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NEGATIVE AND POSITIVE CLEARANCE EFFECT IN 2, 3 AND 4 POINT CONTACT BALL BEARINGS LOAD DISTRIBUTION

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ABSTRACT

The quasi static parameters (PQS) are function of the internal geometry. The positive or a small negative diametrical clearance can be created to satisfy the client technical specifications. A mathematical model in 5DLL is developed to PQS (quasi-static-parameters) analysis affected by a small negative or positive diametrical clearance.

The computer model created at SIRCA can be used, for example, to compute the internal geometry of 4 point contact ball bearings used in truck convoy 5th wheel and are able to satisfy AS/NZS and Regulation No. 55.

Keywords: quasi Static Analysis, 2, 3 or 4 point contact ball bearings, positive clearance, negative clearance, preload

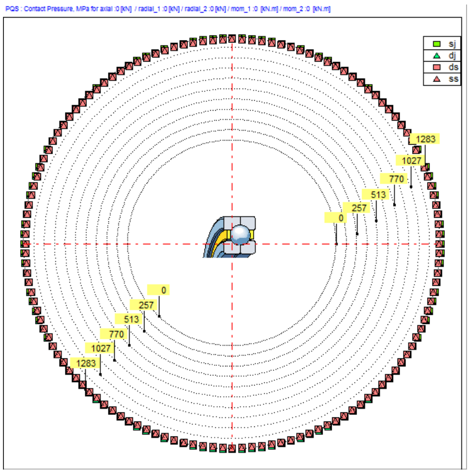
INTRODUCTION

There are numerous cases when the large dimensions slewing rings must assure an initial preload or a small negative clearance. In this case a useful solution is to create and control the preload using a "preload gap" between the duplexes races [1]. For small dimensions ball bearings the preload can be created by fretting of a ring into housing or by other mechanical method. The bearing rigidity is also affected by the clearance value. The mathematical model in 5DLL is presented in [2] and the Jacobian matrix are considered as already know. The mathematical model is applied to 4 types of ball bearings as follows. For all analysis a large size ball bearings with pitch diameter of 945 mm is considered. The ball diameter is 20 mm.

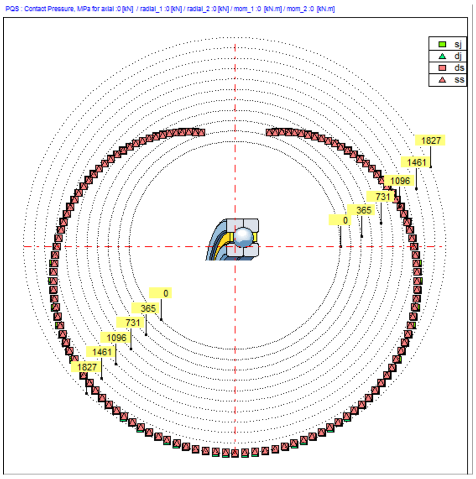
The quasi static parameters (PQS) are a function of the internal geometry of the ball bearing. A positive or a small negative diametrical clearance can be created to satisfy the client technical specifications. A mathematical model in 5DLL is developed to PQS (quasi-static-parameters) analysis affected by a small negative or positive diametrical clearance.

APPLICATION EXAMPLE

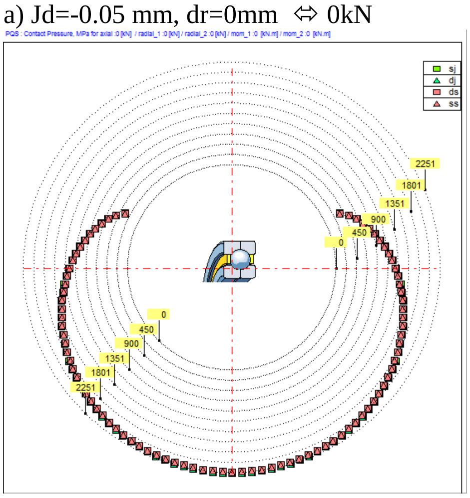
When a 4 point contact ball bearing have a negative clearance [-0.05 mm in this case (see figure 1)] the internal preload produce a uniform contact load and as effect a contact pressure as is indicated in figure 1.a. When a radial external force acts on the bearing then a radial displacement exists and it is function of internal geometry. Figures 1b, 1c and 1d represents the contact pressure distribution on 4 ball contacts as function of the radial displacement or by equivalence as function of radial force. In all graphs in legend sj, dj, ds and ss notations correspond to the 4 possible simultaneous contacts and have the following significations: (ss- stanga sus, dj – dreapta jos, ds – dreapta sus, ss- stanga sus).



