Asian Review of Mechanical Engineering
ISSN: 2249-6289 (P) Vol.1 No.1, 2012, pp.7-12
© The Research Publication, www.trp.org.in
DOI: https://doi.org/10.51983/arme-2012.1.1.2514

Comparative Analysis for Helical Spring and Belleville Spring Used in Aerosol Container Valve

Mehul Modh
Laljibhai Chaturbhai Institute of Technology, Bhandu, Mehsana, Gujarat - 384 120, India.
E-Mail: mehul.modh@lcit.org, modh_mehul@yahoo.co.in

(Received on 10 December and accepted on 15 March 2012)

Abstract - **Aerosol is to spray in fine particles from pressurized fluid. It is widely used in insect killer room freshener as well as perfumes. Various designs of such products are available and they are based on ergonomically as well as aesthetical consideration. In this paper, same consideration is used, model is made in Pro-e software and analysis is made in ANSYS software to justify the answer. Here, two different springs like Belleville as well as Conventional spring called "Helical Spring". Due to application of same load on Belleville as well as helical spring, a graph of load versus deflection is produced. The objective of this work is to prevent the leakage as well as less pressure or effort application on valve of the aerosol container to spray the contains.**

Keywords - **Aerosol Container, Belleville Spring, Helical Spring, Analysis Ansys, Pro-e**

I. INTRODUCTION

Rotheim, a Norwegian engineer and inventor, came up with the first aerosol-can design more than 75 years ago. The technology has evolved somewhat over the years, but the illustrations in Rotheim's 1931 U.S. patent do show most of the major elements found in today's aerosol spray cans.

The basic idea of an aerosol can is very simple. One fluid stored under high pressure is used to propel another fluid out of a can.

A fluid is any substance made up of free- flowing particles. This includes substances in a liquid state, such as the water from a faucet, as well as substances in a gaseous state, such as the air in the atmosphere.

The particles in a liquid are loosely bound together, but they move about with relative freedom. Since the particles are bound together, a liquid at a constant temperature has a fixed volume.

If you apply enough energy to a liquid (by heating it), the particles will vibrate so much that they break free of the forces that bind them together. The liquid changes into a gas, a fluid in which the particles can move about independently. This is the boiling process, and the temperature at which it occurs is referred to as a substance's boiling point. Different substances have different boiling points: For example, it takes a greater amount of heat to change water from a liquid into a gas than it does to change alcohol from liquid to gas.

The force of individual moving particles in a gas can add up to considerable pressure. Since the particles aren't bound together, a gas doesn't have a set volume like a liquid: The particles will keep pushing outward. In this way, a gas expands to fill any open space.

As the gas expands, its pressure decreases, since there are fewer particles in any given area to collide with anything. A gas applies much greater pressure when it is compressed into a relatively small space because there are many more particles moving around in a given area [1].

II. PROPELLANT AND PRODUCT

An aerosol can contains one fluid that boils well below room temperature (called the propellant) and one that boils at a much higher temperature (called the product). The product is the substance you actually use the hair spray or insect repellent.

There are two ways to configure this aerosol system. In the simpler design, you pour in the liquid product, seal the can, and then pump a gaseous propellant through the valve system. The gas is pumped in at high-pressure, so it pushes down on the liquid product with a good amount of force. We can see how this system works in the diagram below.

When we push the head piece down, the inlet slides below the seal, opening a passage from the inside of the can to the outside. The high-pressure propellant gas drives the liquid product up the plastic tube and out through the nozzle. The narrow nozzle serves to atomize the flowing liquid break it up into tiny drops, which form a fine spray [3].

