FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol.1, N° 9, 2002, pp. 1127 - 1133

DESIGN AND CALCULATION OF RING SPRINGS AS SPRING ELEMENTS OF THE WAGON BUFFER

UDC 62-272.43:623.435

Jovan Nešović

Faculty of Mechanical Engineering Kraljevo, Dositejeva Street 19, 36000 Kraljevo
E-mail: javor@ptt.yu

Abstract. *This study represents a modern approach to design and calculation of ring springs which are used as spring elements of the wagon buffers. During exploitation these springs are exposed to an effect of the longitudinal forces of great intensity, there are intensive friction, wear as well as great surface pressure on the adjacent tapered ring surfaces. All these specifications should be taken into consideration during design and calculation and beside that, ring spring has to satisfy recommendations of UIC connected with: capacity, space capacity, final force, working capacity, etc. A modern approach to design includes mathematical (theoretical) model combined with simulation model in order to get main indices connected with the quality of future work. The results of these analyses are confirmed by experiments, too. The experiments are done on the ring spring for "B category" buffer (capacity 50 kJ).*

Key words: *ring spring, working capacity, stress, simulation, tests.*

1. INTRODUCTION

Reflecting devices which are set on the face sides of wagons are responsible for amortizing of longitudinal blows which exist during work. The biggest forces which work along buffer centre line appear during shunting (forming) of train, in other words during collision or blow of wagons themselves. Since there is a striving for increasing of transport efficiency of each wagon, more exactly for expanding of live load transport, increasing of moving and shunting speed, for reducing waiting time, it leads to great increase of longitudinal forces. By amortizing of longitudinal blow, buffers protect the wagon construction itself as well as transport load (which is transported). The quality of the buffer work primarily depends on the quality of built - in spring element, (system) and nowadays a few types of spring elements are used in the world: steel spring, rubber spring, hydraulic systems, devices based on elastic and devices made of TECS PAK material. Ring spring as one of the types of spring elements which are built in wagon buffer, accepts a certain

Received January 13, 2003

quantity of kinetic energy (energy of wagon hit) turning it into potential energy of spring deformation. One part of the accepted energy returns the system in the original state and the other part is spent on work of frictional force and is turned into heat. The quantity of energy which spring element accepts is called **capacity**, and the quantity of energy which is spent on work of frictional force is called **working capacity.** These two characteristics represent a base for choosing types of spring element which will be used in wagon buffers.

2. BASIC CONDITIONS WHICH SPRING ELEMENT OF THE WAGON BUFFER SHOULD FULFILL

These conditions are connected with capacity, dumping of the blows, temperature influence, wear, working age and capacity.

Deformation work (capacity)

Capacity is one of the most important characteristics while estimating some spring element. Spring elements can be with linear and progressive characteristic. Spring systems with linear characteristic have much smaller final force than those elements with progressive characteristic for the same deformation work. Since this force is directly taken in the construction (causes constraint of train), the conclusion can be that from this point of view spring elements with linear characteristic are much more favorable. During wagons' collision (project collision at wagon testing or collision while train forming) behavior of spring elements represents dynamic characteristic and for wagons moving static diagram is competent, because wagons move at relatively small speed in relation to each other. It is desirable for these two characteristics to be similar.

Dumping

Dumping is very important for a big dumping disable the appearance of resonance during braking in a group of vehicles, because performed blows quickly become weak. Analytic dependence of decrease of collision energy is given by formula:

$$\frac{E}{E_o} = (1 - D)^{2n} \tag{1}$$

In this formula, D represents the dumping factor and n a number of oscillations. The dumping factor is about 0.65 with ring spring and that means that after the first oscillation energy reduces to 12.25% of the original and after the second oscillation to 1.2 % of the original.

Temperature influence

UIC predicts that characteristics of spring elements should not deviate in region Đ 40°C to 60°C more than 20% concerning characteristics at temperature of 15°C.

Wear and working age

Spring elements must have a big resistibility to wear and a long working age. Working characteristics with regulated maintenance should stay within the limits for a longer period.

