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STRENGTH AND DYNAMIC ASSESSMENT OF CAGE AND BEARING FOR RAILWAY CARRIAGE

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Abstract: The objective of these analyzes is to evaluate the behaviour of bearing cage in operation and to determine the safety factor towards to yield and ultimate strength of structure, when cage is under load. Safety factor can be defined as force needed to achieve yield or ultimate strength divided by operation force given from dynamic simulation. Second analyze was based on pressing of whole cage in radial direction to determine radial pressing force needed to achieve yield and ultimate strength.

KEYWORDS: cage, MSC Adams, safety factor, dynamic simulation, radial force

1 Introduction

A bearing is an engineering component that serves to transmit forces between moving and fixed parts of a mechanical machine, and is designed to minimize friction between moving and fixed parts of the machine. A bearing in the machine absorbs some forces, while allowing others to move freely [1, 2].

Production in the roller bearing segment for rail vehicles dates back to 1959.The production of single row ball bearings intended for industrial passengers is ensured in accordance with the requirements of EN 12080 [1, 2].

The products:

- single row ball bearings
- single row cylindrical roller bearings
- bearing boxes for freight wagons

Applications:

- axle bearings for freight wagons, passenger wagons, electric and diesel locomotives, electric and diesel motor vehicles and motor units
- gearboxes, traction controls and generators, compressor (air pump) motors and fan drives, electric drive and diesel locomotive drive and charging generators

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Figure 1 shows the bearing used in the rail industry. Specifically a single row cylindrical roller bearing.

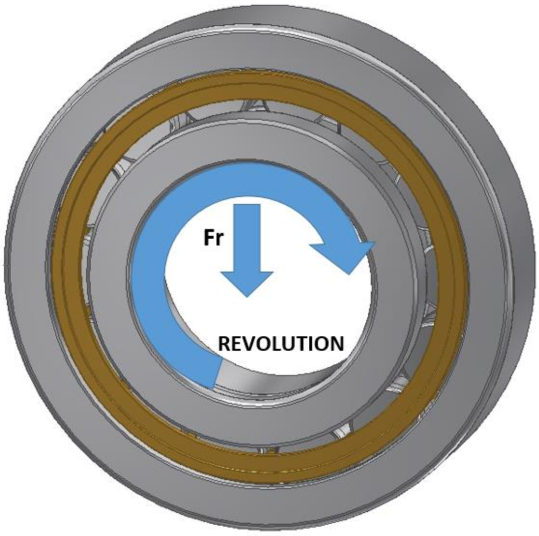

Fig. 1 Single row cylindrical roller bearing

Single row cylindrical roller bearings are able to carry large radial load on a relatively small space. Some applications are able to carry also axial load in one or both directions. Raceways of the outer and inner rings together with the sheet profile of the cylindrical rollers in the shape of ZB allow optimal distribution of the contact pressure in the rolling space. This arrangement also allows advantageous formation of lubrication film between the contact parts of the bearing, optimal rolling, decrease of friction, growth of temperature and therefore lower stress of the junction in the arrangement [3].

At the same time certain mutual misalignment of the rings is allowed and so the bearings cope better with the real operating conditions and contribute to a better reliability and durability during the operating life of the bearings. Cylindrical Roller Bearings are suitable for arrangements, with high requirements for load transfer in connection with high rotation speed, e. g. machine tools, rolling mills, vehicle axle [3].

Cylindrical roller bearings generally consist of two parts – outer or inner ring block on which with the help of cages and guiding ribs cylindrical rollers are fastened and second, separate ring. This arrangement allows separate mounting of rings and so the manipulation of individual parts is made easier. Through the gradual development and introduction of new possibilities in the materials and processing technologies better utilization of the inner bearing space and introduction of application with higher load marked "E" was enabled. Bearings with steel cage are offered in the whole range with higher load. Higher load bearings with brass cage are dependent on technological possibilities and they are indicated in the table section [3].

Separate group are bearings with brass cage where rib is joined to the cage body by unriveting of cross pieces. This arrangement allows more efficient utilization of inner bearing space and offers better working properties mainly in connection with durability. Designation of these bearings is done by additional letters „EDM"[3].

2 Dynamic simulation

The simulation model was defined by a solid body for stiffness dynamics of steel (100Cr6) 7 850 kg / m3 and brass (CuZn40Pb2) 8 440 kg / m3. The outer, inner ring and bodies are made of steel and the cage is made of brass.