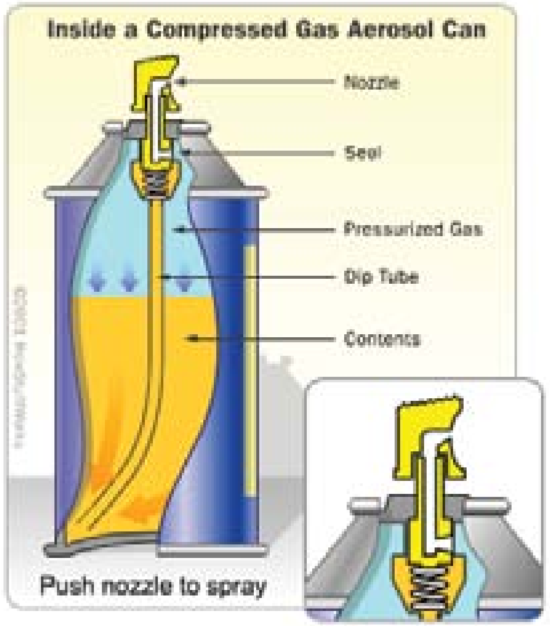


Fig. 1 Working Mechanism of Aerosol Can

III. AEROSOL VALVE SELECTION

John Chadwick [1] in his research paper on Particle Size Control in Aerosol Packages has explained that the aerosol valve system is responsible for both the quantity and quality of the spray produced. The quantity is controlled by the number and diameter of orifices contained within the valve system. The larger, or more open the orifices are, the higher the flow rate will be, given that all other variables in the system remain constant. Spray rate, measured in grams per second, is a primary quantity measurement which defines the spray. For this article, the focus is on the quality attributes of the spray stream generated.

Spray quality refers to several characteristics. A primary measurement is spray geometry, which involves the geometric shape and size of the spray. Typical shapes are: stream, cone, fan, and donut. Particle size is another attribute of spray quality, and here, we focused on how particle size is influenced by the valve system [5]. Aerosol valves are available in a surprisingly wide variety of configurations. Valve companies have, as stock components, an array of actuators, stems, bodies, mounting cups, vapour tap sizes, and dip tube orifice sizes. In fact, it is estimated that there were over 200,000 possible combinations of stock components that can be combined to produce distinct aerosol valves. When a particular orifice is required–one that doesn't exist in a stock component–valve companies have the ability to custom mould the piece for trial evaluations (for a price, of course).

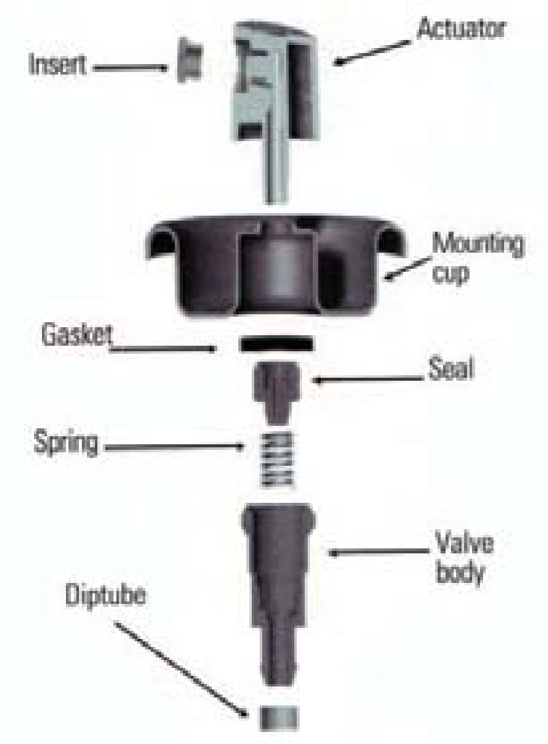


Fig. 2 Aerosol Valve

This wide flexibility in available valve components is what makes controlling the particle size a simple job for the experienced aerosol package designer. Once the formula is established, the package designer can then utilize various orifice combinations, choose to include a vapour tap or not, and then select from a wide array of actuators and inserts to tailor the spray's particle size to suit specific product performance requirements. The two primary valve components which are used to adjust the particle size of the spray plume are the actuator and the vapour tap. The actuator, also referred to as the "button," "spray-head," or "spray-tip," is the component which represents the point of exit of the spray stream. The second component, which has a major impact on spray quality, is a moulded orifice located in the body of the valve and referred to as the "vapour tap."

