How does a bearing ball roll?

The ball bearing is a mechanical system whose purpose is to separate two parts that rotate relatively to each other within an assembly. The main purpose of the bearing is to promote a *rotational* motion instead of a *sliding* motion between the supported parts. To this end, balls are inserted between the two rings of the bearing. These rings rotate relatively to each other. They are both linked to the parts that are in relative movement. Hence, the balls are the link between the rings and they roll on both of them.

The rolling motion is quite intuitive. Roughly speaking, one may see this kind of motion as a body that rotates around itself and easily translates with respect to the surface of another body. The wheel remains of course the most evident application of that sort of motion. It is tempting to compare this configuration to that of the bearing balls, which are spherical bodies pressed between two concentric rings.

But can we actually compare the balls to small wheels? Sadly, no.

To make it clear, let us first study the behavior of a fictive and simplified ball bearing, which is in two dimensions (Fig. 1). The inner and outer rings are here represented by two concentric circles. The balls are also circular and rotate between both rings. Without loss of generality, the inner ring is the only one able to rotate (the further developments can be generalized to any kind of relative rotation between the rings). In that particular case, we may indeed compare the balls to a set of small wheels. The inner ring motion induces a global movement of the balls around the bearing axis. The balls roll on both rings and turn around themselves in a direction opposite to that of the inner ring.

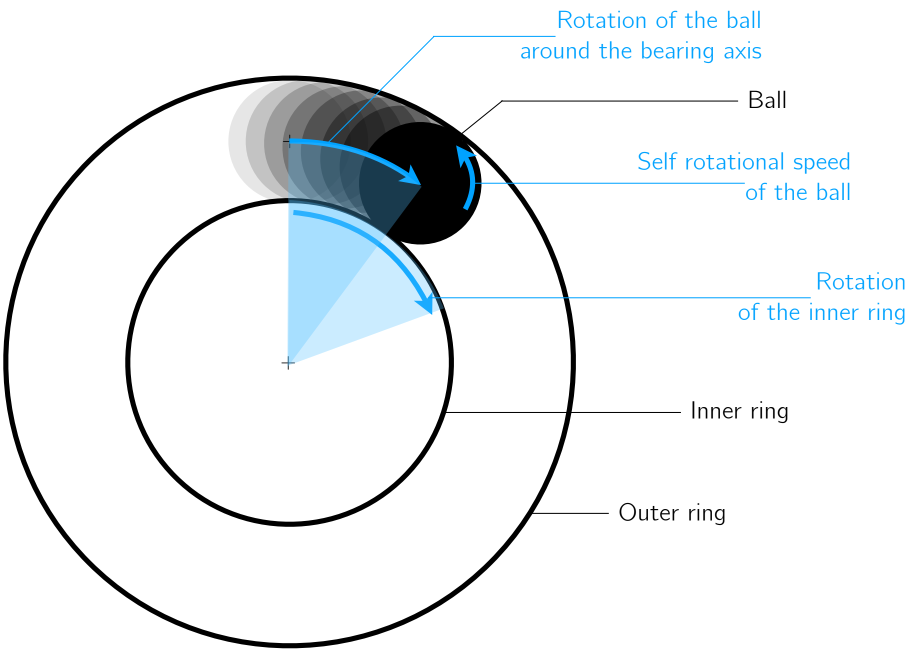

Fig. 1 — Simplified ball bearing (2 dimensions)

The working of this simplified bearing is representative of a radially loaded ball bearing. In that particular case, the balls stay at the bottom of the grooves. As a result, all the rotations are parallel to each other (Fig. 2). This kind of motion is similar to what we could observe by rubbing hands while pressing a ball between them. That is precisely what is represented in Fig. 2: the ball is rolling between two planes.

