The Study of Contact Problems for Small Rolling Bearings Manufactured of Plastic Material

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Engineers think twice before using plastic bearings in their designs, because they have trusted steel bearings for years or because they think plastic can't handle demanding applications or environments. Plastic bearings can endure extreme temperatures, heavy loads and high speeds and offer more freedom when it comes to maintenance. Their resistance to dirt, dust and chemicals make plastic bearings a viable steel replacement. Plastic bearings can reduce costs up to 25%, they are highly wear resistant, with a low coefficient of friction and they can replace pricier alternatives in many applications. Plastic bearings also do not typically need lubrication unless steel balls are used in combination with plastic races and are designed to maintain a low coefficient of friction during the life of the bearing. Compared to steel bearings, which can become pitted and have a higher coefficient of friction, plastic bearings last longer. Also, plastic bearings can be used in wash-down applications, salt water and harsh chemicals without decreasing performance. Water can be considered a lubricant for plastic bearings [1].

Keywords: rolling bearings, polymer, contact stress, simulation, SolidWorks

Plastics (such as acetyl, nylon, PTFE), carbon graphite and other non-metallic materials have been increasingly used as self-lubricating bearings. Their composition has been refined over many years so as to obtain optimal bearing characteristics. These include low friction, corrosion resistance, ability to conform under load (plastic bearings), ability to function under substantial temperature ranges and substantial load-carrying capability. Although temperature ranges, dimensional stability and load limitations of plastic gears are generally lower than those of the metallic bearings, plastic bearings are remarkably versatile and economical [2].

The study conducted in the paper highlighted the importance of finding and identifying the defects that can occur during manufacture or exploitation, with a major influence on the good operation of rolling bearings. For the analysis of a plastic roller bearing with a 7.5 mm diameter, with and without defects, loaded with different values of force, the SolidWorks software was used for the finite element analysis. The final goal is to find the distribution of the vonMises stress, the maximum contact stresses and the deformation of the bearing rollers that appear in the model under a compressive load.

The paper continues the study done in reference [3], based on the research of the rolling contact in bearings, where the author presents conclusions about the normal contact of elastic bodies (Hertz's Theory), the adherence and sliding contact with specifics about the influence of the surface quality at the rolling contact.

The assembly geometry and materials

The bearing assembly is symmetrical and consists of three parts: the top plate L1 x L2 x h, the rolling bearings with an R radius and an L length and the bottom plate L1 x L2 x h (fig. 1). For numerical simulation reasons, the assembly is split in half. The dimensions of the assembly parts are presented in table 1.

The simulation is calculated for the rolling bearing without a defect and with a defect placed at the contact area between the rolling bearing and the top plate. The defect is simulated through a rectangular shape with round edges, the geometry that is presented in figure 2 and the dimensions that are presented in table 1.

The material of the rolling bearing is Nylon 6/10, loaded from the SolidWorks material library, with the properties that are presented in table 2. Because the object of the study is only the rolling bearing, the two plates must be

Table 1
THE MAIN DIMENSIONS OF THE BEARING ASSEMBLY PARTS

The part		Symbol	UM	ϕ 7.5 x 15
The plate		L1	mm	20
		L1	mm	10
		h	mm	1
The rolling bearing		2 x R	mm	7.5
		L	mm	15
The defect	Length	a	mm	4
	Width	b	mm	0.1
	Depth	g	mm	0.025
	Radius	r	mm	0.025

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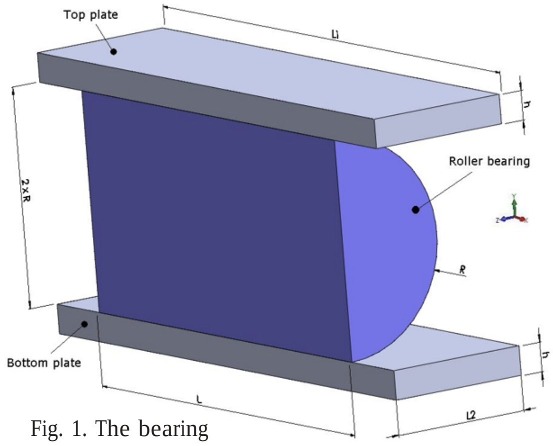