In order to more accurately describe the actual situation in the FEA environment, the physical properties of the actual material must be used. - An elastic modulus E and Poisson ratio have been defined for the linear elastic region of the materials. - CuZn40Pb2 stress strain curve was defined for the non-linear plastic region of the material. Parameters of material models in FEM are given in the following Table 1 and Figure 2 [4, 5].

Table 1 Parameters of material models in FEM

Brass - CuZn40Pb2	www. Materialdatacenter.com
Modul of Elasticity:	105 000 MPa
Poisson's ratio:	0,35
Yield strength:	149,92 MPa
Ultimate strength:	544,72 MPa
Steel – 100Cr6	www. Materialdatacenter.com
Modul of Elasticity:	210 000 MPa
Poisson's ratio:	0,30

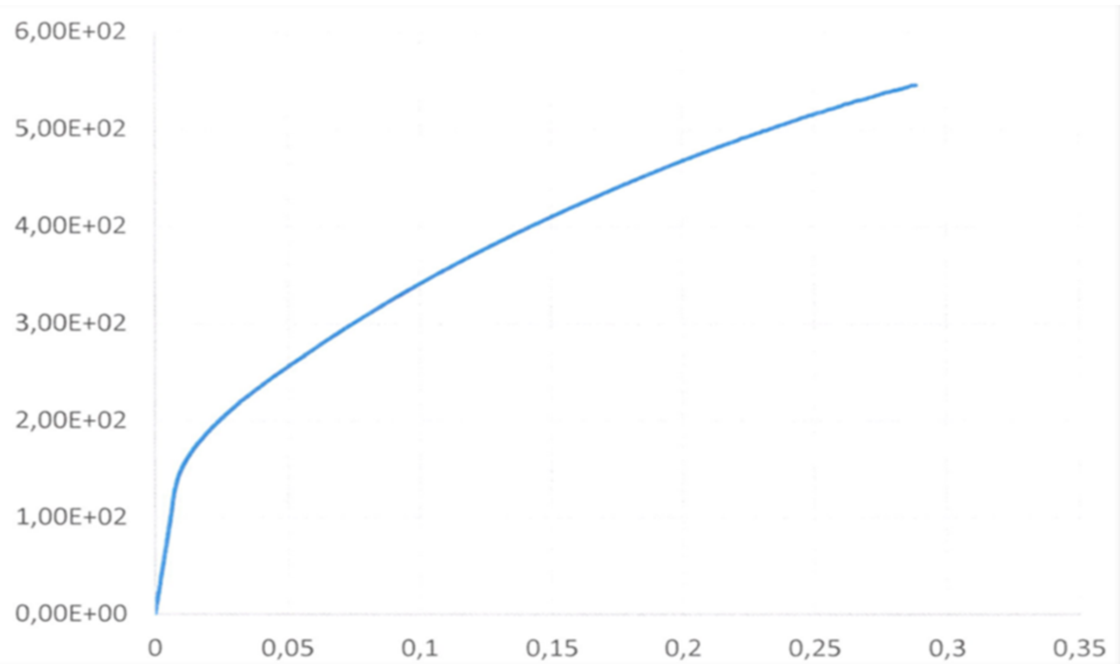

Fig. 2 Stress-strain curve deformation curve for material CuZn40Pb2

The running bearing simulation was performed in MBD environment using MSC Adams software. A radial force (Fr) of 20,000 N was applied to the inner ring. The inner ring rotation speed was set to 2700 rpm. Contact pairs are defined in the contact table as follows: - Contact steel with steel with friction coefficient: static FCS = 0.08, dynamic FCD = 0.02 - Brass cantilever steel with friction coefficient: static FCS = 0.19, dynamic FCD = 0.09 [5, 6].

The dynamic bearing behavior time horizon was selected in 1 second. It represents 45 revolutions of the inner ring. The figure 3 shows the definition of the contacts between the cage and the rollers [5, 6].