Within any given actuator style, there are a number of dimensions that may be altered to influence the spray. Two of these dimensions are the length and taper of the channel leading to the exit orifice of the actuator. The plastic leading to the exit Orifice can be moulded as a straight channel, or the channel can be tapered, or even reverse-tapered.

Each of these configurations has an effect on the resultant particle size. Also, within the actuator there are a variety of mechanical breakup features available to provide increasing breakup of the fluid stream as the stream passes through the actuator. Furthermore, some actuators are designed to accept inserts, which serve to provide additional control over the spray. The second method of controlling particle size in an aerosol system is by including a vapour tap, an orifice which is melded into the side of the valve body. The function of the vapour tap is to draw off the propellant vapour and add it to the liquid stream which is being drawn up the dip tube when the valve is open. By mixing the propellant vapour with the spray stream, the particle size of the spray can be substantially reduced. There is an inverse relationship between vapour tap diameter and particle size. A larger vapour tap orifice allows for a higher ratio of propellant vapour in the spray. The result is a smaller particle size. Obviously, there is an per limit in the size of the vapour tap. In fact, the aerosol designer must be careful to balance the size of the vapour tap orifice with the potential inability to evacuate the can due to premature pressure loss. Also, the aerosol can must be held in relatively vertical position. If the can is sprayed in a horizontal or inverted orientation, the vapour tap will not function, and the Spray stream will rapidly degrade. The actuator and vapour tap variables described above afford the aerosol package designer great flexibility in adjusting the geometry, spray rate and particle size of the aerosol spray. Determining the effect of the various valve design possibilities on particle size is accomplished by using an instrument called an Aerosol Particle Size Analyser. This device projects a light beam between two optical nodes. The systems' electronics rapidly measure and analyse the particle size distribution present within the beam. The associated computer program generates detailed reports, which include particle size distribution graphs, as well as a full array of statistical analyses on the data set. Typically several aerosol samples are prepared for testing. Each sample contains a different valve design alternative. Once the system is calibrated, the test cans are individually sprayed into the beam of the instrument, and the particle size Distribution of each spray stream is analysed and reported [9]. The information provides the relative differences in the particle size distribution of each of the samples. More specifically, the readouts provide information about the relative fineness or coarseness of the sprays. John Chadwick (2004) [2].

IV. Use of Belleville Spring instead of helical spring to reduce the effort of finger

A Belleville spring or washer is formed into a conical or cone shaped geometry. The slight or aggressive conical shape gives the washer a spring characteristic and action.

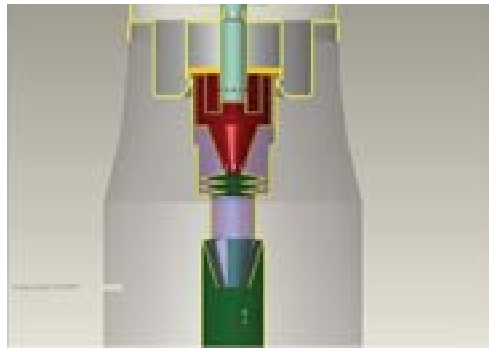


Fig. 3 Use of Belleville Spring in Valve of Aerosol Can

V. Belleville Spring

A Belleville spring or washer is formed into a conical or cone shaped geometry. The slight or aggressive conical shape gives the washer a spring characteristic and action. Belleville washers are typically used as springs where the spring action is used to apply a pre-load or flexible quality to a bolted joint. The equations below will determine the various characteristics including the applied load of a

