SPRINGS

Springs are broadly classified into four groups depending on the forces applied and these are: Compression Springs, Extension Springs, Torsional Springs, and Constant Force Springs. For our specific purposes, it can be seen that either compression or extension springs have to be used.

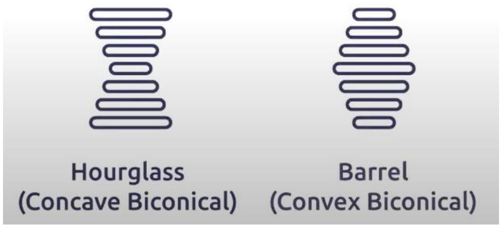
- Compression springs are basically open-coiled springs that are wound to react to mainly compression along its major axis.
- Extension springs are mainly used for absorbing and storing energy while resisting a pulling force. These types of springs mainly come with little to no pitch (gaps between coils) and hence would not apply to our specifications as we would require lateral motion of the spring as well.

Hence it was concluded that compression springs are the ones that suit our needs very well and these springs itself were mainly researched on. Compression springs are further classified into more various types and these are:

- Straight Coiled Springs: These are the most common type of compression spring, consisting of evenly spaced coils with a constant diameter.
    1. Advantages- These tend to have a simple design & manufacturing process and are cheaper to produce than the other types. They also produce a consistent force and therefore provide a predictable, linear force when compressed. They also are very versatile and are available in many sizes so therefore can be used for a wide range of applications.
    2. Disadvantages- These types of springs are very prone to buckling as when they are longer, they buckle very easily under a load when the length exceeds the allowable ratio of the spring's diameter. For our use, we would require a greater length and therefore it would likely buckle and that would be a hindrance for our payload as it means that our object will move faster than it normally should and might make the spring fail due to this buckling action.
- Conical Compression Springs: These springs are designed with a tapered shape, where one end is larger than the other, allowing the coils to nest within each other as the spring is compressed. These tend to be one of the major considerations for our payload as I feel it suits our needs very well *(In-house testing has to be done to check how this would actually compare it with other types of springs)*.

1. Advantages- This type of spring tends to be very space-efficient because the coils can compress into one another, conical springs occupy less space when fully compressed. It also has reduced buckling as the conical shape offers increased stability and reduces the risk of buckling under heavy loads or in longer springs. It also allows it to be accommodated by a wide range of forces since as the spring compresses, the resistance also increases. It also tends to be very versatile.
2. Disadvantages- Tends to be more costly as manufacturing them is highly complex. *(The types of conical springs tend to have very similar features and perform almost similarly, will have to test concave and convex if the standard conical shape will not fit our needs even after testing it).*

- Barrel and Hourglass Springs: Barrel springs have a larger diameter at the center, while hourglass springs have a smaller diameter at the center, resembling their respective shapes.



1. Advantages- Both these designs are heavily optimized to resist buckling, therefore they provide a greater lateral stability when compared to straight coiled springs and conical springs. They also tend to have a very compact design like conical springs. These springs also provide a greater even load distribution as they distribute the load more evenly, reducing the chance of stress concentration on specific coils.
2. Disadvantages- These tend to be very costly to produce due to their specialized shapes and they have to be tested in-house to actually confirm if they will be best for our use.

- Variable Rate Springs: These springs are designed with variable coil spacing (variable rate), providing a progressive rate of resistance as they are compressed.
    1. Advantages- These springs have a progressive force as the spring's resistance increases progressively as it is compressed which makes it suitable for various applications. It tends to have a better performance for dynamic loads as they adjust to different forces over their compression cycle.
    2. Disadvantages- Complex manufacturing therefore leading to higher costs. It has a non-linear response as well due to its variable rate means that the force exerted by the springs changes *which might not make it applicable for our case as our object might move very randomly and very quickly as well (need to test in-house to confirm the same if this spring is required)*.
- Banana (Sideload) Springs: These springs are specifically designed to handle off-center or uneven loads. Their curved design compensates for any side forces that may arise during compression.

    1. Advantages- This is mainly used to handle off-center loads. Their design helps them to remain stable even when side forces are present, which makes them ideal for our payload *(not conclusive- need to test them to confirm this)* where the load may not be evenly distributed. It also prevents uneven wear as it distributes the forces more evenly across the coils, therefore they tend to have extended life periods as compared to the other springs.
    2. Disadvantages- Used only for very specific applications where off-center loads are expected and therefore are not manufactured in bulk and eventually tend to cost appreciably more as compared to other springs.

Conclusion: Every type of these springs serves some or the other purpose in various applications depending on its specific needs, such as:

- Straight coil springs tend to be very versatile and cost-effective but aren't good for situations with limited space or high buckling situations.
- Conical springs are the best to use when limited space is available and higher load stability due to their ability to nest and their reduced buckling risk *(As of now, this seems one of the best options for our payload but would need to test these springs to confirm to what extent they would be useful for us)*.
- Barrel and hourglass springs are mainly used for applications that need high lateral stability and buckling resistance *(not enough conclusive evidence if these springs would work for us, need to test them to conclude if they will be useful for us)*.
- Variable rate springs tends to offer progressive force and are best for applications that have varying load requirements *(tend to have a non-linear response so might not work for us; we need to test these springs to conclude if they will be useful for us or not).*
- Banana springs are used for specific applications involving side loading or off-center forces, thereby providing greater stability and preventing uneven wear *(might be useful for our payload but will have to test them to conclude the same and it will cost more as these springs aren't readily available and would have to be custom made itself mainly.)*

References:

[1] The Advantages of Using Conical Springs Over 70 Trillion Custom & Stock springs

[2] Overview of The Different Types of Compression Springs

[3] The Uses and Benefits of Conical Compression Springs - KB Delta

[4] Types of Springs and their Applications: An Overview | Fictiv

Companies Talked With (didn't get far with any of them and didn't get far as our specific requirements weren't met. Talked with Indian companies as well but no response at all from them).

Tokai Spring industries, Inc.

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