Numerical framework for evaluation of distortions in bearing rings.

Harihara Krishnan Sankaran*†[1], Fabien Cazes*‡[1], Brigitte Bacroix[1], Camille Tribillon[2], and Cyrille Lebreton[2]

[1]Laboratoire des Sciences des Procédés et des Matériaux – LSPM – CNRS , 99 Av. Jean Baptiste Clément, Villetaneuse , 93430, France – France

[2]ADR-ALCEN – ADR-ALCEN, 12 Chem. des Prés, 77810 Thomery. – France

Abstract

High precision ball bearings produced by ADR-ALCEN has specific applications in aerospace and defense sectors. One such specialised bearings are slender bearings whose diameter is far greater than its thickness. The formation of residual stresses during turning creates distortions at each step of material removal process. If the turning process is not tightly controlled, further material processing could deform the rings beyond tolerance limits. This creates a need for accurate determination of residual stresses and distortions and associated uncertainities along the spatial coordinates.
In this work a 4 step approach is used to determine the distortions in bearing rings:

Analytical estimation of cutting forces using Merchant theory (1) and equivalent thermo mechanical loads are estimated using the formulas proposed in (2).

Simulation of the turning process using the previously equivalent thermo mechanical loads using Salome-Meca (3).

Extraction of eigenstrain profiles as function of depth from the surface and fitting using spline interpolation.

Application of the obtained eigenstrain profiles (4) on the real geometry of the ring to obtain distortions and residual stresses. This step only involves elasticity calculations with eigenstrains that are performed either using appropriate beam theory or finite elements simulations or full 3D simulation using Finite Element Analysis package FEniCS (5).

The distortions of the rings obtained from step 4 which corresponds to the industrial problem are of the order of microns which can be very difficult to measure with sufficient precision using conventional measurement techniques. Also by perfoming simulation of the ring that is cut along the radius at one part of the ring, we can obtain larger values of distortion that are easier to measure experimentally. This kind of experimental approach for cut parts

*Speaker

†Corresponding author: harihara.sankaran@lspm.cnrs.fr

‡Corresponding author: Fabien.cazes@univ-paris13.fr

of tubular shape is similar to existing Slitting method (6) that are widely used in tubing community. In addition to existing slitting method, the specific geometry of the rings investigated pushed us to consider not only in plane variation of the radius of the rings but also their out of plane displacements.

Numerical results obtained will be compared to experimental results obtained from the cutting of rings composed of AISI440C provided by the industrial partner. The cut of the rings is performed using Electro-discharge machining and displacements measurements are performed using contact sensors with Coordinate Mesuring Maching (CMM). The results of non-contact measurement of displacement using the non contact measurement setup composed of motorized translation and rotation stages and a laser triangulation sensor may be presented, if available at the time of conference.

Key words : bearing rings , turning simulation, distortions, residual stress, Slitting method, relaxation method, numerical simulation.

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