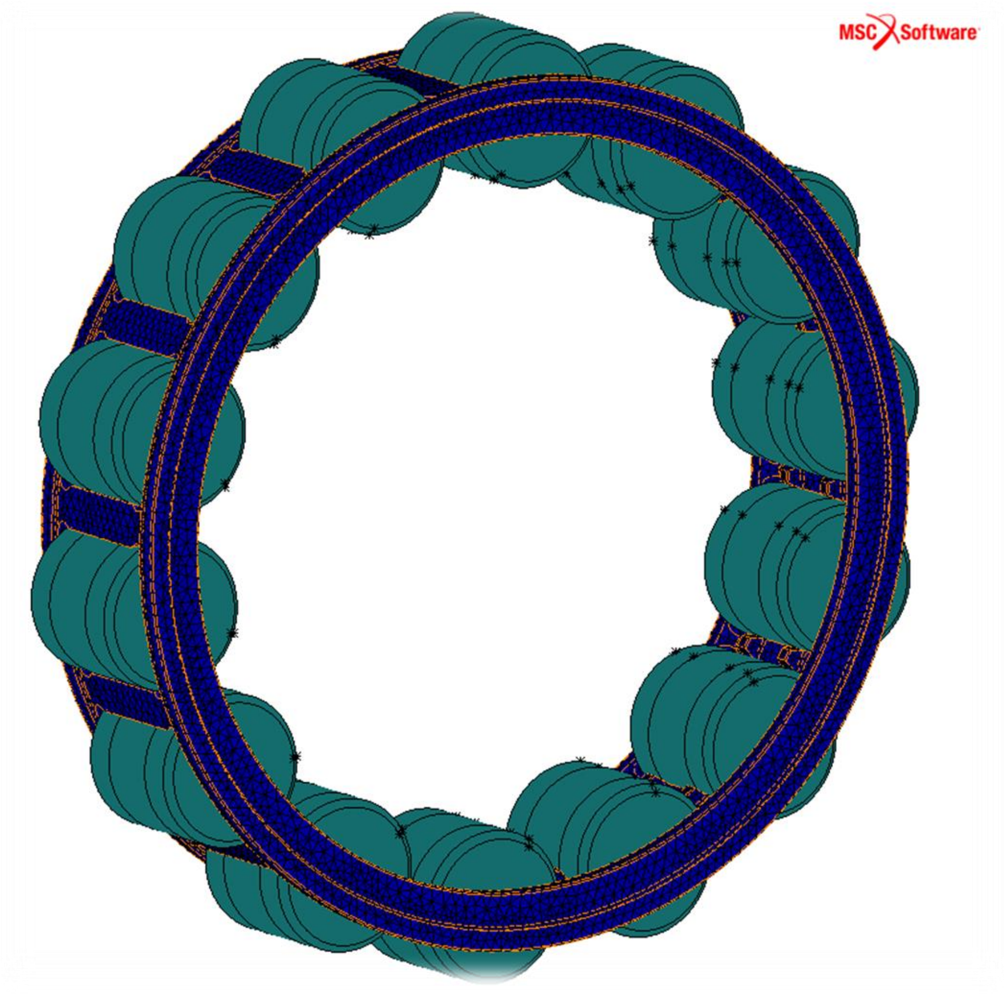

Fig. 3 The contacts between the cage and the rollers

3 Result of dynamic analysis

Figure 4 shows the graph of the contact force between rolling element and inner ring. It is obvious that the contact forces reaches value 8 716.32 N in the loaded area. In relaxed area without preloading the contact force is 0 N.