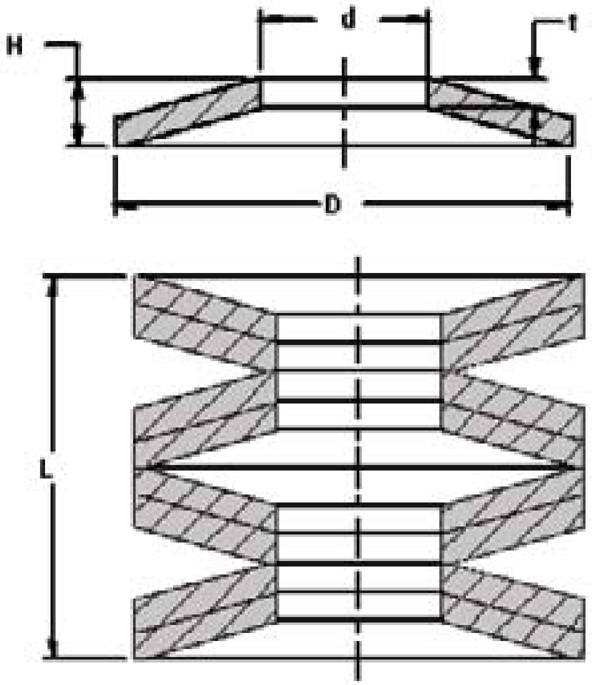


Fig. 4 Spring Washer

Unloaded height of truncated cone of free spring

h = H - t [mm, in] Where:

H = unloaded spring height [mm, in]

t = spring material thickness [mm, in]

Diameter Ratio

$$\delta = \frac{D}{d}$$

Where:

D = outer spring diameter [mm]

d = inner spring diameter [mm]

Calculation coefficient α

$$\alpha = \frac{1}{\pi} \cdot \frac{\left(\frac{\delta - 1}{\delta}\right)^2}{\frac{\delta + 1}{\delta - 1} - \frac{2}{\ln\delta}}$$

Calculation coefficient β

$$\beta = \frac{1}{\pi} \cdot \frac{6}{\ln\delta}\left(\frac{\delta - 1}{\ln\delta} - 1\right)$$

Calculation coefficient γ

$$\gamma = \frac{\delta - 1}{\pi} \cdot \frac{3}{\ln\delta}$$

Limit Washer Deflection

$$s_m = h \quad [\mathrm{mm,\ in}]$$

Where:

h = unloaded height of truncated cone of free spring [mm, in]

Force at Maximum Spring Deflection and Limit Deflection:

$$F_{max} = \frac{4E \cdot t^3 \cdot s_m}{(1 - \mu^2) \cdot \alpha \cdot D^2} \quad [\mathrm{N, lb}]$$

Where:

E = Spring modulus of elasticity [MPa, psi]

t = Spring material thickness [mm, in]

s_m= limit spring deflection [mm, in]

μ = Poisson's ratio

α = calculation coefficient

D = outside spring diameter [mm, in]

Force Exerted by the spring at Deflection:

$$F = \frac{4E \cdot t^4}{(1 - \mu^2) \cdot \alpha \cdot D^2} \cdot \frac{s}{t} \cdot \left[\left(\frac{h}{t} - \frac{s}{t}\right) \cdot \left(\frac{h}{t} - \frac{s}{2t}\right) + 1\right] \quad [\mathrm{N, lb}]$$

Where:

E = spring modulus of elasticity [MPa, psi]

t = spring material thickness [mm, in]

s = working deflection of a spring [mm, in]

p = Poisson's ratio

α = calculation coefficient

D = outside spring diameter [mm, in]

h = unloaded height of truncated cone of free spring [mm, in]

Maximum Pressure Stress in spring at Deflection

$$\sigma = \frac{4E \cdot t \cdot s}{(1 - \mu^2) \cdot \alpha \cdot D^2} \cdot \left[\beta \cdot \left(\frac{h}{t} - \frac{s}{2t}\right) + \gamma\right] \quad [\mathrm{MPa, psi}]$$

Where:

E = spring modulus of elasticity [MPa, psi]
t = spring material thickness [mm, in]
s = working deflection of a spring [mm, in]
p = Poisson's ratio
α = calculation coefficient
D = outside spring diameter [mm, in]
β = calculation coefficient
h = unloaded height of truncated cone of free spring [mm, in]
γ = calculation coefficient

Total Springs in a Set or Stack up

$$\chi = n\, i$$

Where:

n = spring number in a set with unidirectional mounting

i = spring number in a set with opposite mounting or number of sets with unidirectional mounting in a set with combined mounting

Stroke of Deflection of a Spring Set (Stack up)

$$z = i\, s \quad [\mathrm{mm,\ in}]$$

Where:

i = spring number in a set with opposite mounting or number of sets with unidirectional mounting in a set with combined mounting

s = working deflection of a spring [mm, in]

Force Exerted by a Spring Set (Stack up)

$F = n F_1 \quad [N, lb]$

Where:

n = spring number in a set with unidirectional mounting

F1 = force exerted by one washer [N, lb]

Height of Spring Stack up Unloaded

$L_0 = i\,(h + n\,t) \quad [mm, in]$

Where:

i = spring number in a set with opposite mounting or number of sets with unidirectional mounting in a set with combined mounting

h = unloaded height of truncated cone of free spring [mm, in]

n = spring number in a set with unidirectional mounting

t = spring material thickness [mm, in]

Height of Loaded Spring Stack up

$L = L_0 - z \quad [mm, in]$

L0 = Height of spring set in unloaded state [mm, in]

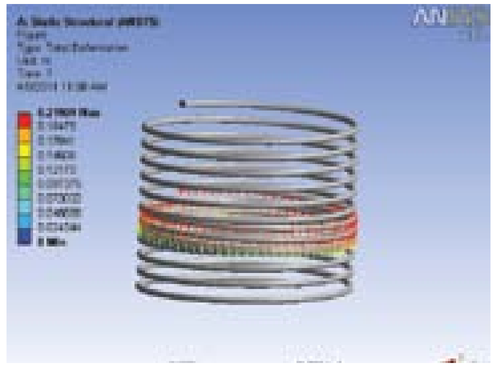
z = Stroke (deflection) of spring set [mm, in]

VI. SPRING ANALYSIS

TABLE 1 MATERIAL STRUCTURAL STEEL

Density	7850 kg m^{-3}
Coefficient of Thermal Expansion	$1.2e^{-005}$ C^{-1}
Specific Heat	434 J kg^{-1} C^{-1}
Thermal Conductivity	$^{6}0.5$ W m^{-1} C^{-1}
Resistivity	$1.7e^{-007}$ ohm m

A. *Helical Spring Analysis*



B. *Belleville Spring Analysis*

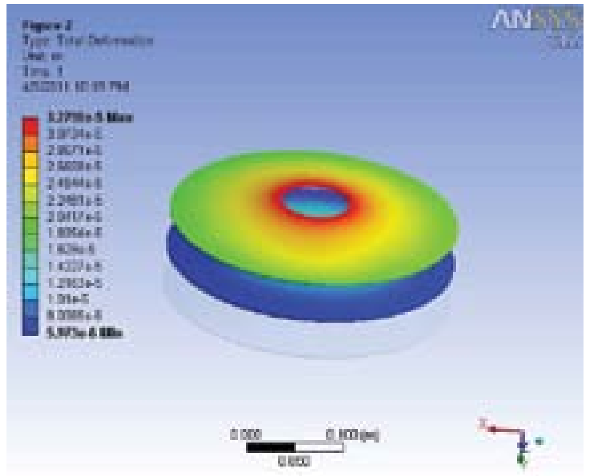


TABLE II OBSERVATION TABLE

Load	Helical Spring Deformation	Belleville Spring Deformation
1	0.024344	0.035
2	0.048688	0.063
3	0.073032	0.093
4	0.097375	0.11
5	0.12172	0.135
6	0.14606	0.165
7	0.17041	0.195