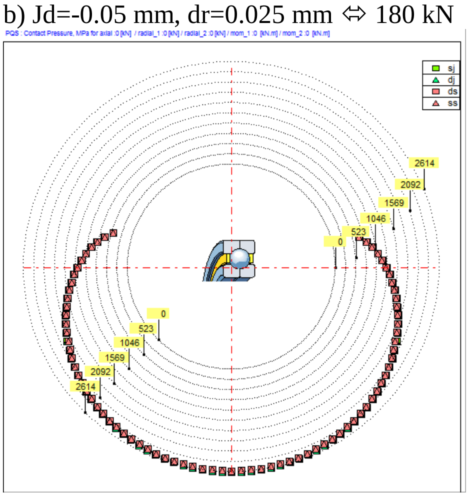
a) Jd=-0.05 mm, dr=0mm ⇔ 0kN



b) Jd=-0.05 mm, dr=0.025 mm ⇔ 180 kN



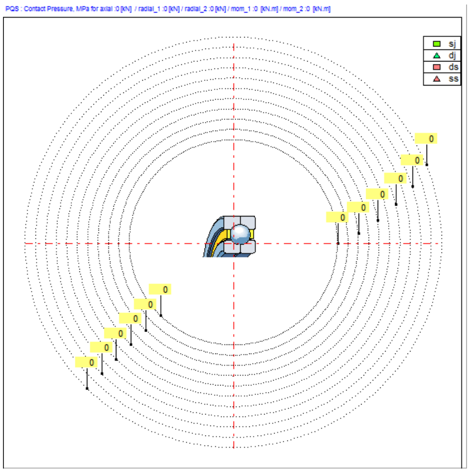
c) Jd=-0.05 mm, dr=0.05mm ⇔ 324kN



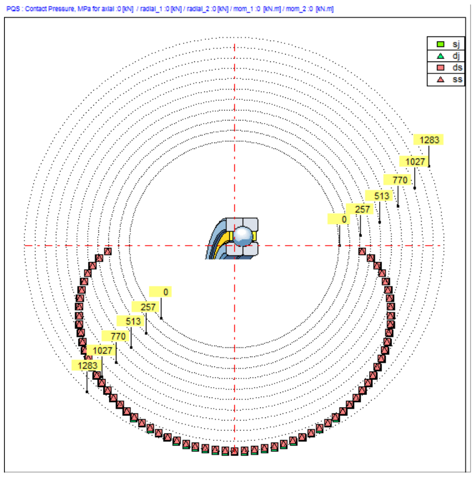
d) Jd=-0.05 mm, dr=0.075mm ⇔ 531kN

Fig. 1. Contact presure distribution for imposed radial displacements and negative clearance

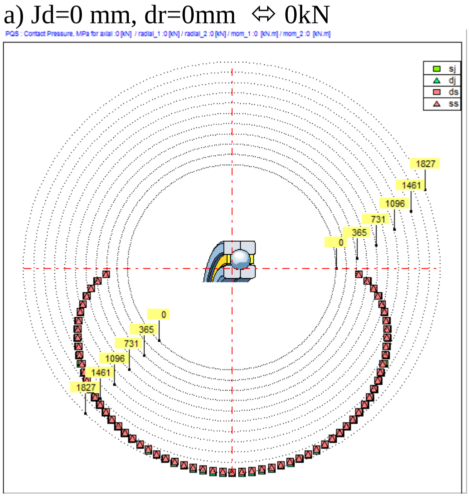
When a 4 point contact ball bearing have a 0 clearance [0 mm in this case (see figure 2)] the load distribution and as effect a contact pressure as is indicated in figure 2.a. When a radial external force acts on the bearing then a radial displacement exists and it is function of internal geometry. Figures 2b, 2c and 2d present the contact pressure distribution on 4 ball contacts as function of the radial displacement or by equivalence as function of radial force.