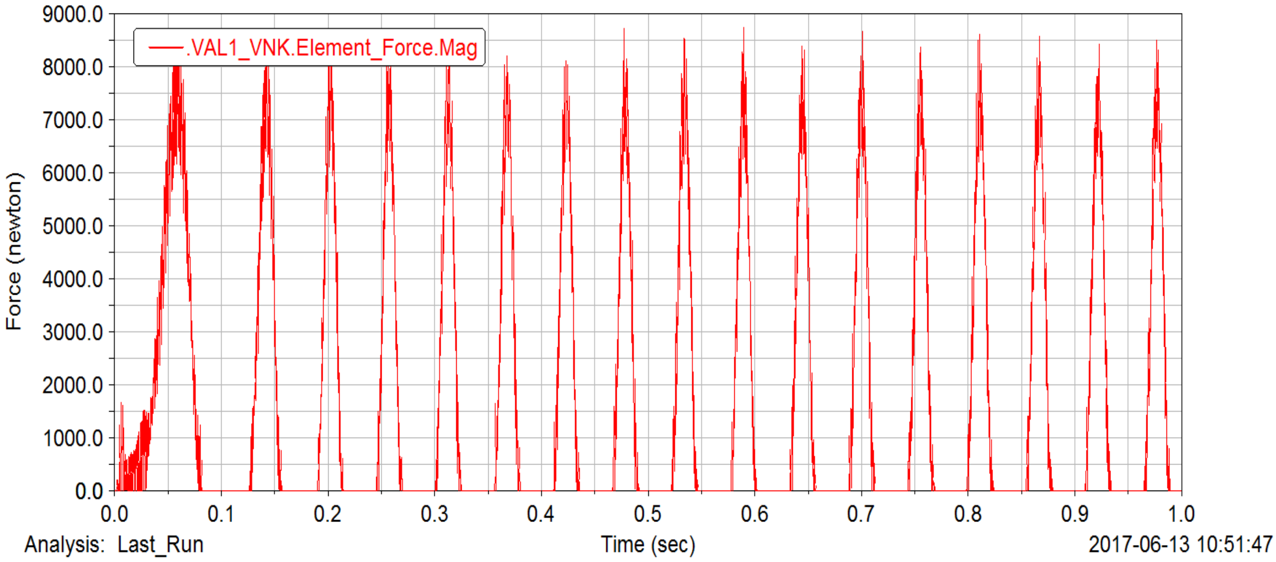

Fig. 4 Graph of contact force between rolling element and inner ring

Figure 5 shows the graph of forces acting on the cage when bearing is running. Irregular curve at the beginning of simulation represents rapid speed-up. For simulation was elected short run-up time in respect computer hardware capabilities. Therefore, the forces are relatively high during speed-up, max. 907.4 N. After run-up the forces are moving at maximum level 407.7 N. With these forces the evaluation of internal power and kinematic conditions in the bearing was considered.

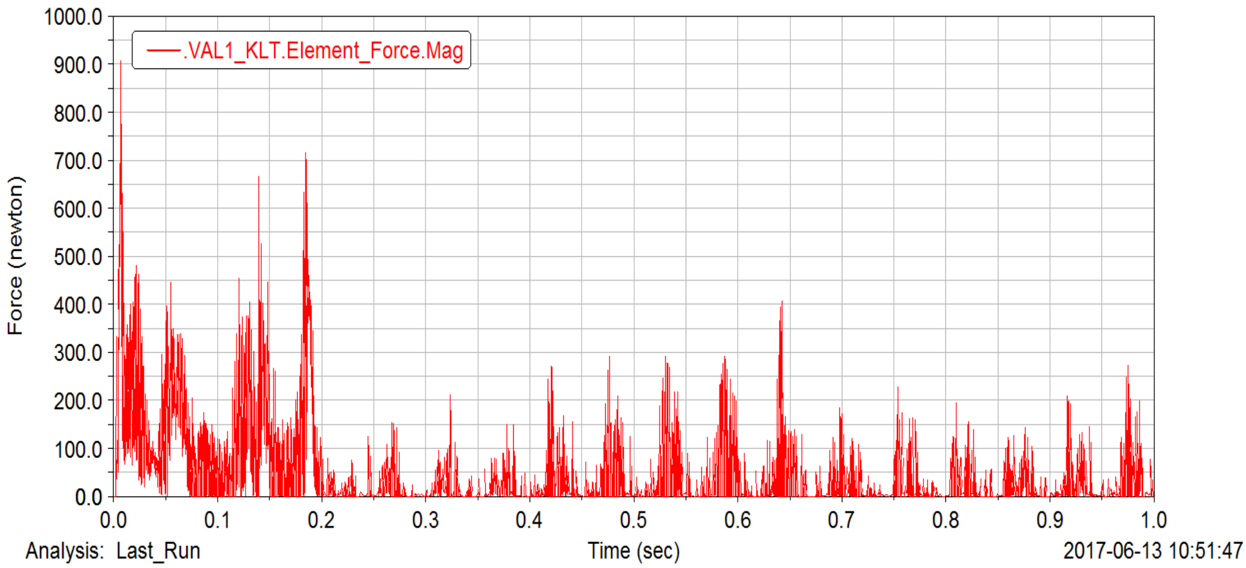

Fig. 5 Graph of contact force between rolling element and cage's rib

4 Static analysis

Presented FEM simulation of cage's rib into the crack was setup using one fourth of symmetric model. Load was applied by defined displacement of rigid surface to deform rib via roller with respecting the direction of load given from previous dynamic simulation. When yield and ultimate strength were achieved, the values of reaction forces were identified. Then safety factor can be defined as a ratio between this reaction forces (at yield and ultimate strength) and maximum dynamic force between roller and cage's rib given by dynamic simulation. Figure 6 represents FEM model used in calculation.