Working capacity

The working capacity of some spring element is very important for calculation of its quality of work. It represents a lose of blow energy and that is the energy which is spent on work of friction force between adjacent surfaces of rings at ring springs. It is determined from the formula

$$A_{\mu} = A' - A'' = (F' - F'')\frac{f}{2} \cdot \qquad (2)$$

Where:

A' - deformation work of spring,
A'' - energy of reverse shift,
f - total deformation of spring,
F' - final force at load and
F'' - final force at unloading.

The dependence of working capacity of ring spring on cone angle β and coefficient of friction μ is given on Fig. 1.

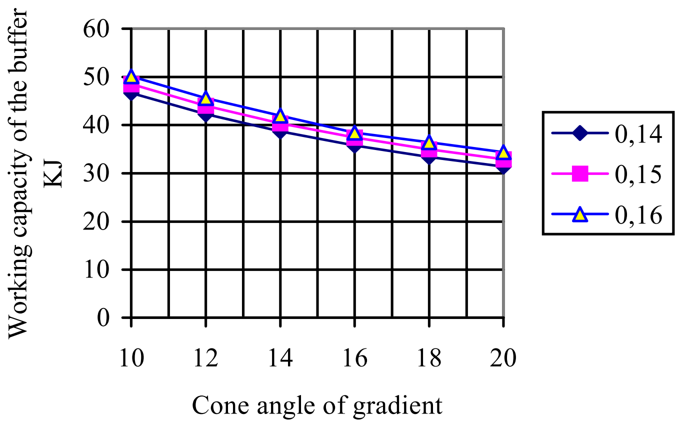


Fig. 1. The diagram of the dependence of working capacity of ring spring

3. Geometric calculation of ring spring and working characteristics

During calculation of geometric characteristics of ring spring, certain limits and demands must be satisfied:

– space capacity,
– magnitude of max deformation,

– capacity and working capacity, and
– material that is used for manufacture.

The dimensions of ring spring directly depend on space capacity in wagon buffer. The outer diameter of the outer ring has to be smaller than the internal diameter of the buffer (200mm) and d_s=196 mm is often adopted. The length of the spring in unloaded state is approximately the same as the length of the buffer ($L \approx 620$ mm), while the length in compressed state is $L'' = 470$ mm. The total number of rings is from 17 to 23.

The total deformation at the end of the process of compression of the spring in the buffer is equal to a sum of deformations:

– deformation during affixture of rings with central screw,
– deformation during fixing a buffer plate, and
– spring shift during work (UIC regulates shift h = 105 mm).

Since spring shift is limited by UIC regulations, then magnitude of accepted work depends on final force. That final force causes constraint of rings (extension on outer and pressure on inner) and dimensions from a viewpoint of strength depends on this force. Working capacity depends on friction on contact surfaces of the rings and cone angle of gradient. Using the diagram (Fig. 1) for appropriate coefficient of friction and wanted working capacity, we can easily determine necessary gradient of the rings β.

The material of the rings has to be with good mechanical and thermal characteristics, with precise regulated chemical composition by UIC, and they are spring steels S 4831 and S 4230.

By using basic formulas of theory of elasticity for calculation of ring breadth, spring rigidity at load and unloading, working stress on inner and outer rings, a program is made for calculation of dimensions and working characteristics of ring springs. Starting data are adopted for one of the possible design solutions of ring spring for " category B " buffer: a number of rings $z = 21$, max spring deformation f_{ax}=153 mm, cone angle of gradient $\beta = 11{,}5^o$, coefficient of friction on contact surfaces of the rings $\mu = 0.15$ and final forces F = 1000 kN.

By calculation using developed program for previous mentioned input data, we got the following geometric magnitude of the ring spring:

– height and breadth of the rings h_s = 44 mm, h_u = 45 mm, b_u = 13,6 mm, b_s = 16 mm,
– spring rigidity: at load $c_o = 9177.09$ N/mm, at un loading c_r = 1586.55 N/mm,
– stress on rings: σ_{ts} = 1276.8 N/mm^2, σ_{tu} = 1468.95 N/mm^2 and
– working capacity $A_\mu = 41{,}73\ kJ$.

