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SLIDE BEARING FOR ELECTRIC MOTORS IN TESLA'S LEGACY

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Abstract: *Nikola Tesla (1856-1943) made numerous inventions and discoveries in the field of electricity, which are the basis of new scientific and technological breakthroughs, started in the late 19th century, and without which our present life could not be imagined. Tesla's work in mechanical engineering has been less studied and published so far, and therefore deserves special attention and interest not only by scientists but also by a chronicler of his life. Besides numerous saved archival documents, personal and technical objects, monographs and serial publications, some samples of slide bearings for electric motors were also found in his legacy.*
The aim of the paper is to present these samples and describe their place in designs of electric motors from that historical period. Authors also provide CAD models based on original samples including some indications of their lubrication and assumed way of operation in electric motor exploitation.

Keywords: *slide bearing, electric motor, lubrication, Tesla, Tesla's legacy, Nikola Tesla Museum.*

1. INTRODUCTION

Nikola Tesla, scientist and inventor, lived and worked in the period that covers both the 19th and 20th century. He belongs to those rare inventors whose inventions for more than a hundred years have not ceased to attract the attention of many scientists and researchers. It was a series of new discoveries, from those in the field of electrical engineering, lighting technology, radio technology, to numerous applications of high-frequency currents in industry and medicine and unusual, original inventions in mechanical engineering and aviation [1].

Thanks to his specialist knowledge and exceptional creativity he was able to solve some technical problems in mechanical engineering and to realize a wide range of new inventions and constructive solutions based explicitly on physical laws. More than twenty years of Tesla's work in the early 20th century is dedicated to the research in this area. Often, without using well established engineering principles, he found his own way to come to genuine and interesting solutions for new design of pumps, turbines, speedometer or fountains. Of particular importance is his contribution to the development of new types of paddleless turbo machines, initiated by the original idea of energy exchange between the fluid in the circuit and turbine discs based on viscous friction [2].

Several original technical exhibits, as well as several articles in newsletters and journals, preserved as a part of Tesla's legacy in the Nikola Tesla Museum in Belgrade, point to the possibility that Nikola Tesla in one period of his life worked on the construction of radial slide bearings for particular types of electric motors. It may be assumed that Tesla was also occupied with the ways and conditions of lubrication of the bearings in the given operational conditions. Preserved specimens of slide bearings and advertising catalogs for electric motors of some U.S. companies from this period lead to this assumption.

2. DESCRIPTION OF ELECTRIC MOTORS AND BEARINGS FOR ELECTRIC MOTORS IN TESLA'S AGE

Thanks to Tesla's discovery of rotating magnetic field the induction motor was designed and a new technology of energy transfer to great distances was introduced, based on the application of polyphase alternate currents [3], [4].

Between the first Tesla's alternate current motors and the present-day ones there is a great difference with regard to their sizes and ratio of weight to power. However, it is only a consequence of the use of better materials and optimization of design and control, while the technical concept remain the same as founded by Tesla' patents more than hundred and twenty years ago.

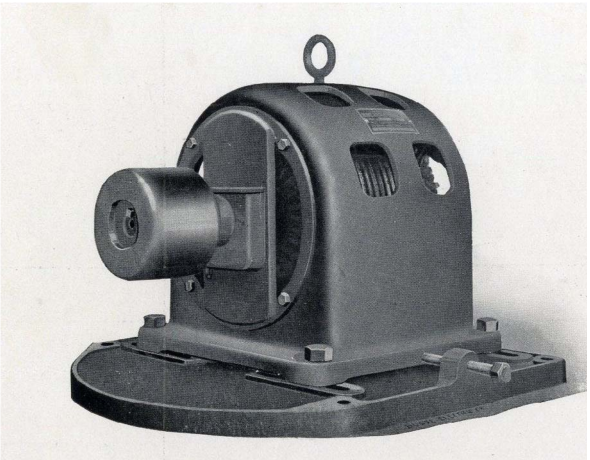

Figure 1. Type EB Induction Motor

Reliability, high average efficiency, long wearing life and low depreciation are obtained by combining correct mechanical design with correct electrical design and by using only the highest quality of materials placed in ample proportion where needed to secure low heating and corresponding capacity for continuous severe service.