FEM analyze of pressing whole cage was provided as well as previous analyze, using one fourth of symmetry (Figure 7). Load was applied using defined displacement of rigid surface in radial direction to deform cage until to achieve yield and ultimate strength.

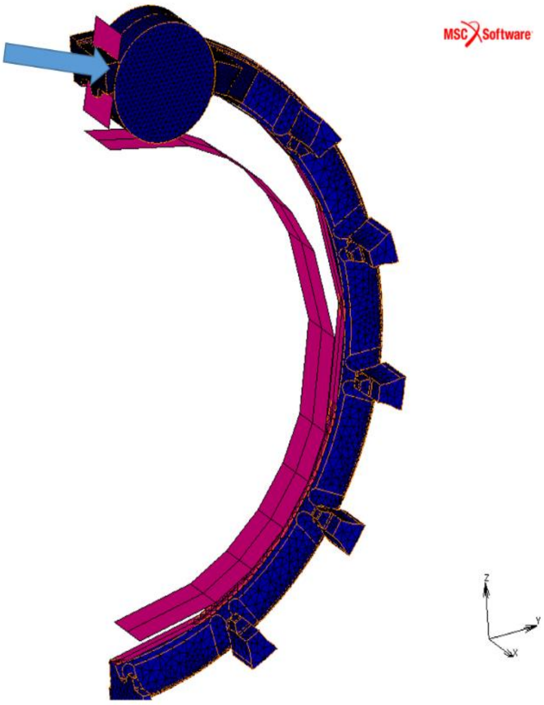

Fig. 6 FEM model used for cage's rib deformation

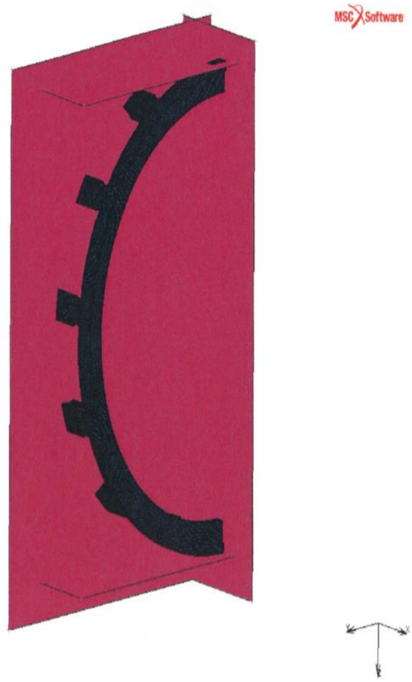

Fig. 7 FEM model used for cage deformation

5 Result of static analysis

Figure 8 shows the stress of the geometry of cage's rib at yield strength. The force needed to achieve yield strength is 3 677.52 N. Elected critical area which was monitored is shown in figure.

