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FIELD QUALITY FROM TOLERANCE ANALYSES IN EIGHT-PIECE QUADRUPOLE MAGNET*

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Quadrupole magnets are used extensively in particle accelerators, synchrotrons, and storage rings all over the world. Excellent field quality in these quadrupole magnets is needed at these facilities, which requires machining the magnet parts to high precision with conventional magnet designs. An eight-piece quadrupole design and assembly method are developed that produce the desired magnetic field quality by accurately positioning the pole tips in a quadrupole magnet. In this magnet, all the parts need to be machined only within standard machining tolerances [1]. This paper presents the magnetic and mechanical tolerance analyses of this eight-piece quadrupole magnet. We performed mechanical tolerance stack-up analyses using the Teamcenter Variation Analysis software [2] to evaluate the relationship of part-level machining tolerances to final magnet assembly errors. We then performed finite element analyses using OPERA [3] to estimate the effect of assembly errors on magnetic field quality and in turn to set the acceptable machining tolerances for parts to achieve the desired magnetic performances. We conclude from our tolerance analyses that 20 microns symmetry in pole tip gaps can be achieved with 50 micron standard machining tolerances, resulting in improved field quality. The analysis results are compared to magnetic measurements of the R&D eight-piece quadrupole magnets.

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