UNIVERSITY COLLEGE DUBLIN

MNMT-DUBLIN

Kinematic Analysis of Multi-axis Machine Tools

Background

As one of the most important types of machine tools in the manufacturing industry, multi-axis CNC machining centers have been widely used for machining parts with complex surfaces. Conventional machine tools using stacked linear axes as the primary motion control system are capable of supporting traditional material removal processes but have inherent thermal stability and stiffness issues. The twin-turret machine in MNMT is radically different, coordinating two rotary axes and a short linear axis in a unique design, providing much higher stiffness and thermal stability than conventional machines.

Industrial demands

Parts in optics, aerospace and medical devices often demand very high geometric accuracies. With the increasing complexity of the designed surfaces of parts, machining strategies are becoming exceedingly complicated, which in turn requires that machine tools have sufficient machining accuracy as well as good dynamic and kinematic characteristics. However, because of the special configuration, the understanding of the machine kinematics becomes an urgent request.

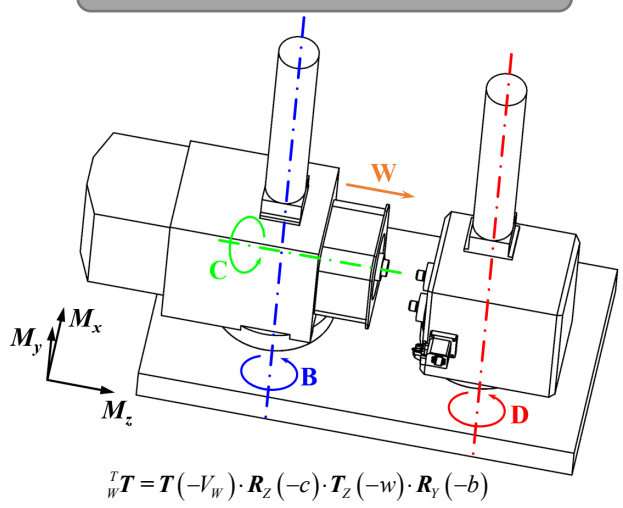
New method

MNMT-Dublin has constructed the forward kinematic (FK) and inverse kinematic (IK) models for the twin-turret machine with both the Denavit–Hartenberg (D-H) method and geometric analysis (GA) method. Compared with the D-H method, the GA method gives a better solution to avoid the singularity problems.

Progress and results

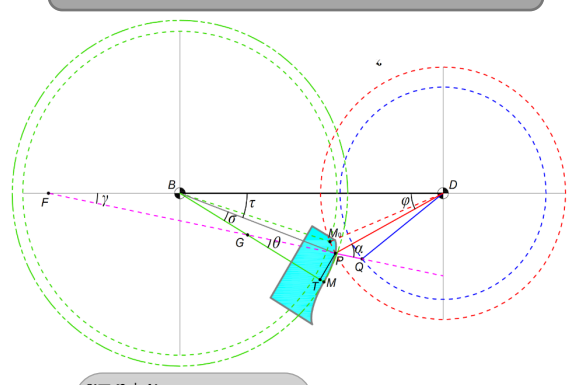
With the constructed FK and IK models, the tool normal machining (TNM) was systematically studied for plane, sphere, aspheric and freeform surfaces. The tool path generation strategy and form error model caused by the tool setting error in the process were successfully developed.

Twin Turret Machine



$$ {}^{T}_{W}\boldsymbol{T} = \boldsymbol{T}(-V_W)\cdot\boldsymbol{R}_Z(-c)\cdot\boldsymbol{T}_Z(-w)\cdot\boldsymbol{R}_Y(-b) \cdot\boldsymbol{T}_Z(L_{BD})\cdot\boldsymbol{R}_Y(d)\cdot\boldsymbol{T}_X(-L_{Tx})\cdot\boldsymbol{T}_Z(-L_{Tz}) $$

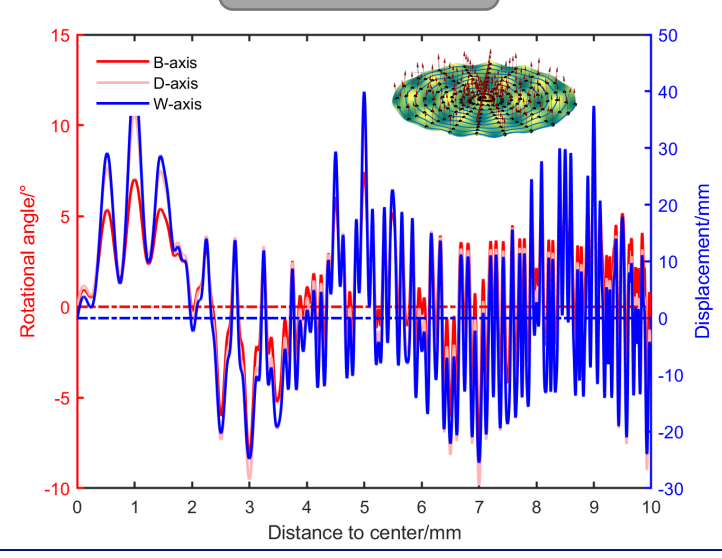
Tool Normal Machinng



$$ \alpha=\varphi+\gamma $$
$$ \gamma+\theta=\tau+\sigma $$
$$ |PT|=|BP|\cdot\sin\sigma $$
$$ \frac{|BP|}{\sin\varphi}=\frac{|DP|}{\sin\tau}=\frac{|BD|}{\sin(\varphi+\tau)} $$

$$ \begin{cases} \beta=\tau+\sigma+\beta_0 \\ \delta=\varphi-\delta_0 \\ w=|BM|-|BM_0| \end{cases} $$

Tool Path



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