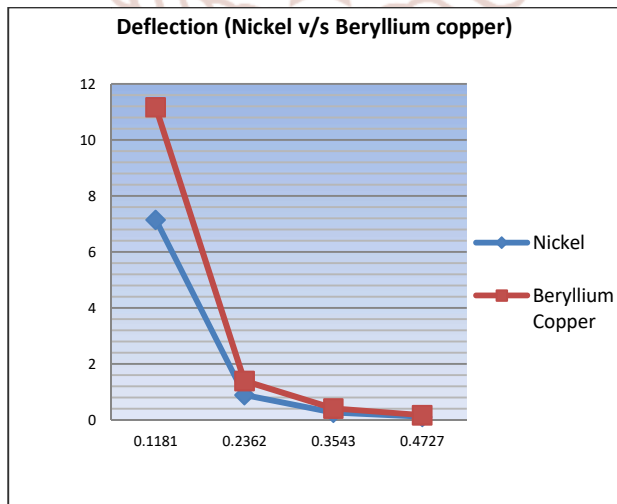
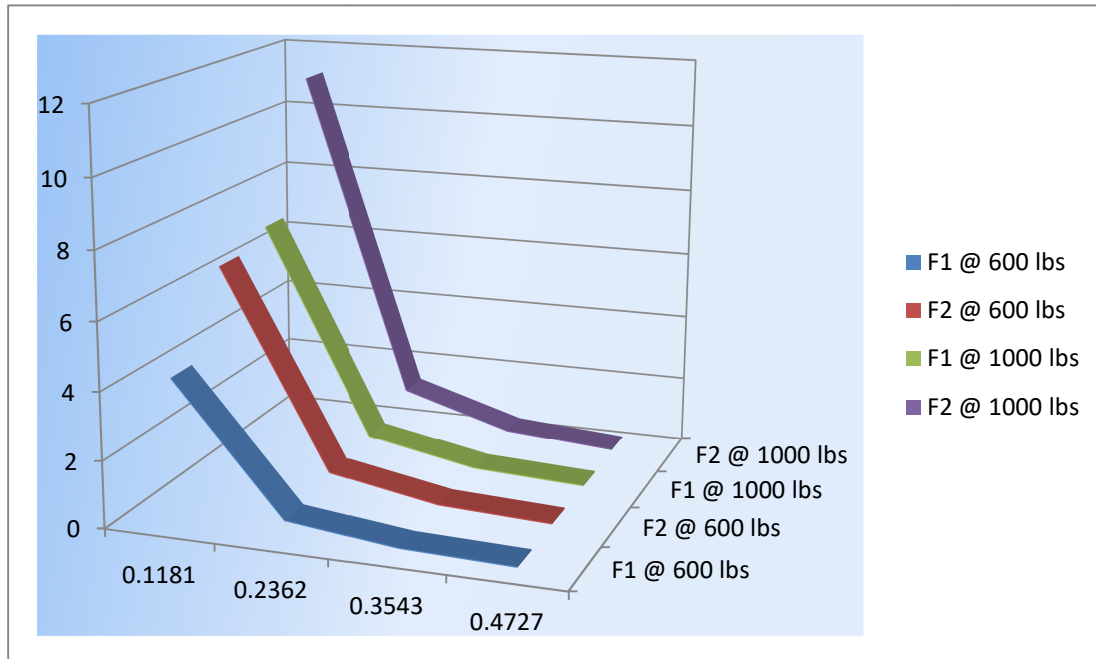


Table 4 calculation of operating stress and deflection for 1000lbs

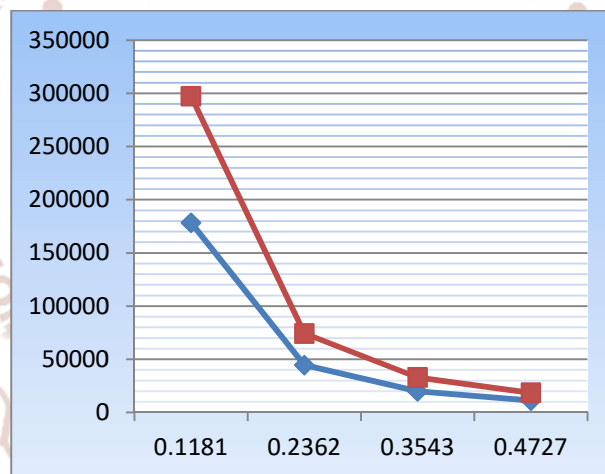
P	K	ID	OD	D _m	Z	b	t	N	E ₁	E ₂	S ₁ = S ₂	F ₁	F ₂
1000	3.88	3.937	4.7244	4.3307	20	0.3937	0.1181	2.5	29007548	18564830	297319.6698	7.147737916	11.16834093
1000	3.88	3.937	4.7244	4.3307	20	0.3937	0.2362	2.5	29007548	18564830	74329.91745	0.893467239	1.396042615
1000	3.88	3.937	4.7244	4.3307	20	0.3937	0.3543	2.5	29007548	18564830	33035.51887	0.264731033	0.413642255
1000	3.88	3.937	4.7244	4.3307	20	0.3937	0.4727	2.5	29007548	18564830	18582.47936	0.111683404	0.174505325



2.1 Comparison of deflection for 600 lbs and 1000 lbs load on the wave spring of nickel & Beryllium copper



2.2 Comparison of operating stress for 600 lbs and 1000 lbs load on the wave spring



—■— Operating stress for 600lbs
—◆— Operating stress for 1000lbs

3. CONCLUSION

- For the wave spring calculation conclude that as the wave increase the frequency of the spring will decrease and also chart shows the frequency versus wave of spring for two different load. Here rapid decrement of frequency from 1000lbs to 600 lbs.
- For the helical spring, frequency versus no. of active coil chart shows that as the no. of active coil decrease frequency also decrease.
- For nickel and beryllium copper wave spring, the result shows that the deflection occur at maximum level in the case beryllium copper having value 11.16834093 on load of 1000 lbs
- For better properties metal matrix composite can be preferred for the future scope.

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