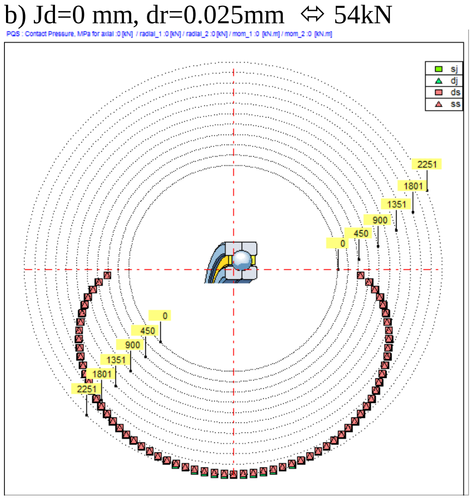
a) Jd=0 mm, dr=0mm ⇔ 0kN



b) Jd=0 mm, dr=0.025mm ⇔ 54kN



c) Jd=0 mm, dr=0.05mm ⇔ 161kN



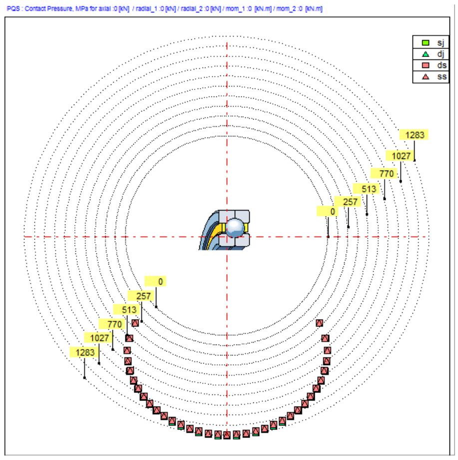
d) Jd=0 mm, dr=0.075mm ⇔ 307kN

Fig. 2 Contact presure distribution for imposed radial displacements and 0 clearance

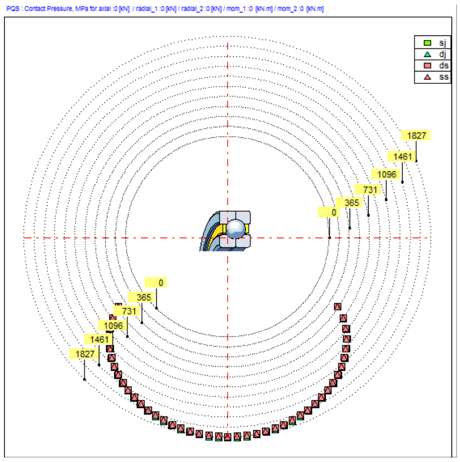
When a 4 point contact ball bearing have a positive clearance [0.1 mm in this case (see figure 3)] the load distribution and as effect a contact pressure as is indicated in figures 3.a, 3b, 3c and 3d as effect of the ring displacement or ad affect of utile force displacement distance (UFDD). The UFDD starts form Jd/2 and is presented in brackets (). Form 0 to Jd/2 is no effect of the imposed radial displacement.

When a radial external force acts on the bearing then a radial displacement exists and it is function of internal geometry. Figures 2b, 2c and 2d represent the contact pressure distribution on 4 ball contacts as function of the radial displacement or by equivalence as function of radial force.

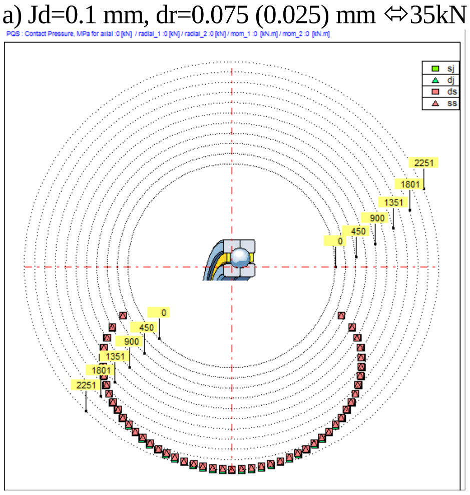
As effect of the data presented in Figures 1, 2 and 3, it results the bearing rigidity in radial direction as function of UFDD. That is presented in Fig. 4.

