

ON OPTIMAL WAVE SPRING

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Abstract

Having limited space in both radial direction and axial direction we can use a wave spring as an alternative to Belleville springs. Wave springs are not used as much as the standard helical springs although the design has been known for more than half a century. Depending on the dimensions of the wave spring the load deflection characteristics can vary significantly. The main difference to the helical spring is that the loading is primarily bending with some torsion.

The wave springs are either stamped or alternatively, they can be formed by wire bending. In the stamping process we achieve a single closed ring with a given number of waves. Alternatively the wave spring can be made by wire bending. For all wave springs the design is such that the spring will expand radially during axial loading. This is also the case for an axially loaded helical spring but to a smaller degree. The radial displacement depends on the wave number. For a traditional wave spring with a rectangular cross section the outer rim has a radial displacement that is smaller than the inner rim. This causes the cross section to rotate during the axial loading. Depending on the unloaded spring geometry this will cause a change in the contact points between the spring and the surrounding structure.

In the present work the wave springs are investigated numerically, using a full 3D finite element analysis, primarily for finding the force-deflection curves. It is shown that we can obtain linear, bi-linear or general non-linear characteristics by changing the geometry. The found numerical stiffness is compared to analytical expressions found in the literature. Further it is investigated how the axial loading influences the radial displacement and the associated cross-sectional rotation.

In the numerical evaluation it is found that the spring material, for a standard spring design, is unevenly loaded. Simple design modification can lead to significantly better designs. Relating the average von Mises stress to the maximum von Mises stress in the spring shows for a single design case, that improvement of more than 220% is possible.