A New Calculation Method for Belleville Disc Springs with Contact Flats and Reduced Thickness

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ABSTRACT

A new calculation method for disc springs with contact flats and reduced thickness is presented in this paper. The analysis aims at putting in evidence the contradiction in standard norms where the standard calculation method for this kind of Belleville springs is used. On the basis of this analysis it is found that standard methods do not work for reduced disc springs because they lead to dangerously wrong results and software developed during this study shows how it is possible to create a new type of standard tables for this kind of springs.

Keywords: Belleville Springs, Coned Springs, Contact Flats, Disc Springs, Reduced Thickness

INTRODUCTION

In 1867 Julien François Belleville of Dunkirk was granted French Patent Number 52399 for the design of a new kind of spring.

That spring was actually a conical shell which could be loaded along its axis either statically or dynamically with the possibility to use not only a single spring but also a stack of springs.

During the last several decades, thanks to their advantageous properties if compared with other types of springs, coned disc springs (also called “Belleville springs”) have been adopted in nearly all areas of technology from the creation of vertical seismic isolation systems (Kitamura, 2003) to the developing of tester for bolt torques in the wind tower field (Abasolo, 2011).

Compared with helical springs, using the same dimensions, disc springs can support a larger load and spring characteristics can be designed to be linear, regressive or, with a suitable arrangement, also progressive.

Furthermore, in comparison with helical springs, if the spring is properly dimensioned, it is possible to obtain a higher service life under dynamic loads.

The most known paper about disc springs is unquestionably the one by Almen and László (1939) and its results are still used as standard method in norms as DIN 2092 (2006) or UNI 8736 (1985) to calculate stresses and displacements in coned disc springs.
Figure 1 shows the cross-section points I, II, III, and IV of a uniform thickness coned disc spring.

Almen and László based their theory on experimental observations according to which the cross-section of the spring merely rotates about a neutral point $S_0$ (assumed to be on the middle line of the cross-section) without undergoing an appreciable deflection.

They agreed with Timoshenko in regarding the radial stresses as negligible and succeeded in calculating tangential stresses and displacements of a coned disc spring subjected to an axial load $F$ uniformly distributed on inner and outer edges (Timoshenko, 1934).

The Curti and Orlando based their hypothesis on the resemblance of fleebly coned springs with circular flat thin plates and they succeeded in calculating not only displacements and tangential stresses, but also radial stresses. However, they concluded with a finding of very low radial stresses and suggested further theoretical and experimental analyses for a more complete evaluation of coned disc springs (Curti & Orlando, 1979).

In standard norms as DIN 2092 (DIN, 2006) and DIN 2093 (DIN, 2006), it is also described a particular kind of disc springs: disc springs with contact flats and reduced thickness.

For disc springs with a thickness of more than 6.00 mm, DIN 2093 specifies small contact surfaces at points I and III in addition to the rounded corners. Figure 2 shows a schematic cross-section of a spring in group 3 as per DIN 2093:

The aim of contact flats is to improve the definition of the point where the load is applied and, particularly for spring stacks, to reduce the friction at the guide rod. The result is a considerable reduction in the lever arm length and a corresponding increase in the spring load,

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Figure 1. Section of a disc spring with uniform thickness

Figure 2. Section of a disc spring with contact flats and reduced thickness, $t'$
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