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Dynamic analisys of the collision between bearing balls during the manufacturing process

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Bearing fatigue studies help to acknowledge many causes of the bearing failures. Nevertheless it is a necessity to analyze the individual bearing components in order to prevent exploitation breakdowns. The current paper aims to evaluate the total energy transfer of the bearing ball collisions that occur during the manufacturing processes.

Keywords: *bearing ball, kinetic energy, dissipated energy, collision, internal energy*

1. Initial data

As shown by a significant number of researchers, bearing fatigue studies help to acknowledge many causes of the bearing failures [1]-[5].

Bearing analysis have been approached by several specialists from different engineering fields: vibration analysis [6], [7], fatigue tests [8], lifetime assessments with different lubricants, etc. Most of the scientific research is related to the bearing assembly and not of the bearing components (inner ring, outer ring, cage, rolling elements). If the bearing components have defects, a shorter lifetime of the bearing is to be expected [9].

In the various processes during manufacturing the rolling elements of the bearings, multiple collisions occur, which are leading to defects of the bearing during exploitation [10]. The initial micro fissures can spread and lead to high vibrations accompanied by a high level of noise. Finally the bearing is degrading. Thus an energetical analysis is to be carried out in order to achieve the critical values of the energy transfer during the manufacturing process.

During the manufacturing process of the bearing balls, one of the causes that may lead to defects is the collision phenomenon. This paper presents a study of the energy transfer between bearing balls during collision.

2. Energy distribution analysis

In order to study the collision of two identical bearing balls with a diameter of 12,7mm, one stationary and the other one in motion, the finite element method program ANSYS has been used [12].

The analysed bearing balls have a number of 44046 nodes, 134035 finite elements, impact speed v_{imp}=3m/s bearing ball mass m_0=8,3657 [g] (Figure 2)

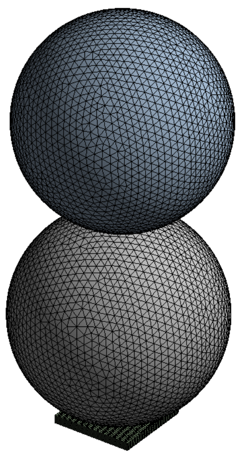

Figure 2. Bearing balls mesh

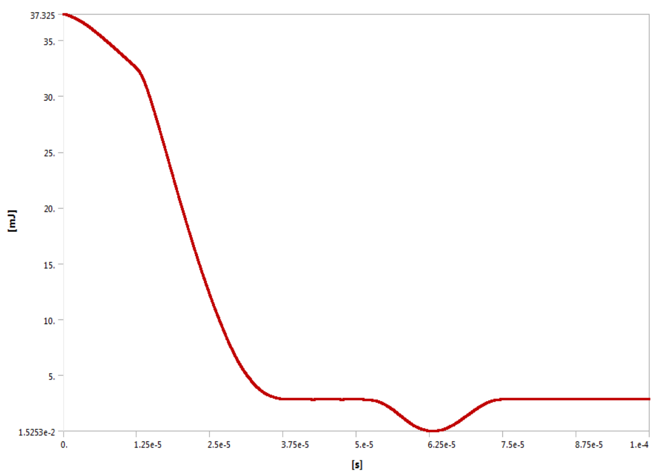

Figure 3. Kinetic energy variation of the ball in motion

During the manufacturing process of the bearing balls multiple collisions occur. From practical observations during the impact moment at t=0 we have the maximum kinetic energy Ec_{max}= 37,325 [mJ], the impact duration being $\Delta t = 1 \cdot 10^{-4}$ [s]. At the impact moment t= $0,625 \cdot 10^{-4}$ [s] the minimum value of the kinetic energy is Ec_{min} = 0 (Fig. 3).

This is the main reason why we can make the assumption that the stress gathered by the bearing ball can be higher than the maximum admissible stress and that the material will exceed the yield point (Figures 9, 10, 11). These stresses will cause local plastic deformations that may later lead to bearing failures.

