Tolerances analysis on a nitrogen spring

Founded in 1978 to produce mechanical wire die springs, Special Springs has quickly became the first company worldwide to manufacture three different product lines complying to three different standards: ISO 10243, JIS B5012 and US Oval Wire. At the end of the 80ies, it also started the production of nitrogen gas cylinders to complete its offer. At the same time Special Springs introduced a series of hexagon socket head shoulder screws 12.9, still unreached for its geometric al mechanical qualities. In 2012 Special Springs gathered in a single plant the production of wire springs and nitrogen gas cylinders covering an area of 16.500 sqm.

Raw materials and thermal treatment processes, as well as any other kind of analysis, are quickly and continuously controlled thanks to a complete internal metallographic laboratory, equipped with the most advanced tools and management software.

Reliability tests are continuously performed in order to maintain and improve the performance of Special Springs products. The two test centres, specifically focused on wire springs and nitrogen gas cylinders, are always at customers' disposal to perform duration tests in relation to the application specifications.

The use of the most advanced software for 2/3D design allow Special Spring technicians to investigate, develop and design products according to the highest standards of reliability and safety.

The project

Special Springs products catalogue includes several different kinds of nitrogen springs. Each type of spring is characterized by the force range that it is able to exert and by its size. As shown in Figure 1, the tolerance associated to the spring height is about ± 0.25 mm, a value which is guaranteed by Special Springs to its customers. The width of the tolerance zone of 0.5 mm, applied to the vertical dimension of the springs, is an objective that Special Springs is able to reach with the productive processes and the related technologies currently available. This generates a very low number of scraps of "out of tolerance" products, about a 0.5 %. Something has changed in this very successful scenario, when an important customer made a challenging request to the company: to guarantee a dimensional tolerance on the springs total height of ± 0.10 mm, thus reducing the initial value of ± 0.25 mm. At this stage it became necessary for Special Springs to understand the repercussions due to this reduction of the tolerance applied to the height on its own products, and in particular: how much would the "out of tolerance" scraps increase? Assuming that the percentage of scraps remains unchanged, which modifications should be required, thus generating the minimum possible costs?

In order to find an answer to these two questions, Special Springs has instructed EnginSoft to investigate the tolerance analysis on a nitrogen spring. The tolerance analysis is based on a statistical approach in order to understand how the tolerances applied to the single nominal dimensions of the project affect, combining themselves, the final size, that may represent, as in this case, a very important product requirement.

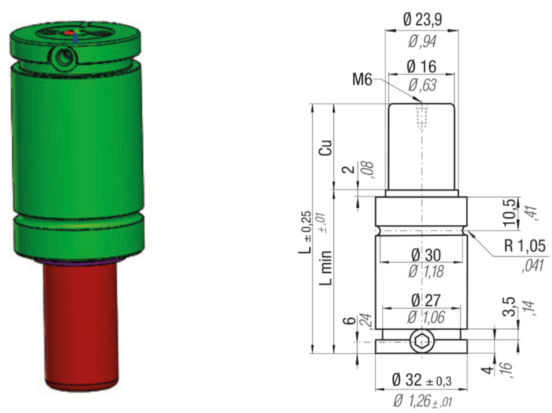

Fig. 1 – Simplified CAD model of a nitrogen spring under investigation and definition of vertical dimension with related tolerance of ± 0.25 mm

The development of the model

The model of the tolerance analysis has been built using the Cetol 6σ software, developed by the American company Sigmetrix.
The development of the model consists of the following phases:

- *Definition of the contacts between the single parts of the assembly*. The software allows to define in a flexible way any kind of kinematic joint, managing the single degrees of freedom which are constrained. Cetol 6σ has furthermore advanced functionalities that allow to automatize this phase, thus dramatically reducing the development time of the model. In particular, when the assembly constraints are set in the 3D CAD, Cetol 6σ is able to read and to import them inside the model. The single parts of a nitrogen spring that are involved in the model are four: body, ring, bush and rod (Fig. 2). The rod rests on the bush in the area of the upper flange.; the bush is then constrained to the body by means of the ring that keeps it in the right place using the groove in which it is hosted.
- D*efinition of the scheme dimensioning of the single parts.* This phase consists of the translation of the information included in the 2D drawings: the dimensions and the related tolerances (both dimensional and geometric) are included in the model and represent the quantitative information on the place variability and the relative orientation between plains, the axis, surfaces, etc. Furthermore, if datum notes (DRF – datum reference frame) are present in the 3D CAD model, dimensional and/or geometric tolerances, the software can one come identify and manage them automatically, Such information are imported in the model avoiding redundant action in the 3D CAD.
- *Definition of the target size and analysis execution.* Following the procedure described in the model, only some parts of the assembly are considered, that is those affecting the size to be calculated; the height, in this case. The method of constraints creation between the single parts of a set used by Cetol 6σ allows to take into account in an automatic way only the geometric characteristics that somehow influence the size. The advantage is that of neglecting the total geometric complexity of the single parts, since it is not required by the objective under investigation: practically speaking this means a great saving of time in the model set-up phase.

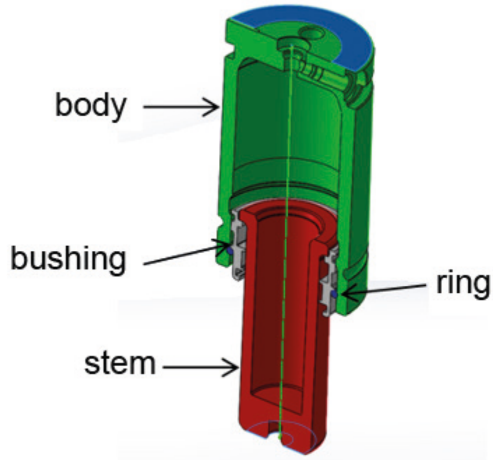

Fig. 2 – Identification of the assembly parts that directly affect the dispersion of the height value around the average value

Achieved results

A first calculation has been performed to validate the obtained model: at a nominal value of height of the nitrogen spring of 138.10 mm, a ±0.25 tolerance has been applied. The achieved result (Fig. 3) is in line with the experimental results obtained by Special Springs on the height size of the nitrogen springs. After the validation, a new customer's requirement has been applied to the calculated distribution, that is the width of the tolerance zone of ±0.10 around the nominal value. This has allowed to estimate a scrap percentage of about 24.3% in the current production conditions and with the available technologies (Fig. 4)
Summarizing, in the case Special Springs would satisfy the customer's requests, it would mean to forecast a 25% of scrap products.

This information can be used to estimate the costs and therefore for a more reliable quotation.
The tolerance analysis does not only provide such information. It is possible to identify the tolerances that mostly affect the dispersion of the statistic distribution and to act so to meet the requirements with the minimum impact as far as costs are concerned.
The tolerance with the highest impact on the dispersion of the height values around the average calculated value is corpo;alloggiamento_@anello;to_topPlane (see Fig. 5), with a nominal value at drawings of X mm (tolerance ISO 2768-mK: ±0.20 mm). Fixing the tolerance at this

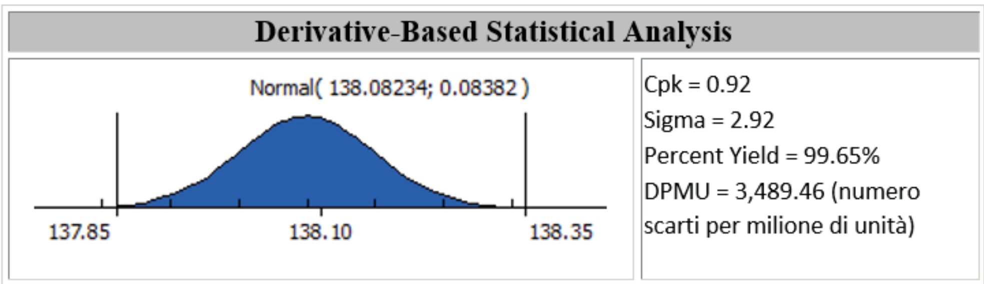

Fig. 3 – Statistic distribution of the nitrogen spring height requiring a tolerance of ±0.25 mm. The tolerance analysis foresees a scrap value of about 0.35%