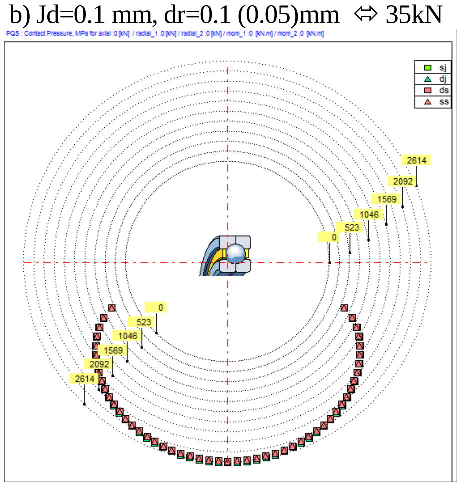


a) Jd=0.1 mm, dr=0.075 (0.025) mm ⇔35kN



b) Jd=0.1 mm, dr=0.1 (0.05)mm ⇔ 35kN





c) Jd=0.1 mm, dr=0.125 (0.075)mm ⇔253kN d) Jd=0.1 mm, dr=0.15 (0.1)mm ⇔421kN

Fig. 3. Contact presure distribution for imposed radial displacements and positive clearance

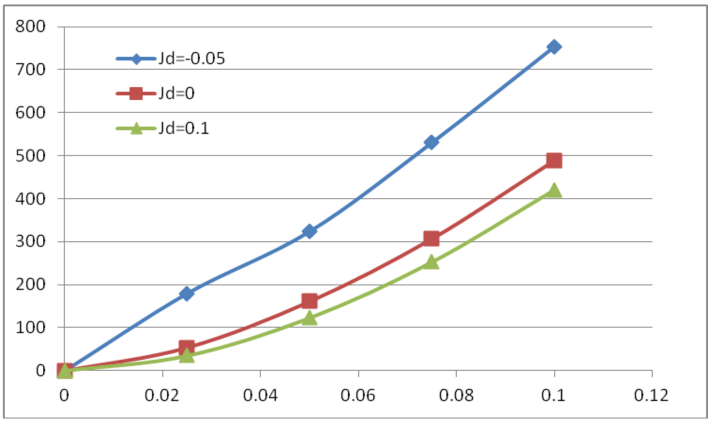


Fig. 4. The bearing rigidity as function of UTDD parameter

The mathematical model in 5DLL were applied to the 4PCBB ball bearing with 2 different external load conditions considering the negative, zero and positive diametrical clearance effect in the PQS.

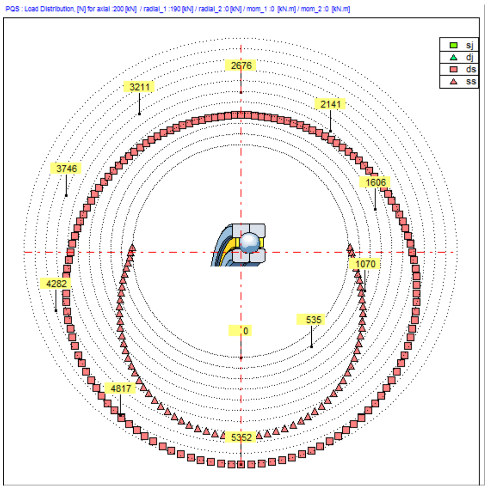
The first set of load is note S1 and corresponds to:

S1={axial: 200 kN, radial 1: 190 kN, radial 2:0 kN, Moment1: 0 kN.m, Moment2: 0 kN.m}.

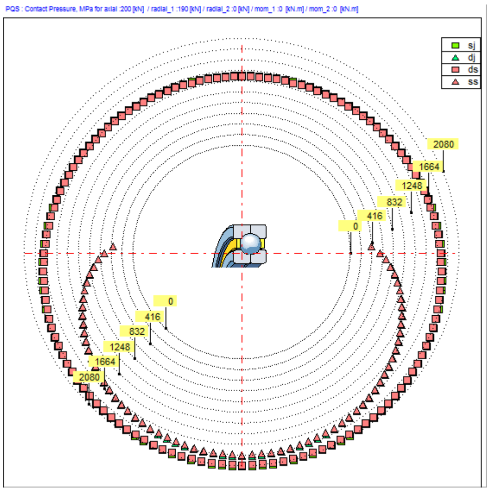
The 2nd set of forces is noted S2 and corresponds to:

S2={axial: 350 kN, radial 1: 414 kN, radial 2:142 kN, Moment1: 150 kN.m, Moment2: 133 kN.m}.