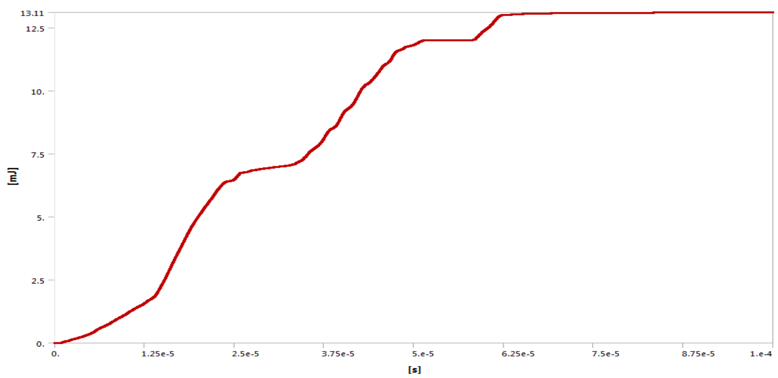

Figure 4. Dissipated energy through plastic deformation at the bearing ball in motion. (E_{max} = 13,11 mJ)

The total kinetic energy from the impact moment between the bearing ball in motion and the stationary bearing ball, both considered to be without manufacturing defects, is Ec_{max} = 37,325 [mJ]. This energy is distributed as following:

- The elasto-plastic deformation energy is forming the contact area between the two bearing balls with a value of 13,11 [mJ] equal at the bearing ball in motion and the stationary bearing ball (fig.4 and fig.7) at the $\Delta t = 0{,}625 \cdot 10^{-4}$ [s];
- The internal energy (fig. 5 and fig. 8), has different maximum values during the impact sequence with the values 11,022 mJ and 16,353 mJ, and at the end of the impact sequence at $\Delta t = 1\ 10^{-4}$ s with the values 10 mJ and 14 mJ;
- A fraction of the initial kinetic energy at the end of the impact sequence is 5 mJ and 1 mJ, (fig. 3 and fig. 6);
- The energy dissipated through friction between the two bearing balls is 9,215 mJ : {37,325 – [13,11 + 10,0 + 5,0] = 9,215 mJ}.

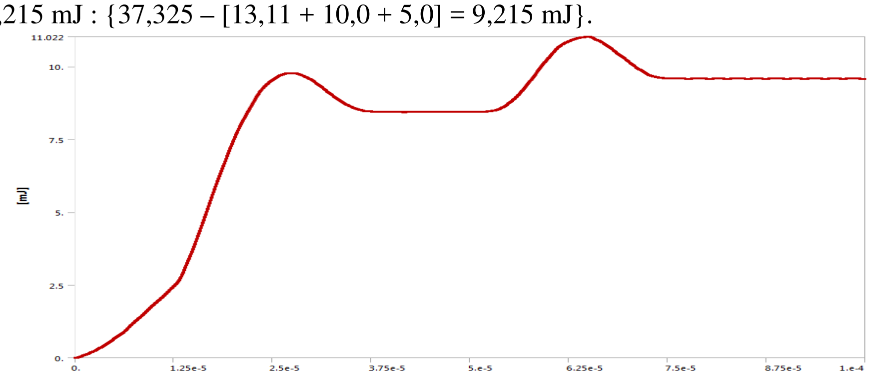

Figure 5. Internal energy for the bearing ball in motion (E_{max} = 11,022 mJ)

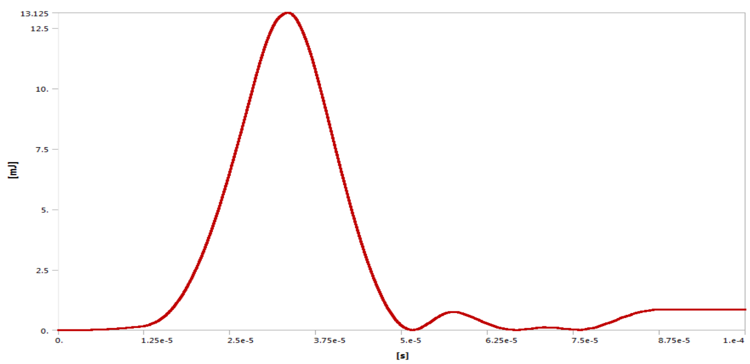

Figure 6. Kinetic energy for the stationary bearing ball (E_{max} = 13,353 mJ at Δt = 0,3 10^{-4} s)

