Research Report of Laser Coarse-fine Coupling Tracking Measurement for Robot Errors

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A novel measurement for robot errors is proposed through the cooperation of three Universities under the AC21 project support. The laser coarse-fine coupling tracking measurement is carried out in the measurement for robot dynamic or static errors. The research objects include robot pose, motion trajectory and parameter relationships between dual robot base coordinates. The measurement can not only meet the requirements of the large range, rapid response and dynamic tracking, but also achieve the high accuracy of submicroradian magnitude due to the particular opto-mechanical design with low cost. The research contents can be summarized as follows.

(1) Theoretical modeling of laser coarse-fine coupling tracking measurement system, error analysis and system constitution. The measurement theory of coarse-fine coupling tracking is studied in order to build the theoretical model of the beam through the coarse tracking mechanism and fine tracking one. The simulation research on the beam tracking and aiming is carried out according to the mathematical model of tracking methods. As a result, the tracking range of coarse tracking mechanism is no less than $\pm 15°$ in pitch angle and $\pm 180°$ in azimuth angle. The maximum beam scanning velocity of coarse tracking mechanism attains 0.5°/s and the maximum scanning acceleration is 0.05°/s2 with the tracking accuracy is better than 50 μrad. The fine tracking range is no less than 1400 μrad both in level and vertical field angle with the tracking accuracy better than 0.5 μrad. The hundredfold decreasing relation from prism titling angle to beam deviation angle is theoretically validated in the fine tracking mechanism.

(2) The error model of laser tracking mechanism. The error model of coarse-fine tracking mechanism is deduced by the differential method. The beam deflection errors induced by prism rotation angle, prism angle have been discussed respectively. The mating relations among the prism deviation angle, step motor stepping angle and encoder resolution are studied according to the above analysis. The key technology parameters and hardware organization are selected as follows by the theoretical analysis. A rectilinear step motor is used and main parameters is 1.8° / stepping angle,

namely the step length 7.9375 μm. The inner diameter of encoder is 40 mm with grating 6000, and the recommending measurement step is 5.4". The PC numbered card is applied with a subdivided signal till 4096 frequency doubling (line period and measuring step).

(3) Research on robot pose and position (kinematics) model and error model. The optimization algorithm to improve the calibrated condition is studied through the simulation method. The algorithm principle to study the robot harmonious motion trajectory is proposed, and the valuation method of motion trajectory deviation is accordingly built. According to the mission definition of double robots, the mathematic model of double-robot basis coordinates is analyzed by the method of coordinate conversion. Moreover, the removing error method is further studied by the simulation analysis. The submitted research paper has been submitted to Proceeding of SPIE and an inventive patent is accepted in China.

(4) The testbed makeup for robot errors. Based on the primary laser tracking experiment testbed, the integrated design and analysis is carried out, including design of micro-displacement adjustment device, a complete drawings, detailed structure analysis and simulation, and some inventive patents are applied too. After building robot experiment platform together with the laser tracking measurement system, the optics calibration and adjustment is performed to complete the robot test. Then the relations between the laser tracking measurement system and robot pose, especially the harmonious motion parameters, are studied. The measurement data transfer method is proposed. The robots calibration method is studied in order to perform the test experiment, data handling and error analysis. Some factors affecting the uncertainty of test accuracy are also studied. The research paper has been published in Optica Applicata, Vol.39, No. 2, 2009.

(5) Further research development plan. The above research is also funded by the Chinese Academy of Sciences. The next research will focus on the dual-robot motion trajectory test, especially the dynamical error research. The test method and experiment project will validate the theoretical analysis and simulation results. Some error evaluation method will be further studied for the improvement of the whole experiment system, and related valuable conclusions can be drawn as references in practical robot applied fields.

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