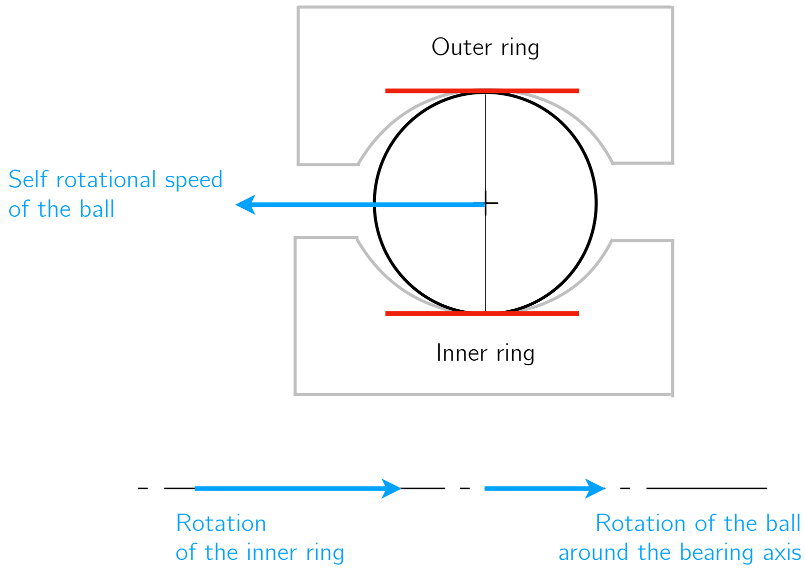

Fig. 2 — Rotation of a ball of a radially loaded bearing

Nevertheless, it is much more complicated to determine the positon of a bearing ball once the bearing loading is combined (axial load, radial load, misalignment torque...), as depicted in Fig. 3. As the ball has the ability to move between the rings, the relative motion of those rings implies that the self rotational speed of the ball is no longer parallel to the rotation of the mobile ring. As a consequence, even if the ball still turns around the bearing axis, it cannot simultaneously roll like a small wheel on both rings anymore.

The description of such motion is complex[1]. Let us only precise that the ball is only capable of exhibiting a pure rolling motion (like a wheel) on both rings, but not at the same time. Those two positions are depicted in Fig. 4. In fact, the two particular orientations are never reached and the self rotational speed axis of the considered ball systematically lies in an intermediate location (that is represented by the blue zone in Fig. 4).

[1] If you are interested about this topic, we kindly invite you to read the article *Influence of the balls kinematics of axially loaded ball bearings on Coulombic frictional dissipations* by J.-L. Bozet and C. Servais, ASME Journal of Tribology, 2017.