Fig. 1. The bearing assembly

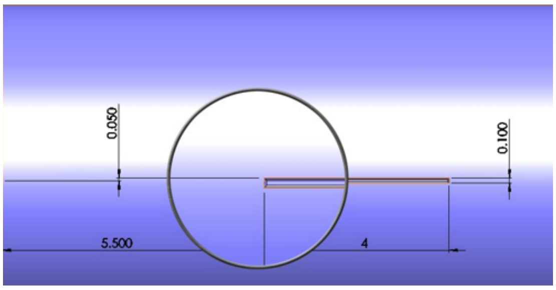

Fig. 2. The geometry and dimensions of the defect

Property	UM	Nylon 6/10	Infinit
Elastic Modulus	N/mm^2	8300	2.1 x 10^{11}
Poissons Ratio	-	0.28	0.49
Shear Modulus	N/mm^2	3200	318.9
Density	kg/m^3	1400	-
Tensile Strength	N/mm^2	142.56	-
Yield Strength	N/mm^2	139.04	62000

Table 2
THE MECHANICAL AND PHYSICAL PROPERTIES OF THE BEARING ASSEMBLY PARTS

very rigid; this condition was imposed in SolidWorks by adding a material with infinite properties that are specified in table 2.

The Boundary conditions

The simulation will be done on half of the assembly based on the following considerations:

- the symmetry can help reduce the size of the problem and lead to more accurate results; the results on the un-modelled portions are deduced from the modelled portion; the symmetry requires that geometry, restraints, loads, and material properties are symmetrical [4], which is true in the case of the bearing assembly;

- the symmetry condition will stabilise the model; in the absence of the symmetry condition, the bearing rollers can move in unwanted directions and the contact phenomena will be incorrectly simulated.

This analysis requires the *Surface* type conditions imposed through the *Contact Set* connection. *Surface* contact may be applied between two faces of different shapes and can only be specified as a local condition. The faces can but don't have to touch initially, but are expected to come in contact once the load has been applied to the model. The mesh on both surfaces is not identical, so there is no node to node correspondence. The *Surface* condition represents nonlinear problems and requires an iterative solution [5, 6].

The *Contact Set* condition with the *No penetration* option is imposed between the roller bearing and the lower side of the top plate and the upper side of the bottom plate (fig. 3). With the *No penetration* option, the selected components or bodies do not penetrate each other during simulation, regardless of their initial contact condition. By default, bodies do not penetrate themselves if the deformation during simulation is sufficient to cause self-intersection.

The *Fixed* condition is imposed at the lower side of the bottom plate, (fig. 4). For solids this restraint type sets all translational degrees of freedom to zero.

Preparation of the model for analysis requires restraining the loaded part to prevent rigid body motions and, at the