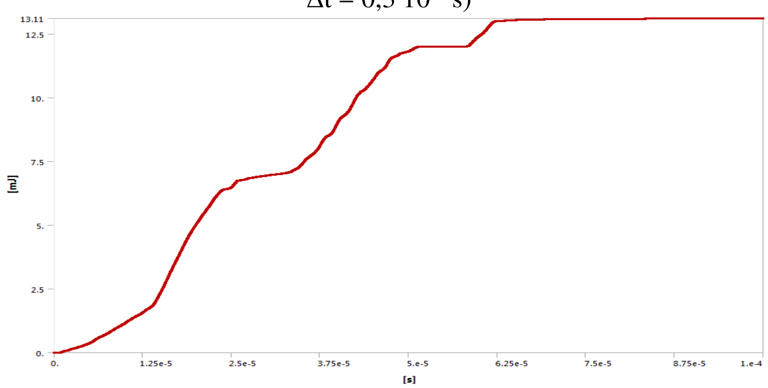

Figure 7. Disipated energy through plastic deformation for the stationary bearing ball (E_{max} = 13,11 mJ)

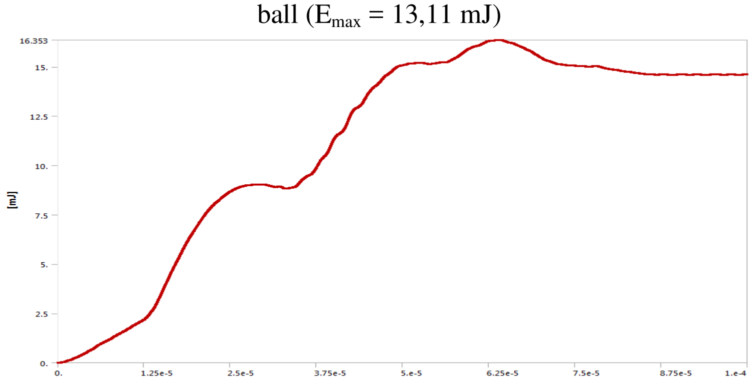

Figure 8. Internal energy for the stationary bearing ball (E_{max} = 16,353 mJ)

The data obtained in the graphs from fig 3 – 8 is summarized in tables 1 and 2.

Table 1. Bearing ball in motion

No	Energy type	t =0 [s]	t =0,625. 10^{-4} [s]	t =1.10^{-4} [s]
1	Kintetic [mJ]	37,325	0	5,000
2	Plastic deformation [mJ]	0	13,110	13,110
3	Internal [mJ]	0	11,022	10,000
	Total	37,325	24,132	28,110

The energy disipated through heat transfer:
ΔE = 37,325 - 28,110 = 9,215 [mJ] = 2,202 10-3 [C], [13]

Table 2. Stationary bearing ball

No.	Energy type	t =0 [s]	t =0,625. 10^{-4} [s]	t =1.10^{-4} [s]
1	Kinetic [mJ]	0	0	1,000
2	Plastic deformation [mJ]	0	13,110	13,110
3	Internal [mJ]	0	16,353	14,000
	Total	0	29,463	28,110

3. Stress and deformations that develop during impact of the bearing balls

The variation of the maximum stress and deformations during the impact sequence interval Δt = 1.10^{-4} [s] are presented in the graphs from fig.9 and fig.10. The maximum compression stress is σmax = - 543,31 [MPa], and the maximum deformation is: Δmax = 0,1 [mm].