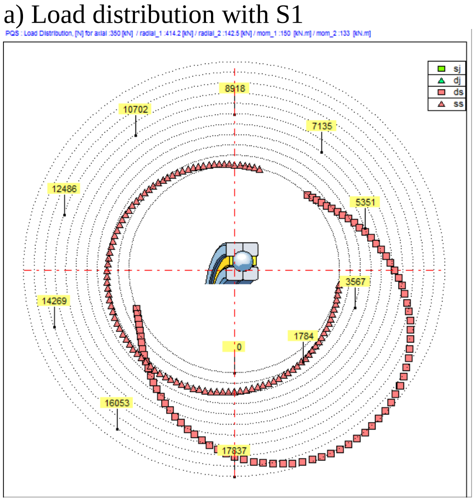
For the two sets of loads S1 and S2, the PQS parameters, when Jd=-0.05 mm, data are presented in Figure 5.



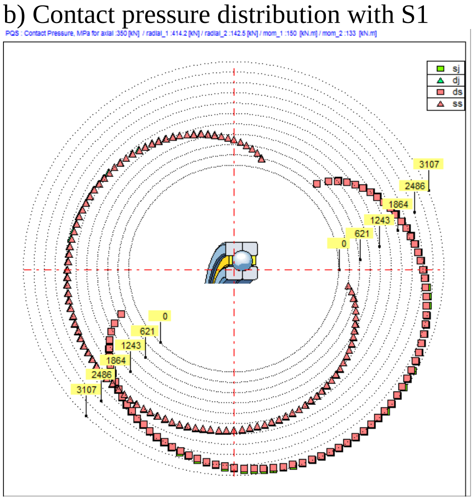
a) Load distribution with S1



b) Contact pressure distribution with S1



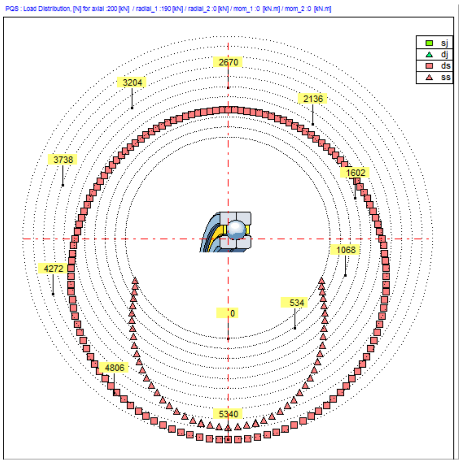
c) Load distribution with S2



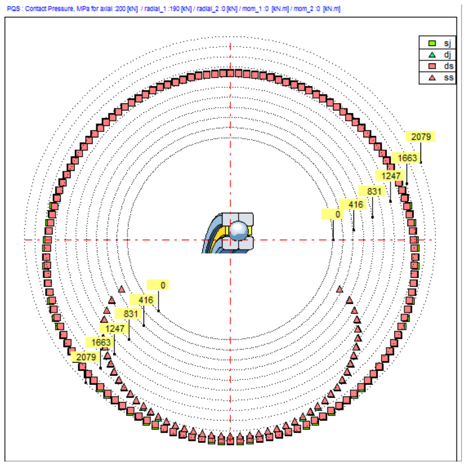
d) Load distribution with S2

Fig. 5. Load distribution and contact pressure for S1 and S2 data sets and negative clearance

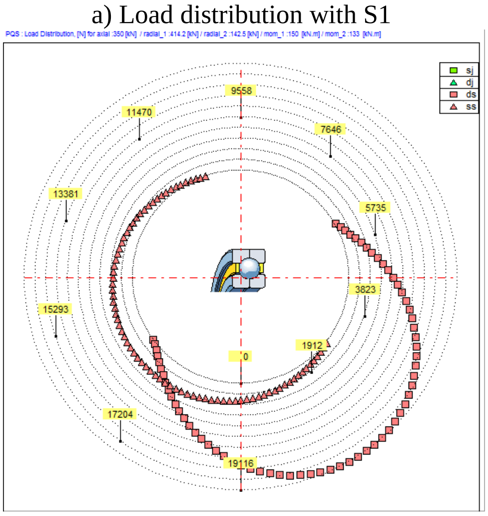
For the 2 sets of loads S1 and S2 the PQS parameters when Jd=0 mm are presented in Fig. 6.