They are manufactured as open motors with as much protection to the active parts as is consistent with proper openings for inspection, free ventilation, and adjustment of brushes. They are also furnished with solid enclosing covers or with ventilated or semi-enclosing covers to meet special conditions. These machines can be furnished for suspension from side walls or ceiling by turning the bearing brackets. All parts are interchangeable and the design is rugged, compact, simple and adaptable to any sort of work where reliable electric motor is required.

At the time of Nikola Tesla, the electric motor shafts were supported by slide bearings. Bearings are of composite bearing metal, snugly fitted and secured in bearing brackets and lubricated by multidisc ring oilers which convey oil to the surface of revolving shaft from the recessed pockets in the bearing brackets.

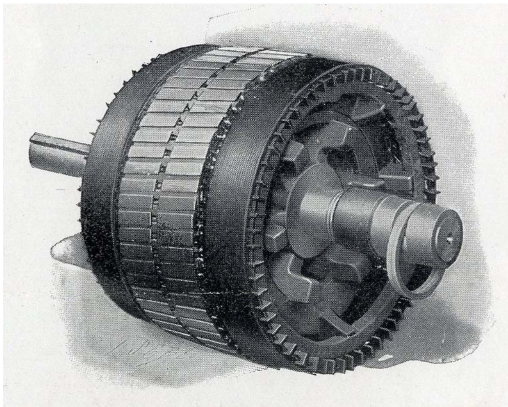

Figure 2. Rotor of Standard Induction Motor

Nowadays slide bearings are phosphor bronze sleeves, adequately grooved for oil circulation, and are interchangeable end for end. Brass oil rings of special design and large diameter feed an abundant supply of fresh oil constantly to the shaft, thereby assuring minimum wear on shaft and bearings. The principle of lubrication of those bearings is shown at the Figure 3.

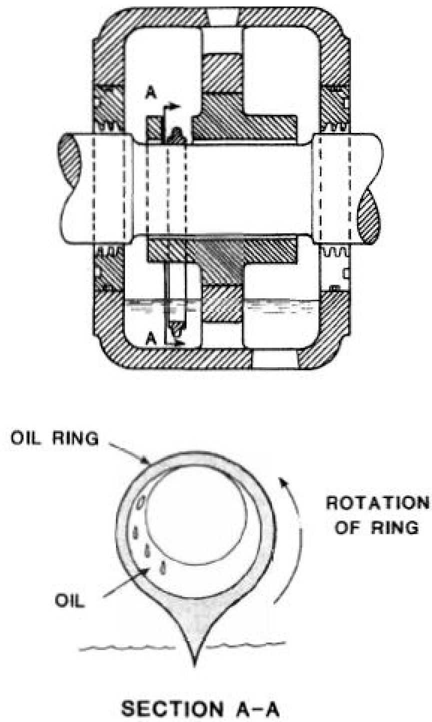

Figure 3. Lubrication of bearing by means of an oil ring

3. EXAMPLES OF SLIDE BEARINGS IN TESLA'S LEGACY

Tesla's estate represents a unique entirety which is preserved, investigated and studied within the bounds of three basic collections of the Nikola Tesla Museum: Archives, Collections and Library.

Tesla' personal assets and technical objects are not only a historical nad material evidence of Inventor's life and work but also a first-class source for the study of the history of technical and technological progress at the end of 19th century and the beginning of 20th century in the Europe and USA.

The preserved technical objects are arranged in four of ten collections of the Museum. These are: Electrical engineering collection, Mechanical engineering collection, Chemical engineering collection, and Collection of minor technical objects. In other words, technical collections of the Museum are organised in accordance with the scientific disciplines in which the objects were either used or represented the results of research performed [5].

