Development and Realization of Rotary Anode Type X-ray Tube Using Liquid Metal Lubricated Bearings for High Speed Medical CT

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1. Abstract

In a rotary anode type X-ray tube for medical imaging, the rotating target for emitting X-ray is enclosed in an atmosphere of high vacuum. Conventionally, the bearings supporting the rotating target consist of ball bearings coated with solid lubricants such as Pb or Ag. However, such kinds of ball bearings have the drawbacks that the lubrication characteristics is unsteady, and in the case of high bearing load the rotation speed of target is limited. In order to satisfy the requirements of helical scan CT (computed tomography) of high scanning speed, new X-ray tube possessing high capability bearings that can operate normally under high centrifugal force is needed. Moreover, lowering the X-ray dosage and shortening the imaging time are important concerns for the diagnosis by medical CT. The new X-ray tube developed is provided with fluid lubricated bearings adopting liquid metal lubricant. As a result, the drawbacks of ball bearings have been overcome, and the X-ray tube with performances that satisfies the requirements of high speed medical CT has been realized.

2. Technology

Shown in Fig.1 is a helical scan type X-ray CT. An X-ray tube located on one side of the center hole and an X-ray detector located on the opposite side across the center hole are contained in the gantry. During the diagnosis, by revolving the X-ray tube and the detector around the center hole and inserting the bed into the center hole simultaneously, helical scan is achieved.

Fig.2 shows the X-ray tube developed. The fluid lubricated bearings for supporting the rotating target are lubricated with liquid metal such as a gallium alloy. The rotating mechanism consists of a stationary shaft with hydrodynamic grooves engraved on its surface, and a rotating body in which the target is contained. The rotating body rotates about the stationary shaft and is supported by the bearings.

In order to satisfy the requirements of high speed medical CT, the original technologies shown below are adopted in the design of the X-ray tube.

(1) As shown in Fig.3, hydrodynamic hybrid bearings containing a plain bearing part between the grooved parts are adopted. By the wedge effect of the plain part, the bearings are capable to support high bearing load. As a result, the vibratory stability and the capability for supporting high bearing load are achieved simultaneously.

(2) As shown in Fig.4, a design that can keep the stationary shaft parallel to the rotating body in a fine state even under the action of large centrifugal load, is adopted. As a result, the formation of excellent lubricating film of the bearings under the loading conditions of high speed medical CT are ensured.

(3) A surface treating technology for creating the reaction layer with the gallium alloy has been developed. As a result, the wettablity of the gallium alloy has been secured.

By these technologies, the requirements of high speed medical CT were satisfied. And, for the kind of X-ray tubes using liquid metal lubricated bearings, the developed X-ray tube is the first one that applicable to

high speed medical CT (< 0.5sec per 1 slice imaging). The performance and the merits of the X-ray tube are as follows.

(1) While with a large output capability, the rotating mechanism with a high rotation speed of 10,800rpm which is about twice of that of conventional X-ray tubes has been realized. As a result, the X-ray dosage can be reduced to 1/2, and high resolution images that superior to those of conventional X-ray tubes can be obtained.

(2) The X-ray tube can withstand the centrifugal acceleration (over 24G) induced by the scanning of high speed medical CT.

(3) By using liquid metal lubricated bearings, malfunctions due to poor lubrication have been eradicated. As a result, steady product life of the X-ray tube is obtained, and high reliability is realized.

3. Conclusion

By the X-ray CT equipped with the above X-ray tube, the X-ray dosage to the patients can be reduced. Moreover, because high resolution images can be obtained, the early detection of focuses of diseases becomes possible and the effects on the prevention of erroneous diagnosis can be expected.

The production of the X-ray tube has already started, and the production increase program for the next year and those years following goes smoothly.

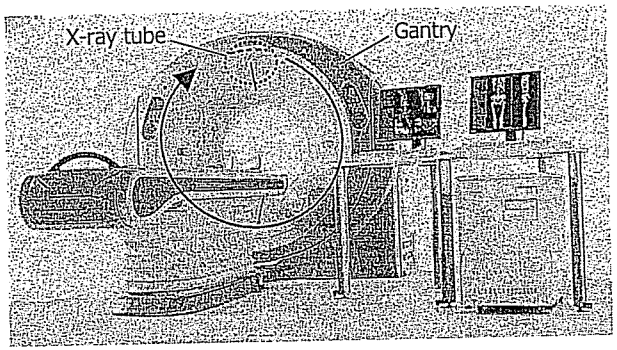

Fig. 1 A helical scan type CT

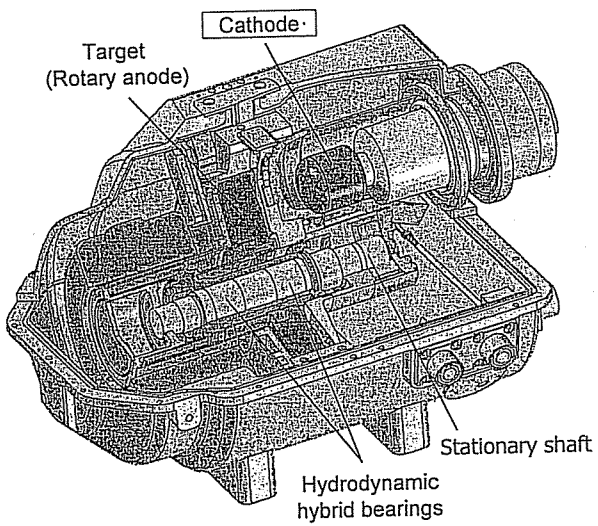

Fig. 2 Composition of the new X-ray tube

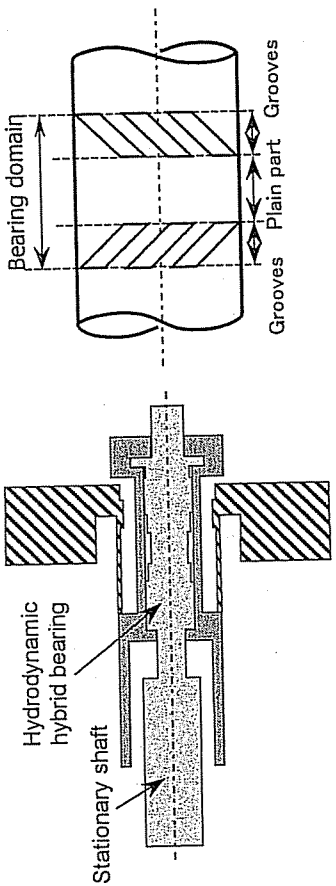

Fig. 3 Hydrodynamic hybrid bearing of the stationary shaft

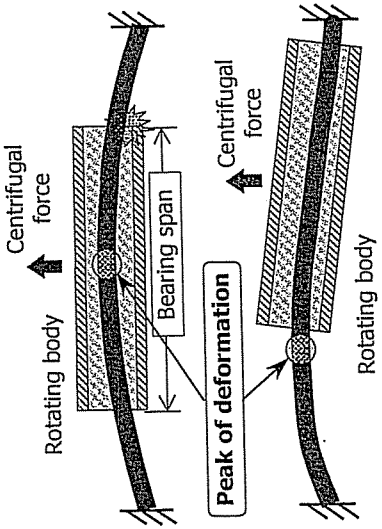

Fig. 4 Concept of the design used to keep the parallelism in the bearing span