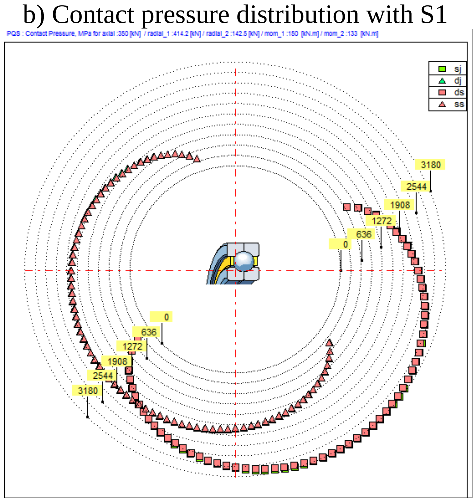
a) Load distribution with S1



b) Contact pressure distribution with S1



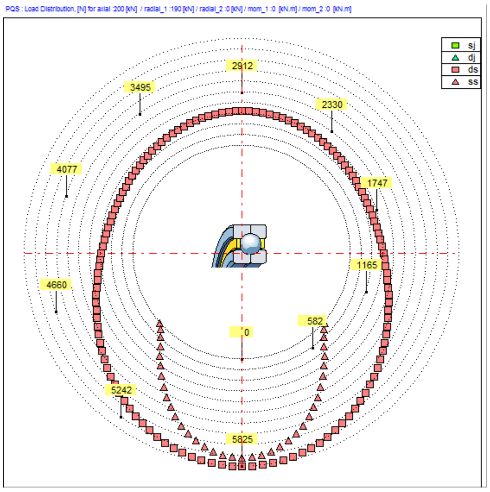
c) Load distribution with S2



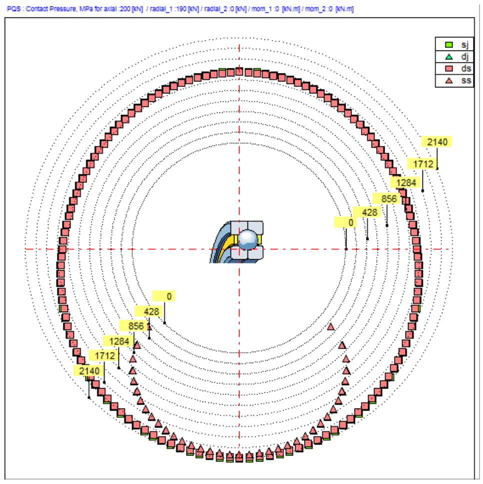
d) Contact pressure distribution with S2

Fig. 6. Load distribution and contact pressure for S1 and S2 data sets and 0 learance

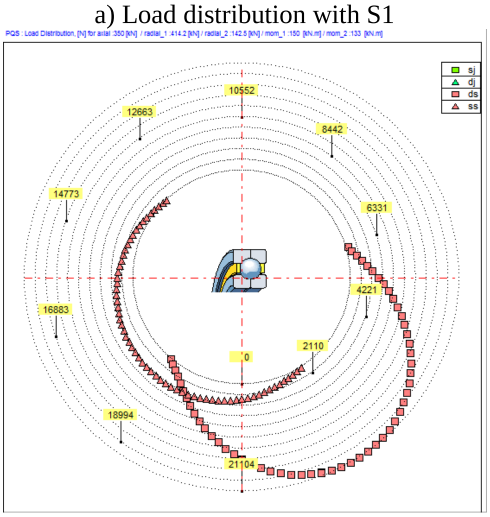
For the 2 sets of loads S1 and S2, the PQS parameters when Jd=0.1 mm are presented in Fig. 7.