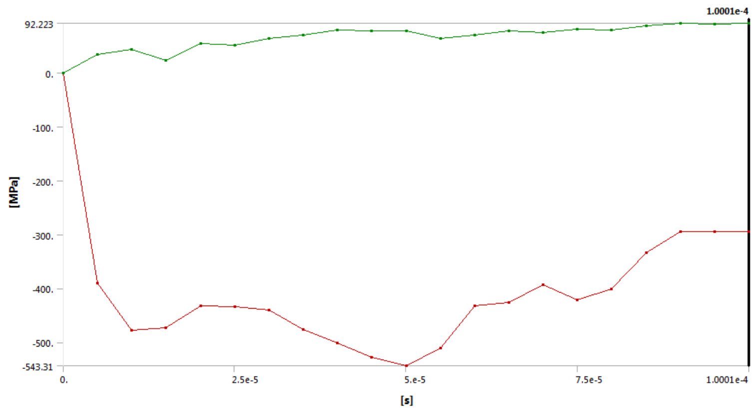

Figure 9. Normal stress during impact. {σmax = - 543,31 [MPa]}

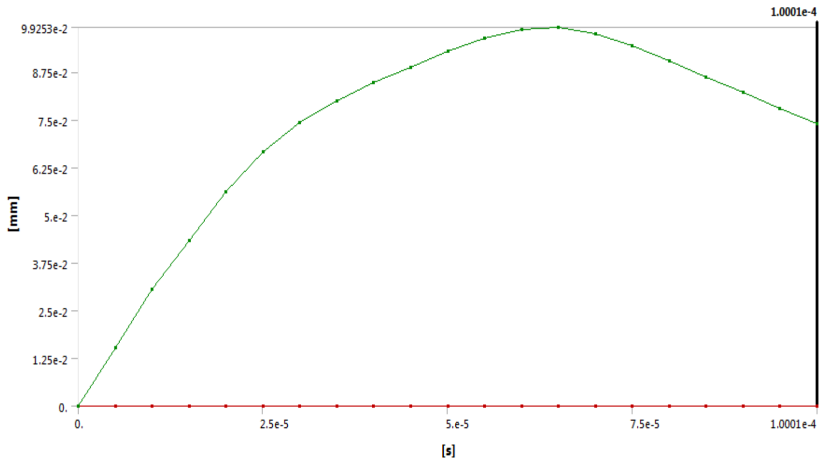

Figure 10. Total deformation on the normalized direction. {Δmax =0,1 [mm]}

Von Mises equivalent stress has the maximum value: σech = 330,37 [MPa] as shown in figure 11.

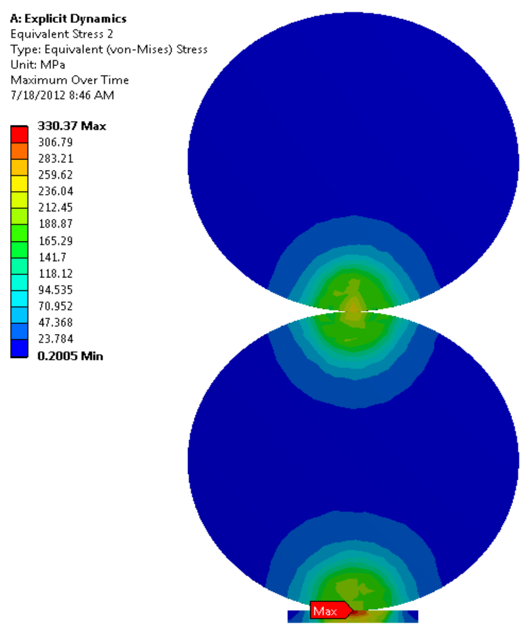

Figure 11. Von Mises Stress {σech = 330,37 [MPa]}

4. Conclusion

The total energy during the impact interval of $1\cdot10^{-4}$ s, has the value Ec,max = 37,325 mJ at the start of the interval, drops to 0 at the moment t = $0,625\cdot10^{-4}$ s, a fraction is dissipated into plastic deformation energy of the bearing ball in motion E_p = 13,11 mJ and its internal energy E_i =11,022 mJ. Both energies represent 67,33% from the maximum kinetic energy at the collision time (t = 0), the rest is dissipated through friction and becomes heat:

ΔE = 37,325 - 28,110 = 9,215 [mJ] = 2,202 10-3 [C]

It can be highlighted from the energy analysis that the deformation energy that leads to the impact area and the energy sum (internal and part of the initial kinetic energy) are equal for the two bearing balls (in motion and stationary) with the values 13,11 mJ and 15 mJ.

The high values for the normal and equivalent stress at the impact moment, similar to the maximum yield point of the material, suggest the possibility of permanent deformations of the bearing balls with negative effects during exploitation.

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