Analysis of the structure of a precision winding using computer simulation

V A Kolesnikov¹, N V Rokotov¹

¹Department of Mechanical Engineering, Saint-Petersburg State University of Industrial Technologies and Design - 18, Bolshaya Morskaya, Saint-Petersburg, Russia

mash@sutd.ru

Abstract. The article presents the results of computer simulation of winding structures. With random winding, a significant change in the structure of the winding product occurs even with a slight increase in the diameter of the package. With precision winding, slight deviations in the pitch of the winding of the thread lead to a significant change in the structure of the winding product.

1. Introduction

The most common approach in the study of the structure of winding products is described below. It is necessary to select one of package edges and record points where wound thread reaches this edge. The location of the sequence of these points characterizes the structure of the resulted winding product. This approach, widely used by researchers, does not fully give an idea of the mutual arrangement of the threads and their distribution both over the layers and surface of the winding body [1]. The properties of a winding product are determined by many factors, including cross-sectional dimensions and properties of the wound thread, its tension, thread winding angle, force applied by the press roller or friction cylinder, etc. The structure of winding product has dramatic influence on its properties.

2. Simulation method

To obtain a visual representation of the structures of the winding product, as well as to study the patterns of formation of the structures of winding bodies, algorithm and software have been developed in the MATLAB environment, which allows you to build the location of the cross-section of each individual thread, which reaches set cross section of the package. The position of the package section is set by angle \( \varphi \), measured from the initial position of winding body.

Upon modeling, it was assumed that the deformation of the thread that occurs during winding due to the effect of the lower and upper layers is not considered, and the cross sections of the threads are represented by circles, the diameter of which is equal to the diameter of the undeformed thread.

The following data were taken as the initial data during modeling: the length of the thread \( B \), winding pitch \( H \), thread diameter \( d \) and initial diameter of the wound package \( DN \).

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Figure 1 shows the structures obtained by simulating the random winding method \((d = 0.3 \text{ mm}, \text{the angle of the hoisting angle } 17.5127^\circ)\) with increase of diameter from 95.0 to 95.5 mm. It should be noted that the structure of the winding product changes with increase of package diameter. This is due to the fact that upon random winding there is no rigid kinematic connection between the bobbin holder and traversing mechanism, reduction ratio between them changes during winding, which also results in change of structure.

Figure 2 shows variants of the structure of the winding product at precision winding \((d = 0.3 \text{ mm}, \text{Dn} = 95 \text{ mm})\). Upon precision winding, reduction ratio between traversing mechanism and the bobbin holder remains constant throughout the entire winding cycle. Thus, winding pitch and its structure do not change. The package structure varies greatly even with a slight change in the pitch of thread coils. Sudden changes in the structure are observed when pitch changes by tenths or even hundredths of a millimeter.

Figure 2 shows honeycomb winding that has loose structure. At pitch increment of 0.007 mm (Figure 2, b), the package structure becomes quite dense and coils are laid almost close to each other, forming the so-called closed winding. When increment changes by 0.001 mm (from 96.65 mm to 96.651 mm), the structural density of the package [2] appreciably increases (Figure 2, e, f). As a result of modeling, it was established that such an alternation of dense and loose structures occurs even with insignificant change in winding pitch, and intermediate structures are formed between these structures. These examples of these structures are shown on Figure 2, c, d, e.
3. Results

The main disadvantage of precision winding is the reduction of the winding angle with increase of package diameter due to the fact that the winding pitch remains constant. When the smallest possible angle is reached, the package becomes unstable and the coils tend to stall at the edges. To prevent this phenomenon, so-called stepwise precision winding method is used. The essence of this method lies in the fact that reduction ratio is kept constant at certain winding stages, between which it changes sharply in order to maintain the angle of winding of the thread within specified limits. This stepwise sharp change should occur in such a way that the packaging structure does not change significantly. This can be reached by maintaining the same second-order pitch [2]. First, it is necessary to diameters D at which the value of coil winding angles $\alpha$ reaches the maximum permissible value considering current coil pitch H. Then, it is necessary to determine coil pitch, at which winding angle will be within given range. Based on the described methodology, we have selected values of pitches and modeled structures shown on Figure 3.

Figure 2. Results of modeling. Precision winding, all dimensions are shown in mm: a) H=96; c) H=96.007; d) H=96.01; e) H=96.03; f) H=96.65; g) H=96.651
**Figure 3.** Simulation results. Stepwise precision winding, all dimensions in mm:

- a) $D=95$, $H=120.039$, $\alpha=21.55^\circ$;
- b) $D=105$, $H=153.92$, $\alpha=25^\circ$;
- c) $D=135$, $H=200.199$, $\alpha=25.17^\circ$;
- d) $D=175$, $H=250.499$, $\alpha=24.30^\circ$

4. Conclusion

Figure 3 shows that in case of stepwise precision winding having a dense closed structure, the structure changes slightly with increase if diameter due specially selected parameters (thread diameter 0.98 mm). In this case, the angle of winding of the thread, in contrast to the classical precision winding, is within the specified limits. The limits for change in thread winding angle are set directly by the developers, and the smaller the allowable range of changes in winding angle, the more often a sharp change in reduction ratio occurs. Thus, stepwise precision winding combines the advantages of random and precision windings.

References

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