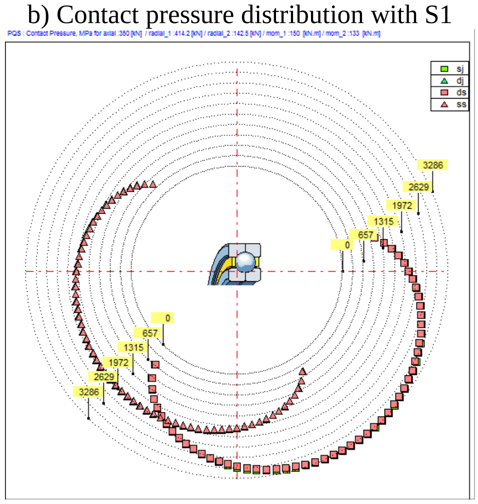
a) Load distribution with S1



b) Contact pressure distribution with S1



c) Load distribution with S2



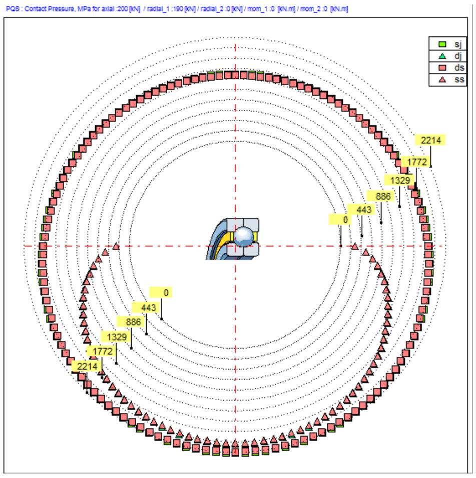
d) Load distribution with S2

Fig. 7. Load distribution and contact pressure for S1 and S2 data sets and positive clearance

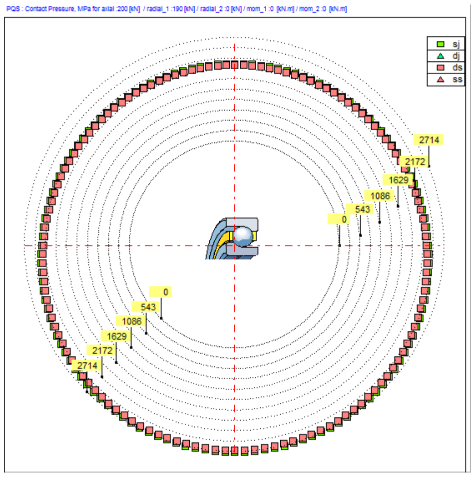
For the same major dimensions and 0.52 conformities and S1 set of external loads, the model is applied to different other types of ball bearings as is presented in Figures 8 and 9. When Jd=-0.05 mm and S1, the PQS for different types of ball bearings is presented in Figure 8, as follow.

The selected bearing types are

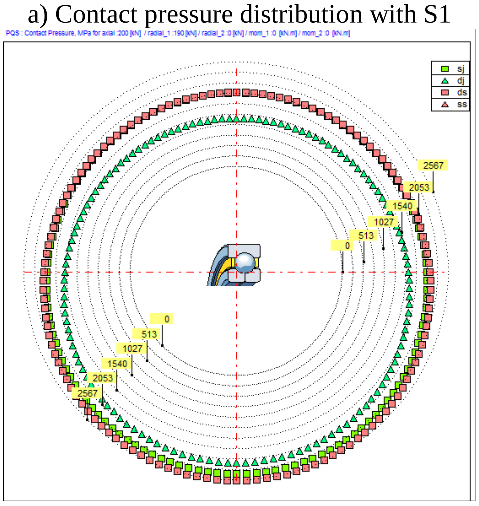
- a 4 point contact ball bearing (schematically presented in Fig 8.a),
- an angular contact ball bearing (schematically presented in Fig 8.b),
- a 3-point contact ball bearings with splited rings (schematically presented in Fig 8.c – with inner ring splitted, and Fig. 8.d – with outer ring splitted).



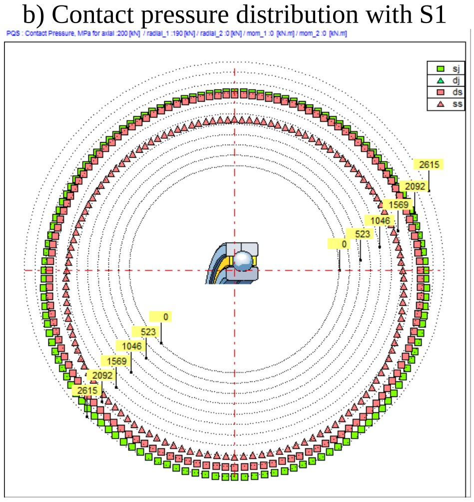
a) Contact pressure distribution with S1



b) Contact pressure distribution with S1



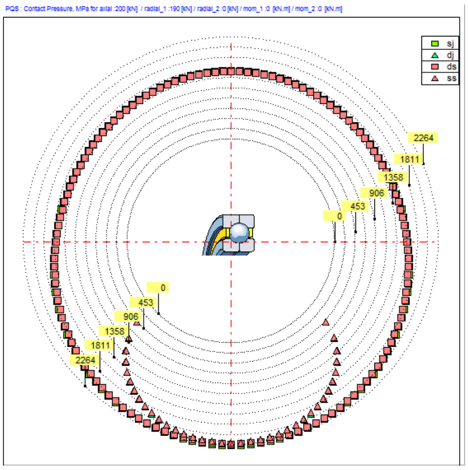
c) Contact pressure distribution with S1