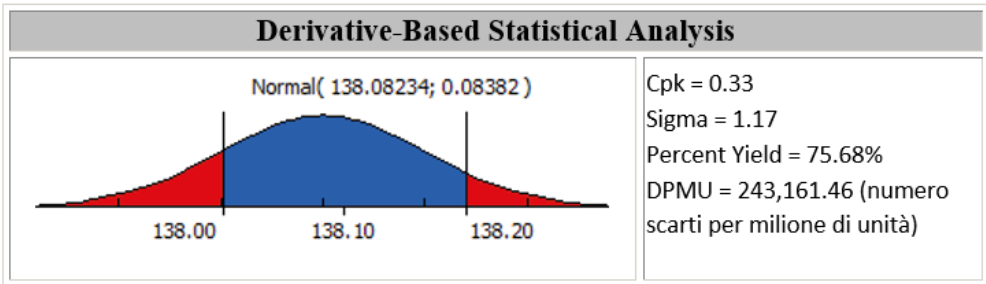

Fig. 4 – Statistic distribution of the nitrogen spring height requiring a tolerance of ±0.10 mm. The tolerance analysis foresees a percentage of scrap products of about 24.32%

Name	Label	Value	Contribution (>= 1%)
corpo;1 / alloggiamento_@anello / to topPlane	D-6	X 6.09 ±0.20	64.32%
corpo;1 / topPlane / to A	B-1	85.00 ±0.10	16.08%
boccola;1 / alloggiamento_@anello / Minor Size	C-4	Y 1.35 ±0.10	5.64%
corpo;1 / alloggiamento_@anello / Minor Size	E-7	Z 1.35 ±0.10	5.60%
stelo;1 / topPlane / to contact_@boccola	B-1	71.00 ±0.05	3.95%
boccola;1 / alloggiamento_@anello / to bottomPlane	B-1	A 8.91 +0.05 -0.00	1.00%
boccola;1 / bottomPlane / to topPlane	C-1	23.50 +0.05 -0.00	1.00%

Fig. 5 – Tolerances and related dimensions with the highest influence in terms of percentage on dispersion of the height value of the nitrogen spring in comparison with the average value. Percentage contribution on the standard deviation. In the "label" column, there are the drawing coordinates, where the dimensions are present

size at ±0.05 mm, the products satisfying the height requirement of ±0.10 go from about 75% to 92% roughly (Fig. 6).
The second tolerance with the highest impact on the dispersion is corpo;topPlane;to_A with a nominal value at drawings of 85.00 mm (tolerance ±0.10 mm). Reducing this tolerance to ±0.05 mm, it is possible to reach an efficiency of about 96.5% (Fig. 7).

The average value of the calculated distribution is different from the nominal one. This is due to the presence of non-symmetrical tolerances in relation to the nominal values in the model. In particular the tolerance with the highest impact on the average value displacement is: boccola;bottomPlane;to_topPlane (23.5 +0.05 -0.00 mm). Keeping the width of this tolerance zone, but changing it into 23.50 +0.03 -0.02 mm, it is possible to achieve a centred process with an efficiency of the 97.6% (Fig. 8).