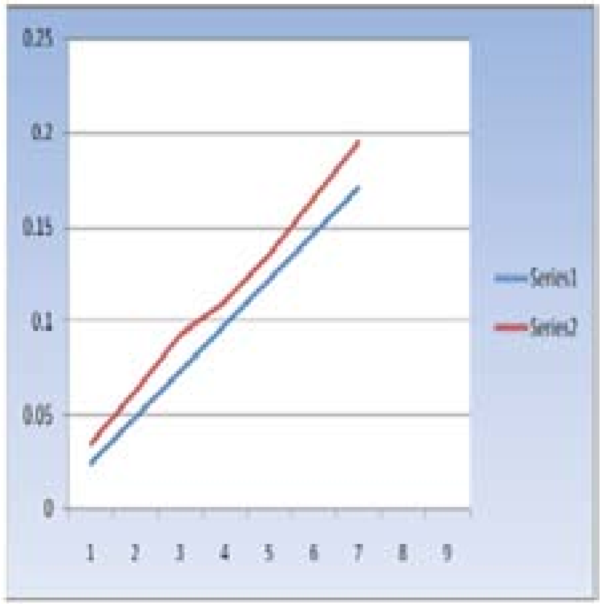


Fig. 5 Graph Deflection Vs Load for Helical and Belleville Spring

X axis- Load

Y axis- Deflection

Helical Spring Deflection

Bellville Spring Deflection

VII. CONCLUSION

New design of aerosol spray considering its aesthetic and ergonomic consideration. Various design carried out in a pro engineer of the aerosol product caps and bottles. Assembly of whole aerosol spray and parts showed different. Shutter mechanism provided for the prevention of leakage in an aerosol spray can draw in pro-engineer.

Use of Belleville spring instead of helical which is conventionally used in an aerosol spray product. Also analysis of Belleville spring done on ANSYS. The effort required for operating the aerosol spray having Belleville spring is much less than conventional helical spring which enables to its use in a specified applications where we can operate the aerosol product with a minor effort.

REFERENCES

[1] John Chadwick, "Particle Size Control in Aerosol Packages", *Spray Technology & Marketing,* December 2004.

[2] D. Chatterjee, A. Datta, A K Ghosh and S K Som, "Effects of Inlet Air Swirl and Spray Cone Angle on Combustion and Emission Performance of a Liquid Fuel Spray in a Gas Turbine Combustor", IE (I) Journal.AS., 2004.

[3] B. Digvijay, B. Kulshreshtha, B. Saurabh, Dikshit and S. A. Channiwala," Variations of Spray Cone Angle and Penetration Length of Pressure Swirl Atomizer Designed For Micro Gas Turbine Engine", *International Journal of Dynamics of Fluids,* 2009.

[4] R.Holownicki, G.Doruchowski, A.Gody and W. Swiechowski, "Variation of Spray Deposit and Loss with Air-jet Directions", 2002.

[5] Developments of the Bonding Mechanism and Process in Cold Gas Dynamic Spray, *Materials Review,* 2007-08.

[6] "Research Developments of Preparing Coatings by Cold Gas Dynamic Spraying", *Materials Review,* 2008-09

[7] "Preparation of Ni-based alloy diamond composite coatings by cold spray", *Materials Research and Application,*2009-01

[8] "Numerical simulation of supersonic free jet flow field in cold gas dynamic spraying technique" , *Welding & Joining,* 2008-09

[9] "The Use of Computational Fluid Dynamic Code for Modelling Spray from a Mistblower", Silsoe College, Cranfield Institute of Technology, Bedford, MK45 4DT, UK. Available 26 April 2002.

[10] "The Bending-deformation Theory of Thick Plates and Its Application to Springs", Application Research on the Negative Stiffness of Disk Spring used in Low Frequency Precision Vibration Isolation, New Technology & New Process, 2009-10