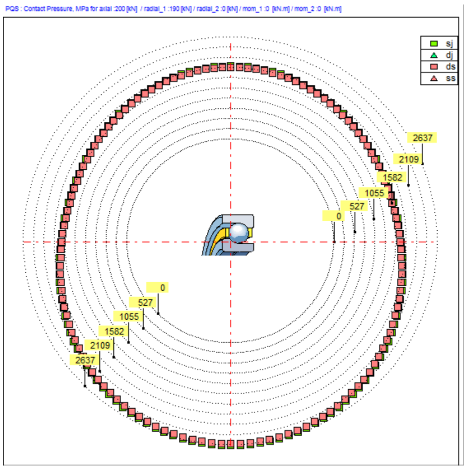
d) Contact pressure distribution with S1

Fig. 8. Contact pressure distribution with S1 and negative clearance

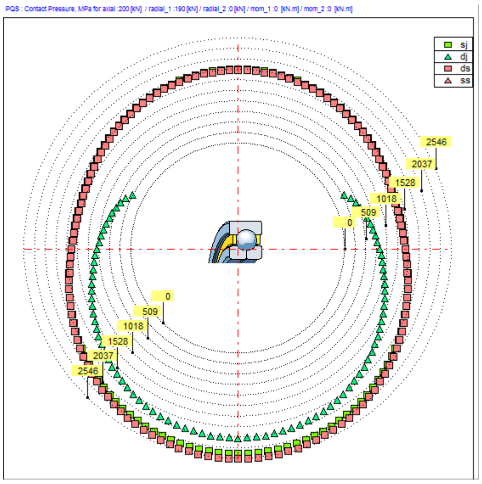
When Jd=0.1 mm and S1 the PQS for different types of ball bearings is presented in Fig. 9, as follow. The selected bearing types are 4 point contact ball bearings (schematically presented in fig 9.a), angular contact ball bearings (schematically presented in fig 9.b), 3 point contact ball bearings with splited rings (schematically presented in fig 9.c – with inner ring splitted, and 9.d – with outer ring splitted).



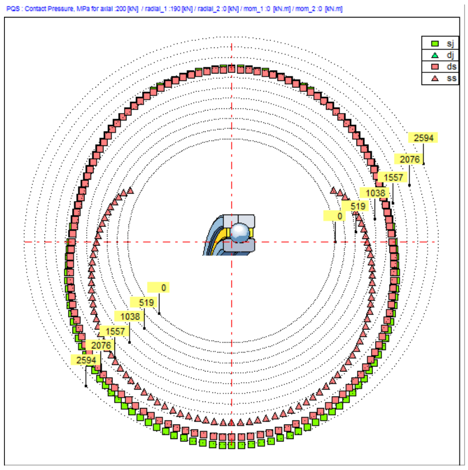
a) Contact pressure distribution with S1



b) Contact pressure distribution with S1



c) Contact pressure distribution with S1



d) Contact pressure distribution with S1

Fig. 9. Contact pressure distribution with S1 and positive clearance

CONCLUSIONS

The mathematical model shows the influence small negative and positive diametrical clearances in PSQ in different ball bearings type. The existing mathematical models works for positive radial clearance or for 0 radial clearance. Results form the charts and the model work also in 5DLL (3 forces and 2 tilting moments) with negative clearances. The unitary model works for 4 point contact ball bearings, 2 point contact angular ball bearings and also for 3 point contact ball bearings. The computer model created at SIRCA can be used, for example, to compute the internal geometry of 4 point contact ball bearings used in truck convoy 5th wheel and are able to satisfy AS/NZS and Regulation No. 55, where the working loads are imposed in 5DLL as function of D (dynamic radial load) and V (vertical imposed load) on the 5th whell [3, 4].

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