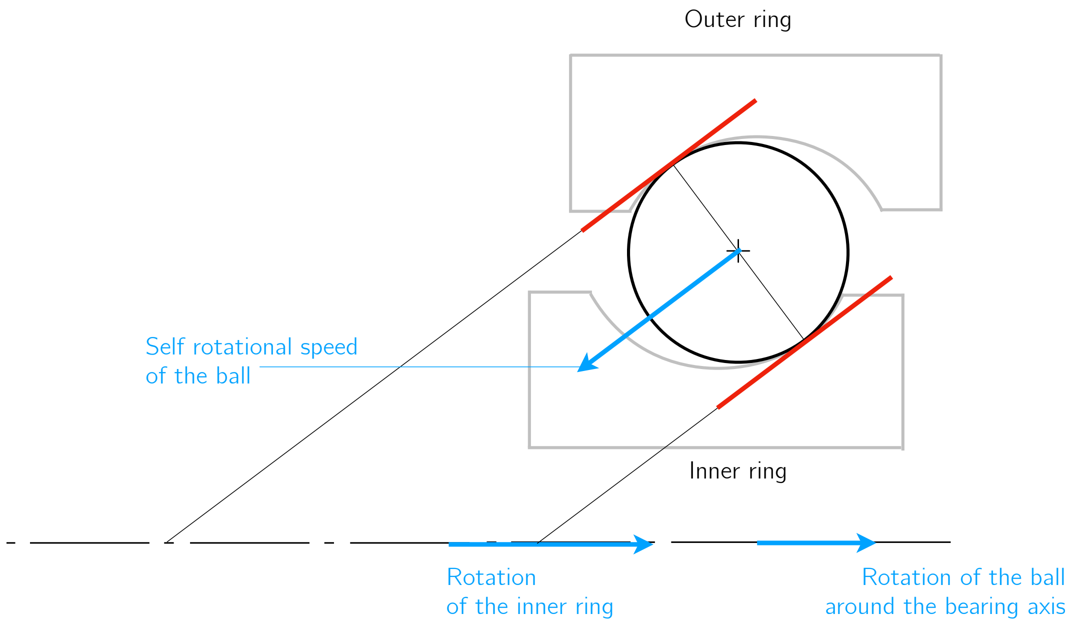

Fig. 3 — Rotation of a ball under a combined loading

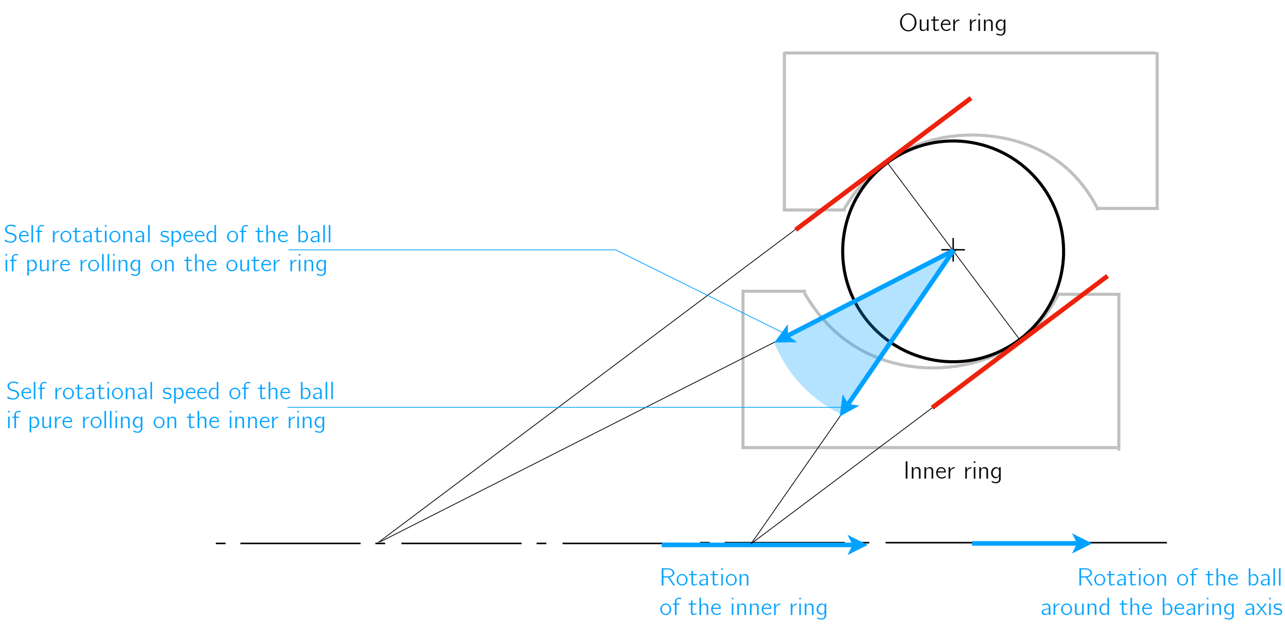

Fig. 4 — Position of the self rotational speed axis of the ball in the case of a pure rolling motion on the rings.

The motion of the ball is now far from that of a wheel on a plane. Indeed, the rotation of a ball on its grooves is closer to the behavior of a soccer ball between two players making passes. Hence, if the ball is observed relatively to one of its rings, one may observe that a *pivoting* rotation is superposed to the rolling motion. The resulting motion can be seen as the combination of the rotations of a wheel and a spinning top.

The presence of a pivoting component is not negligible. Indeed, pivoting is the main source of heat within ball/race contacts. Scientific curiosity apart, understanding how a bearing ball rolls and pivotes is critical in order to optimize the working of a ball bearing. However, surprisingly, current computational tools are still not capable to accurately determine the orientation of the self rotational speed of a bearing ball.

APO-GEE has an innovative computational approach at its disposal, which is able to comprehensively describe how a ball rolls and pivotes within any kind of ball bearing. As a matter of fact, methods developed by APO-GEE use fundaments that take an opposite orientation compared to existing tools. Existing tools use a Newtonian formalism, which is based on the equilibrium of forces and moments. The core of the approach developed by APO-GEE is made of a brand new equilibrium criterion, which is based on the power. It has been the object of an in-depth mathematical demonstration. Indeed, it occurs that satisfying this criterion is equivalent to satisfying the Newton's laws of motion. Nevertheless, contrary to the Newton's approach, the use of the methodology of APO-GEE gives the possibility to completely compute the kinematics of the balls, which leads to the real equilibrium of the ball bearing.

We do not reinvent the ball. But we make it roll.

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