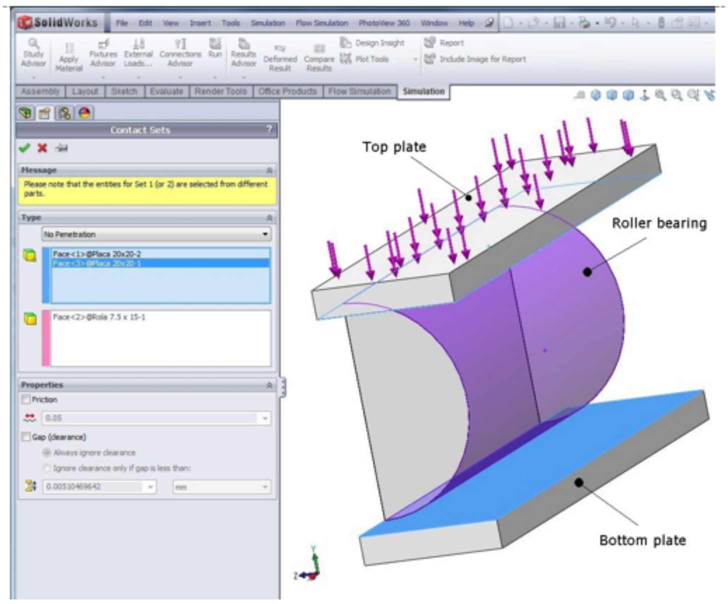

Fig. 3. The Contact Set between the roller bearing and the plates

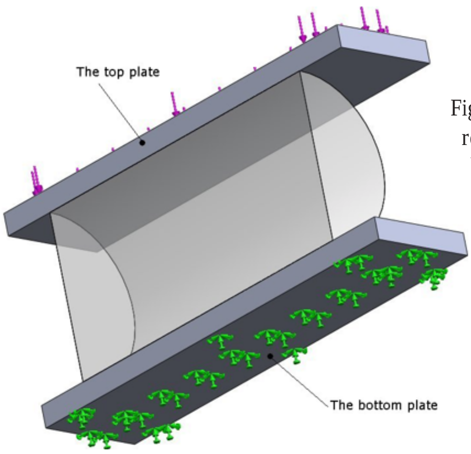

Fig. 4. The Fixed restraint at the bottom plate

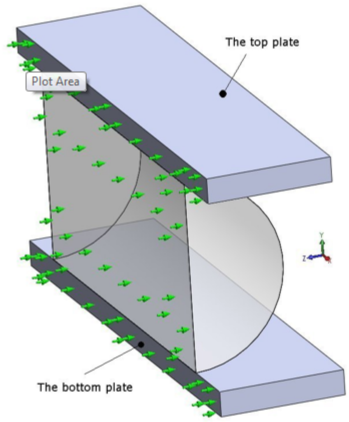

Fig. 6. The **S**ymmetry restraint

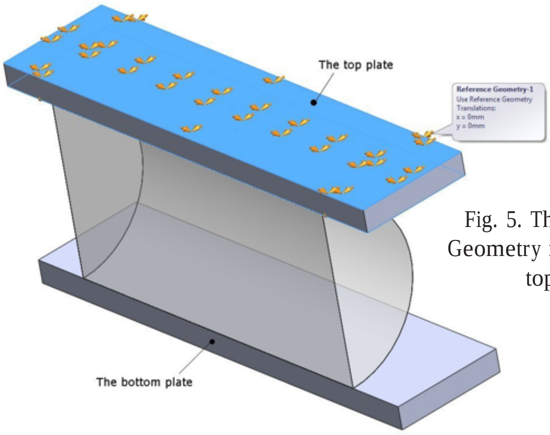

Fig. 5. The Reference Geometry restraint at the top plate

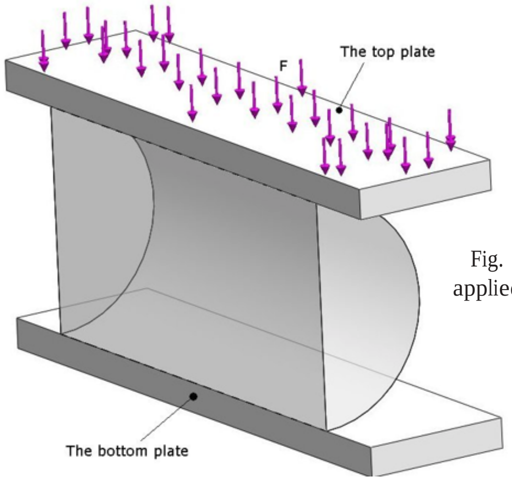

Fig. 7. The force applied on top plate

same time, setting it free to move in the direction of the load. This can be accomplished by restraining the loaded face in both in-plane directions while leaving the normal direction (the direction from which load is applied) unrestrained [5] (fig. 5).