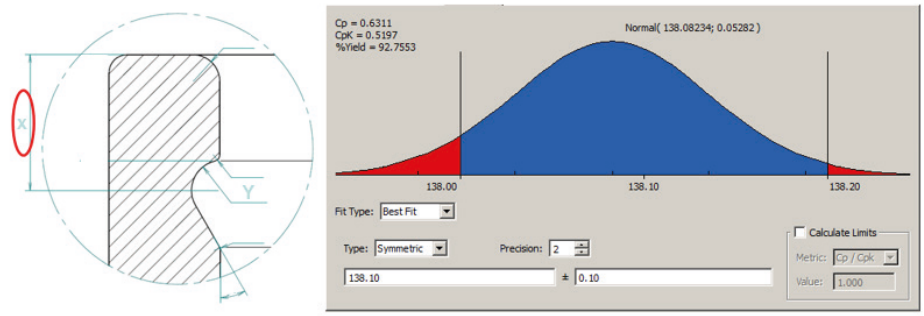

Fig. 6 – Definition of the dimension corpo;alloggiamento_@anello; to_topPlane and statistic distribution of the nitrogen spring height with tolerance requirement of ±0.10 mm as a consequence of the tolerance reduction of X mm from ±0.20 mm to X ±0.05

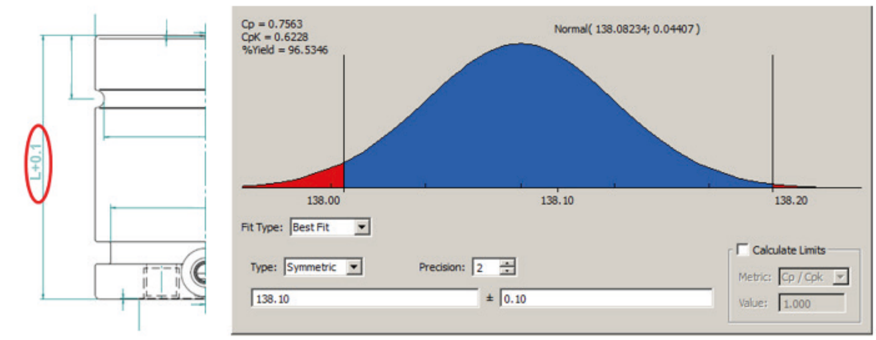

Fig. 7 – Definition of the dimension corpo;topPlane;to_A and statistic distribution of the nitrogen spring height with tolerance requirement of ±0.10 mm as a consequence of the tolerance reduction from 85.00 ±0.10 mm to 85.00 ±0.05 mm

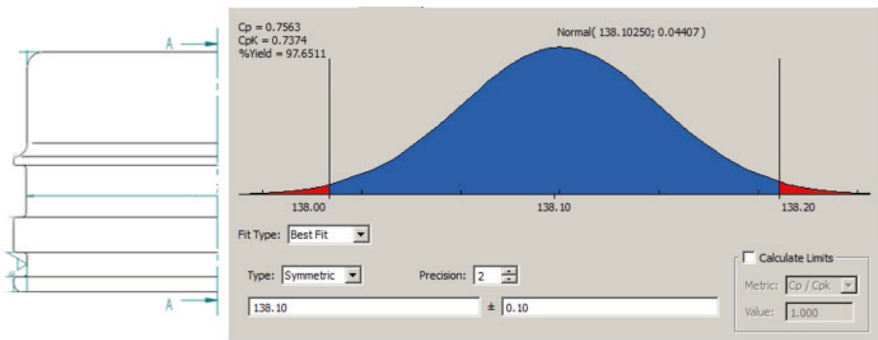

Fig. 8 – Definition of the dimension boccola;bottomPlane;to_topPlane and statistic distribution of the nitrogen spring height with tolerance requirement of ±0.10 mm as a consequence of the displacement of the tolerance zone from 23.5 +0.05 -0.00 mm to 23.50 +0.03 -0.02 mm

Conclusion

By means of the propagation of the tolerances inside the dimensional chain it has been possible to identify the dimensions and the tolerances of highest impact on the functional size and therefore it has been possible to act on the reduction of possible scrap products, avoiding to manage them in a general way, that is reducing tolerances in an indiscriminate way.

Such result can be achieved reducing just two tolerances, among the hundreds of them present in the project drawings and the displacement of the third tolerance, keeping its width value (no influence on the production costs, since it is not necessary any further precision machining).
The activity carried out by EnginSoft has allowed Special Springs to identify the dimensions and the related tolerances to maintain and verify the quality to meet the product requirement requested by the final customer. The requirement is met assuming that all parts are produced respecting the tolerance they have been assigned by the project.

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