The working diagram of the project spring is shown on Fig. 2. The point of outjump can be seen on the diagram of working characteristic of the spring. The spring has less rigidity up to that point (line rigidity of smaller gradient) than after it (rigidity line is steeper). This is the result of the split inner rings (there are two of them) which can be deformed easier than others until they touch each other with their split surfaces (in the point of outjump) and begin to behave as unsplit (the spring has more rigidity). This is very important because it enables easier assembly, in other words a connection of the rings by central screw and easier deformation of the spring while putting it in the buffer itself.

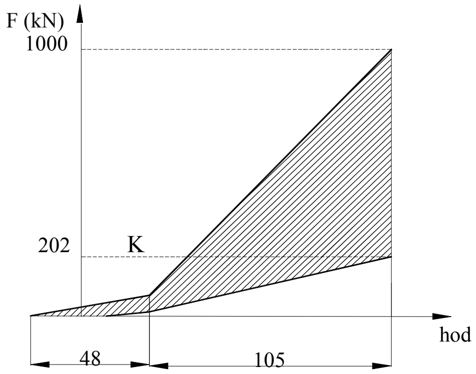
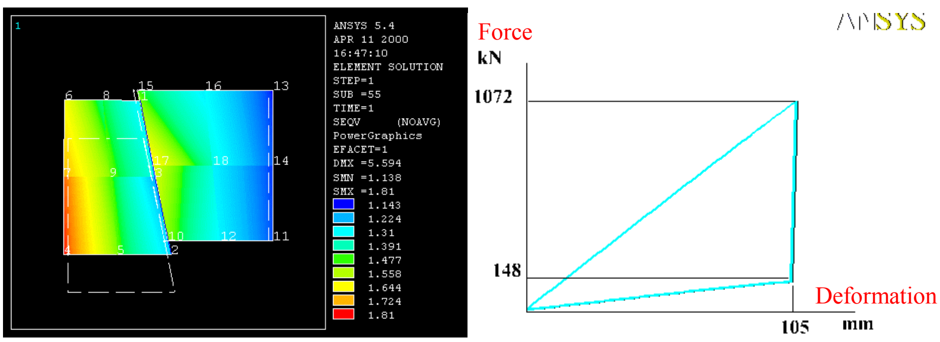


Fig. 2. Working characteristic of the project spring

4. Simulation of work of the ring spring

In order to analyse the problem of work of the ring spring by the method of finite elements, it's necessary to simplify the model in some way. We assumed that the construction of the ring spring was axial - symmetrical as well as load. Dissymmetry is given to construction by the central split inner rings. However, during assembly of the spring into the wagon buffer, they should rest with their split surfaces so that the construction can be considered as symmetrical during work. Since the construction is axial - symmetrical as well as load, analyses will be done by axial - symmetrical finite elements.

We are going to use isoperimetric four truss joint axial - symmetrical elements during analysis. Since the spring consists of 20 segments (the sliding combination of cone surfaces of outer and inner rings), we will observe behaviour of one of these segments in work. Analysis of work of outer and unsplit inner ring is also done. Sliding of cone surfaces is described by contact boundary conditions, by introduction of mean coefficient of friction which appears here. Because of that we used a special type of finite elements, so - called GAP elements.



a) b)

Fig. 3. a) The field of actual stress at the end of the process of compression of spring, b) working diagram, got from calculation of MKE

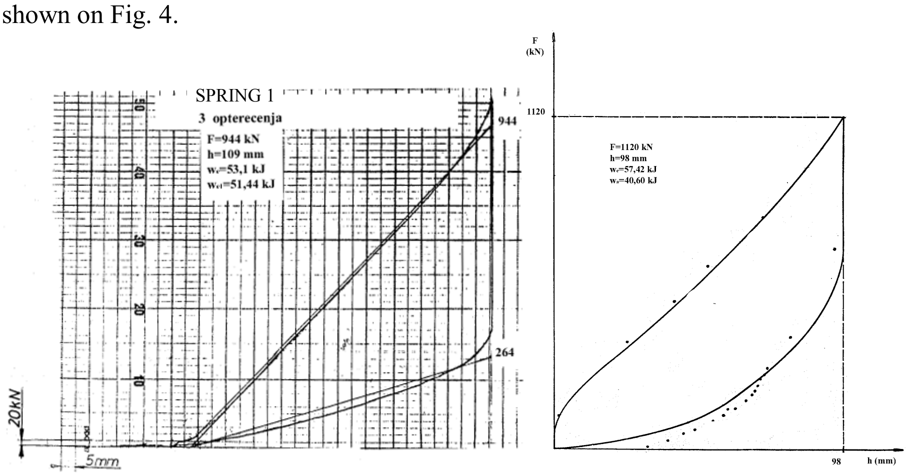
The calculation included linear and non-linear analysis, for during spring max shift of 105 mm actual stress σ_{eu} = 1872 N/mm^2 appeared on interior of inner rings which is bigger than R_{ep}= 1620 N/mm^2 for this material Fig. 3.a).

