As a result of these investigations and tests, it has been possible to determine the heat-treatment necessary to obtain the desired low level of hydrogen content which will prevent the formation of blisters. Fig. 11 illustrates the reduction in the hydrogen content of commercial steel after it has been heat-treated for use as thrust-bearing pads. It was found that heat-treating the pads for one to two weeks at 600 C depending on the thickness of the steel would reduce the hydrogen content to less than 0.12 RV. Steel containing such a low hydrogen content will not cause babbitt blisters.

That the desired results are obtained is further insured by an adequate quality control. Hollow drilled samples on each set of bearing pads, reflectoscope checks, and fluorescent-light inspection of each pad, as shown in Figs. 12 and 13, insure that thrust-bearing pads free of hydrogen and having a well-bonded babbitt free of porosity are produced.

Conclusion

It has been established that hydrogen contained in commercial steels is responsible for the babbitt blisters observed in bearings. A low level of hydrogen content is required to prevent the formation of blisters. This low level is obtained and insured by suitable heat-treatment and quality control.

As a result of this investigation, the quality of the babbitt bond also has been improved. The improved manufacturing process combined with modern inspection techniques results in thrust-bearing pads of high quality and increases the reliability of large water-wheel generators.

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We would like to acknowledge significant contributions made by engineers from various departments of the Westinghouse Electric Corporation. Messrs. John Boyd and Howard Kaufman of the Research Laboratories were responsible for showing that babbitt blistering was the result of hydrogen in the steel. Dr. E. W. Johnson of the Research Laboratories conducted the extensive literature survey and formulated the method of hydrogen removal. Messrs. E. A. Fox, W. Reichenecker, and S. A. Rosecrans of Materials Engineering were instrumental in the development of hydrogen elimination and measurement techniques.

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Discussion

L. C. Galloway.[6] The information contained in this paper will be encouraging to both the manufacturers and the operators of hydroelectric generators. The authors and their associates are to be congratulated for the progress they have made with a difficult and expensive problem.

The writer's company has manufactured Kingsbury-type thrust bearings for many years and could boast an almost trouble-free record. However, after the war, development of a metallurgically bonded babbitt coincided with the increase in hydrogen level in steels noted in the paper, and the result was a number of expensive bearing failures. The blisters problem was solved by substituting a mechanical anchorage with dovetailed slots for the metallurgical bond.

This solution is a mixed blessing, however. It is difficult to keep the babbitt adhering firmly to the steel pad with mechanical anchors and thereby to provide a permanently flat surface. This difficulty was overcome by a considerable amount of research in the shape and number of the anchors. Also, the cutting of these anchors is expensive.

The trouble is that it takes a long time to prove that blisters will or will not develop and some may be reluctant to accept the authors' assurance that one year of operation will tell the story. However, if the problem is solved a major difficulty in thrust-bearing operation has been overcome.

Authors' Closure

Mr. Galloway's discussion is very much appreciated. Early in our investigation the solution of using mechanical anchorage was also considered. It is obvious that this method prevents positively the formation of blisters. However, the solution of removing the hydrogen from the steel was preferred, since it is believed that a sound metallurgical bond between the babbitt and the steel pad has many other advantages, particularly from the standpoint of resistance to fatigue.

This latter solution has proved to be entirely practical from the manufacturing standpoint; furthermore, tests and experience indicate that it very effectively prevents the formation of blisters.

In regard to the time required for blisters to occur in untreated steel, it is the authors' experience that blisters, when they develop, appear within a few months after the bearing is placed in service. When the hydrogen level is not sufficient to produce blisters at an early date, all evidence indicates that the blisters will not occur later.

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