For solid models, the *Symmetry* restraint imposes that every face that is coincident with a plane of symmetry must be prevented from moving in its normal direction. The *Symmetry* restraint type applies this condition automatically to all selected faces (fig. 6).

The force is applied on the upper side of the top plate, figure 7, with the following values: 25, 50, 75, 100, 125 N and is considered a loading for a single roller bearing.

Results and discussions

The results of the simulation are presented numerically in table 3 and graphically in figures 8, 9, 10, for the roller bearing with and without a defect, where:

- $\sigma_{vonMises}$ – represents the vonMises stress;

Table 3
THE RESULTS OF THE ANALYSIS FOR THE ROLLER BEARING
ϕ 7.5 x 15

F	Without defect			With defect		
	$\sigma_{vonMises}$	σ_k	Δ_{max}	$\sigma_{vonMises}$	σ_k	Δ_{max}
N	MPa	MPa	mm	MPa	MPa	mm
25	33.2	59.8	0.00688	52.9	93.5	0.00337
50	66.4	119.7	0.00466	105.8	186.9	0.00503
75	99.5	179.5	0.0099	158.7	280.4	0.0075
100	132.7	239.3	0.01041	211.6	374.6	0.01021
125	152.7	295.1	0.01655	262.6	460.9	0.03849

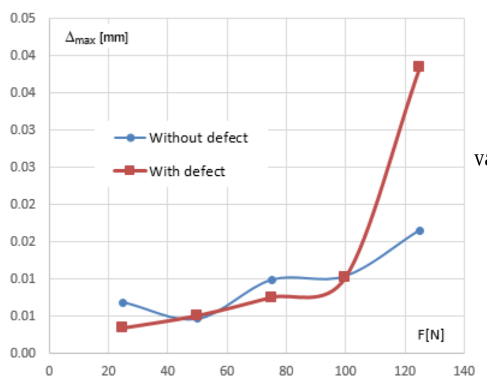

Fig. 8. The variations of the displacement

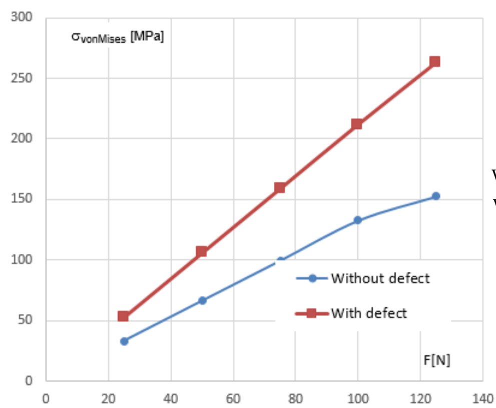

Fig. 9. The variations of the vonMises stress

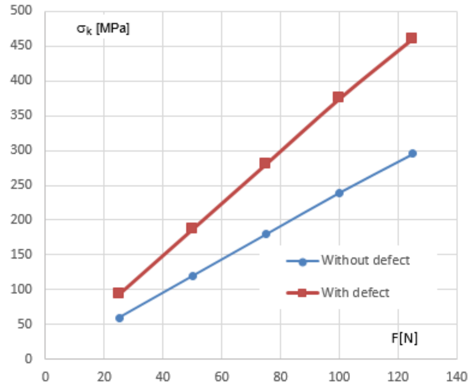

Fig. 10. The variations of the contact pressure

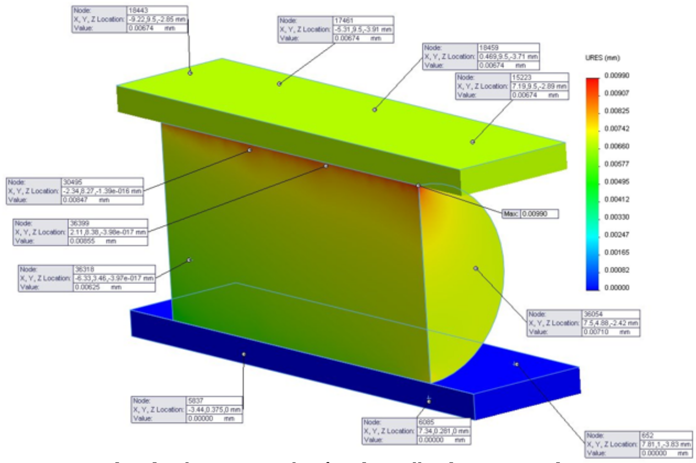

Fig. 11. The displacement plot for the roller bearing without a defect and F=75 N

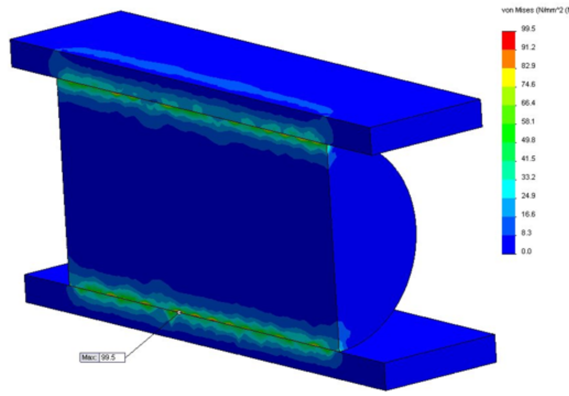

Fig. 12. The vonMises plot for the roller bearing without a defect and F=75 N

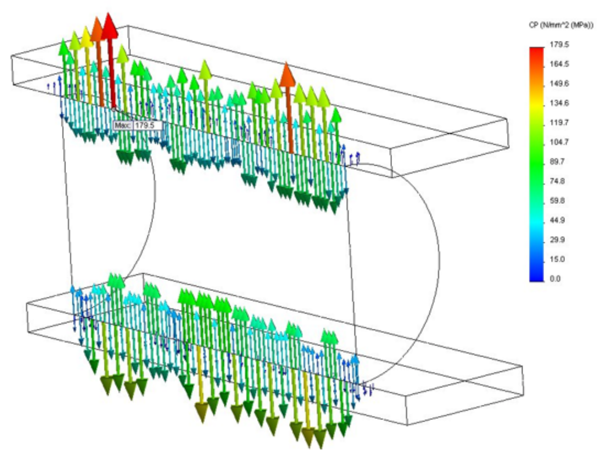

Fig. 13. The contact pressure plot for the roller bearing without a defect and F=75 N