By supplemental non-linear analysis it is shown that the influence of plasticity is small (σ_p = 1.42 N/mm^2) and since it is placed in a narrow zone, it can be neglected.

The working diagram of the spring, got by this analysis, is shown on Fig. 3.b. It is almost identical with a diagram got by mathematics calculation.

5. Experimental tests

Experimental tests of working capacity of ring spring include static and dynamic tests. Working capacity at static tests is got by testing characteristic of ring spring, and working characteristic got by this testing is shown on Fig. 4. At dynamic tests working capacity of spring element can be seen while testing for protection of construction; working capacity shown on Fig. 4.



a) b)

FIg. 4. Working characteristic of ring spring
a) static characteristic (A_μ = 40.74 kJ), b) dynamic working characteristic

6. Conclusion

The methodology of calculation of dimensions and working characteristics of ring spring, which is used in wagon buffer shown during work, includes analytic calculation combined with simulation model (calculation by MKE). Values of characteristic dimensions are almost identical in calculations done by both methods. We can conclude that these two methods complement each other and serve for fine adjustment of dimensions and for wanted spring characteristics. By supplemental experimental analysis, we can draw a conclusion that the difference, which appears, between theoretical calculations and experiment is smaller than 4%. Therefore, we can conclude that all the limitations and assumptions while modeling the construction are chosen well and that this methodology can freely be applied in practice.

REFERENCES

1. J. Nešović: Istraživanje radne sposobnosti prstenastih opruga odbojnika vagona, Magistarski rad, Mašinski fakultet Kraljevo, 2000.
2. M. Ognjanović, V. Miltenović: Mašinski spojevi, Građevinska knjiga, Beograd, 1993.
3. J. Friderichs, K. Buttler: Berechung der Stoβeinrichtungen fur Eisenbahnnjagen, Krefeld, 1987.
4. Grupa autora: Inženjersko mašinski priručnik 2 i 3, Zavod za udžbenike i nastavna sredstva, Beograd 1992.
5. P. Orlov: Fundamentals of Machine Design 5, Mir Publishers – Moscow 1980.
6. M. Kojić, R. Slavković, M. Živković, N. Grujović: Metod konačnih elemenata - linearna analiza, Mašinski fakultet Kragujevac, 1998.
7. T. R. Chandrupatla, A. D. Belegundu: Indroduction to Finite Elements in Engineering, New Jersey, 1991

PROJEKTOVANJE I PRORAČUN PRSTENASTIH OPRUGA KAO OPRUŽNIH ELEMENATA ODBOJNIKA VAGONA

Jovan Nešović

U ovom radu je dat jedan savremen pristup pri projektovanju i proračunu prstenastih opruga koje se koriste kao opružni elementi odbojnika vagona.U toku eksploatacije ove opruge izložene su dejstvu podužnim silama velikog intenziteta, prisutno je intenzivno trenje, habanje, kao i veliki površinski pritisci na dodirnim konusnim površinama prstenova. Sve ove specifičnosti treba uzeti u obzir pri projektovanju i proračunu, a pored toga prstenasta opruga mora zadovoljiti preporuke UIC-a vezane za: kapacitet, smeštajni prostor, krajnju silu, radnu sposobnost, itd. Savremen pristup projektovanja obuhvata matematički (teorijski) model kombinovan sa simulacionim modelom radi dobijanja glavnih pokazatelja vezanih za kvalitet budućeg rada. Rezultati ovih analiza potvrđeni su i eksperimentalnim putem i to na prstenastoj opruzi za odbojnik klase "B" (kapaciteta 50 kJ).

Ključne reči: prstenasta opruga, radna sposobnost, napon, simulacija, ispitivanje.