In the Mechanical engineering collection there are three original objects, which indicate the possibility of Tesla's interesting in the area of tribology. Two preserved objects, items No. T.23.103 and No. T.23.104, represent machined pieces for manufacturing a slide bearing for electric motors of that period. Both pieces are made of brass by turning on the lathe. We assume that these were experimental pieces which had to enable a realization of Tesla's subsequent modifications and improvements, devised in order to ascertain optimum final characterictics and design of a radial slide bearing.

Their dimensions are almost equal: inner diameter is 15.9 mm, outer diameter 27 mm, while maximum outer diameter of both machined pieces is 28.6 mm. A slight difference in dimensions of these pieces is expressed only in their overall lengths: 44.6 mm at T:23.103 vs. 44.5 mm at T:23.104.

Figure 4. Machined piece for slide bearing T:23.103 (Collection of Objects from the Field of Mechanical Engineering)

However, the main difference between these two pieces is a hole of 5.1 mm diameter and 2.2 mm depth, bored additionaly on the outer surface of one of these pieces (T:23.104). Boring of this hole points to Tesla's initial considerations about the choice of an adequate design which would secure a more uniform delivery of oil into all parts of the shaft of electric motor.

Figure 5. Machined piece for slide bearing T:23.104 (Collection of Objects from the Field of Mechanical Engineering)

The third preserved object is registered in the same collection as item No. T: 23.102. It represents Tesla's design of radial slide bearing, by its shape and other characteristics typical for mounting into the electric motors of that period. Confirmation of their similarity we can find in the advertising catalogues, published by "Diehl Manufacturing Company", Elisabethport, New Jersey, preserved in Tesla's estate. These catalogues, together with catalogues of other American manufacturers of electric motors, suggest that Tesla was paying a thorough attention to the research and development in the fields of science and engineering relevant for his activity [6], [7].

Tesla's slide bearing T: 23.102 are made of brass, by turning on lathe and milling. Its dimensions, except the overall length of 44.2 mm, are identical with those of pieces T: 23.103 and T: 23.104. It suggests that all the three pieces represent a result of a research carried out on a specific type of radial slide bearing.

On the outer curved surface of Tesla's radial slide bearing, next to the opening for oil ring, there are also two smaller circular holes of different radii. Looking on the opening for oil ring, the greater hole, 5.7 mm diameter, is positioned at the left side of the curved surface of the bearing. The smaller hole, 2.3 mm diameter, is placed on the rear side of the curved surface. These two holes, with regard to their diameters and positions on the curved surface of the slide bearing, had to secure maintaining the level of lubricant at the proper height, and on the other hand, to prevent the possible excess of oil to penetrate into the interior of an electric motor and come into contact with its windings.

By comparison of Tesla's design, with holes bored on the curved surface of his slide bearing, with similar design of slide bearings built into electric motors made by Diehl Manufacturing

Company, a clear distinction with regard to the position of holes can be made. At Tesla's design, the greater hole is placed on the left side of the curved surface, at one-third of the bearing height, looking from the opening for oil ring. At the slide bearing of the American manufacturer, however, a hole of similar dimensions, bored for the same purpose, is placed on the top of the curved surface of the bearing, behind the opening for the oil ring. (Precise data are not given in the advertising catalogues). As to the hole with smaller diameter, which is placed on the rear side of Tesla' slide bearing, an adequate comparison was not possible, because the hole of similar dimensions could not be found on the photographs and drawings in the advertisings of the manufacturer.

On the inner surface of Tesla's radial slide bearing, along its axis, two spiral.shaped grooves, each one of 1mm width and approximately 1 mm depth, are cut. Their purpose is to render a more uniform delivery of oil into all parts of the motor shaft and to return excess oil into the central tank.

Figure 6. Model of Tesla's radial bearing for electric motors, T:23.102 (Collection of Objects from the Field of Mechanical Engineering)

However, the original oil ring of Tesla's slide bearing T.23.102 has not been preserved. Lack of this ring makes impossible a complete comprehension of Tesla's design and ascertainment of its performances in terms of lubrication.