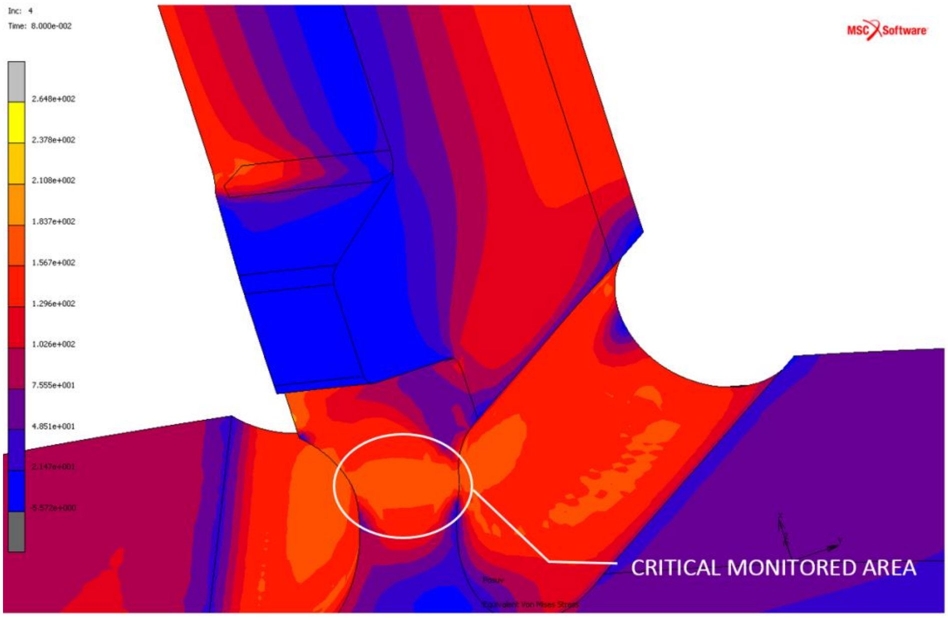

Fig. 8 Stress of the cage's rib, critical area at yield strength

Figure 9 shows the plastic deformation of cage's rib at the ultimate strength. The force needed to achieve ultimate strength is 17 469.11 N.

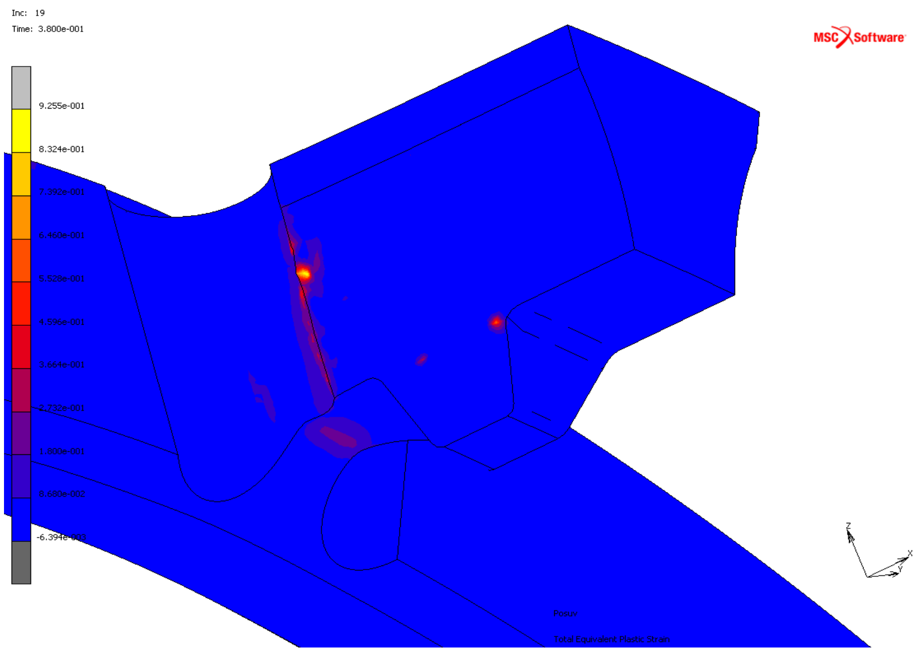

Fig. 9 Plastic deformation of the cage's rib ultimate strength

CONCLUSION

On the basis of dynamic analyses, it can be concluded that the cage's angular velocity shows smooth running and there is no drop in speed during operation of the bearing at defined load. Graphs of the contact forces between the rings and rollers comply with the conditions of bearing behavior in operation. On the basis of stress analyses we can conclude that the force value needed to deform the cage's rib and whole cage under radial press until to achieve yield and ultimate strength sufficiently exceeds compared to values of acting forces from dynamic analyzes are sufficiently small to deform the cage.

Based on these facts we can conclude, that the safety factor against the occurrence of plastic deformation as well as crack of the cage is sufficient. See Table 2.

Table 2

Force at cage's rib from dynamic analyze	Force on cage's rib at yield strength	Force on cage's rib at ultimate strength	Safety factor of the cage's rib – yield strength	Safety factor of the cage's rib – ultimate strength	Radial force on cage to achieve yield strength	Radial force on cage to achieve ultimate strength
407.7 N	3 677.52 N	17 469.11 N	**9.02**	**42,85**	1 959.60 N	4 724.00 N

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