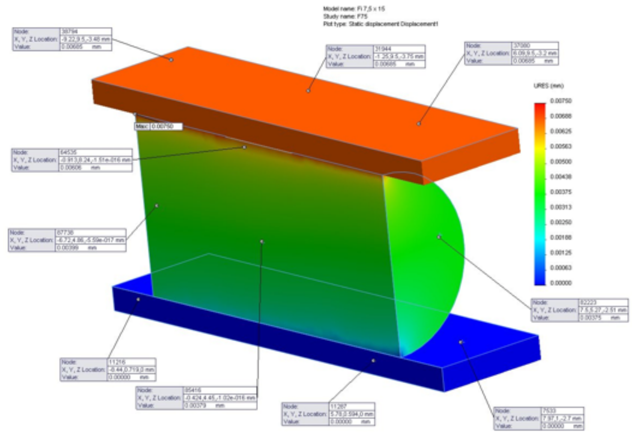

Fig. 14. The displacement plot for the roller bearing with a defect and F=75 N

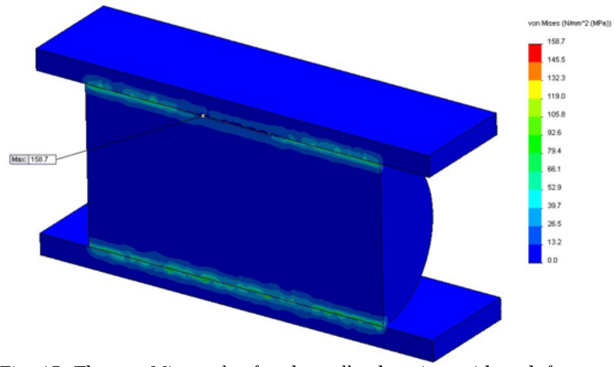

Fig. 15. The vonMises plot for the roller bearing with a defect and F=75 N

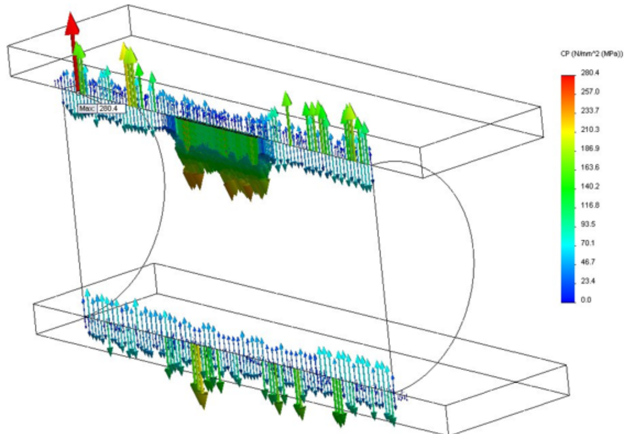

Fig. 16. The contact pressure plot for the roller bearing with a defect and F=75 N

- σ_k – represents the contact pressure; the contact pressure is developed in areas where two bodies come into contact during the analysis and no penetration contact is defined;

- Δ_{max} – represents the maximum displacement.

From these results, a major difference between the roller bearing with and without a defect can be observed. The vonMises and contact pressure values increase almost twice, while the displacement remains relatively constant. Compared to the 139.04 MPa yield strength of the nylon 6/10, the roller bearing without the defect can be loaded with maximum 100 N, while the roller with a defect can be loaded with a maximum of only 70 N.

The displacements, vonMises and contact pressure plots for the roller bearing with and without a defect are presented in figures 11 ÷ 16, only for F=75 N.

Conclusions

The paper highlights the significant influence of a defect in the geometry of a roller bearing loaded with a force, regarding the vonMises and contact pressure values compared to the same geometry of the roller without the defect. The defect can occur during treatment and processing, but also during the exploitation of the bearings. The motion speeds of vehicles are continually increasing and it is necessary, beginning with the design phase, to ensure a maximum safety during their exploitation. From a theoretical point of view, the analytical solution of the contact problem between roller bearings with a defect is quite difficult. Using simulation software, like SolidWorks, various answers and solutions can be obtained for different conditions and materials.

References

1.***8 http://www.bocabearings.com/bearing-types/plastic-bearings.

2.*** http://www.sdp-si.com/Design-Data/Plastic-and-Non-Metallic-Bearings.php.

3.MANESCU, T., Jr., Contributions to the analysis of stress and strain state in the balls of small radial bearings, with and without manufacturing defects, PhD Thesis, Eftimie Murgu University of Reºiþa, 2014.

4.*** SolidWorks Help.

5.KUROWSKI, P. M., I., Engineering Analysis with COSMOSWorks Professional. Finite Element Analysis with COSMOSWorks 2005, SDC Publications, ISBN 1-58503-249-2

6. ZGIRIAN, G., DEMETRESCU, I., GHEORGHIU, H., IOVU, H., HADAR, A., ATANASIU, C., Modelarea unor compozite polimerice: de la sinteza la proprietati mecanice si calcule cu elemente finite, Rev. Chim. (Bucharest), **56**, no. 7, 2005, p. 757

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