Generally speaking, oil rings have the purpose to enable a continuous delivery of fresh oil to slide bearings and shaft, and in this way to secure their minimum wearing during the operation of electric motors. Due to this purpose, oil rings are of greater diameter and of specific design. They are mounted on the outer side, at the opening cut in the curved surface of the slide bearing. In this way, they continuously adhere to the shaft, rotate together with it, lubricating it with a considerable quantity of oil. Oil rings are made of brass or a similar material. In the advertising material printed by Diehl Manufacturing Company we can find photographs of slide bearings with an oil ring of a particular design.

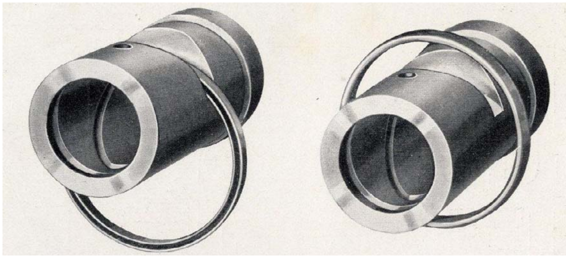

Figure 7. Type of Bearings Used on Diehl Polyphase Induction Motors

4. 3D CAD MODELS OF TESLA'S SLIDE BEARINGS

To have better insight into the samples, CAD models have been designed using CATIA V5 R18 software. Besides giving faithful representation of samples, these models can be used for further analysis in terms of stresses and deformations. This can be the subject of subsequent investigation.

Figure 8. 3D CAD model of the machined piece T:23.103

Figure 9. 3D CAD model of the machined piece T:23.104

Figure 10. 3D CAD model of Tesla's radial slide bearing T: 23.102

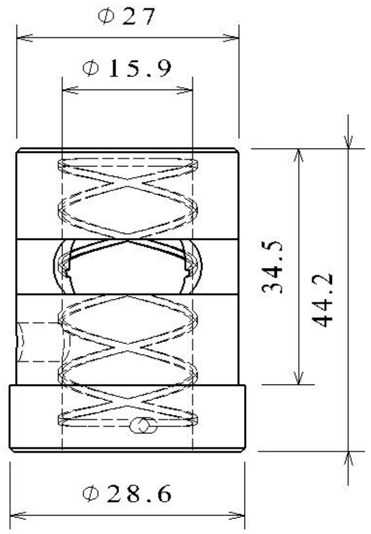

Figure 11. 3D CAD (transparent) model of radial bearing, dimensioned.

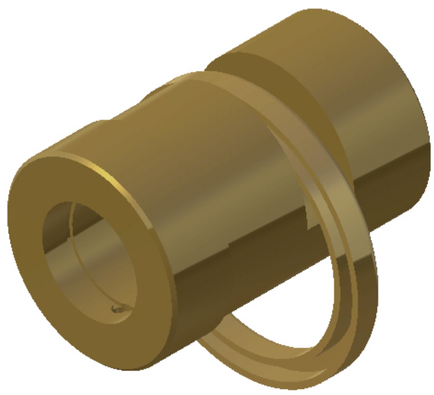

Figure 12. Presumed assembly of bearing and oil ring

5. CONCLUSION

This paper gives types and operational performances overview of sliding bearings that were common in use during the last century when Nikola Tesla investigated and studied electric motors and also their construction and application. Some of those original sliding bearing samples that are keeping in Nikola Tesla Museum in Belgrade are presented following with corresponding CAD models made in CATIA software.

Although we cannot say for sure that Tesla designed the bearings, the fact that they stayed at his heritage forces us to consider this possibility and examine all the features of these cases.

Taking into account that more than 50% of electric motors failures was due to improper lubrication of bearings, analysis of bearings from Tesla's heritage can lead to clearing his thinking in the area of Tribology, as well his contribution in engineering in general. The role of bearing those are current applied in electric motors are more significant, where besides sliding, also rolling bearings are frequently applied. Most electric motors do not contain “special” bearings. The only differences between an electric motor bearing and any other bearing are the higher noise standard and possible electric insulation to prevent electric current passage through the bearing. To reduce noise, process tolerances are much closer, which keeps the bearing running quieter.

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