

# Chapter 5

## CONCLUSION

In this document, an overview of design theory on kinematic couplings has been presented with specific detail to the classic ball and groove coupling and the newer three pin coupling. A collection of implementation and installation guidelines are also presented for using these couplings in an industrial setting. In particular, the theory and guidelines have been directed towards design of couplings for use under high load and detrimental conditions. Proper analysis of static and disturbance forces as well as contact stress at the contact points allow for inclusion of kinematic coupling elements into these settings.

Through the application of kinematic couplings to a small scale calibration device, kinematic couplings have made an entrance into the industrial setting via a metrology application. The use of this device allows for quick recalibration of the home position of the ABB IRB 6400R robot, as well future use on other robot lines. Challenges overcome in the design of the device include developing solutions for applying preload simply and consistently, while preventing the calibration device from falling off the robot. A novel design developed is the dynamic V-groove, which allows a device perpendicular to gravity to measure a rotation parallel to gravity without developing instabilities. At the project start, a target of 0.2 mm was placed on the repeatability of the home position calibration. The final prototype maximized repeatability of the robot to device interface and minimized device manufacturing errors to successfully meet project requirements.

Through the application of kinematic couplings to a medium scale, high load interface, kinematic couplings have become a viable option for inclusion in the menu of design tools available to the industrial designer. The research presented in this thesis shows preliminary results demonstrating the improved performance provided by kinematic couplings when applied to the high load wrist interface of the ABB IRB 6400R robot. Applications of kinematic coupling theory have not been done previously on this scale. In order to present a baseline measurement of coupling design, the classic ball and groove coupling design was developed and tested on the wrist. Because of the high loads present at the wrist, canoe ball elements were used in place of standard hemispheres to reduce contact stress while retaining repeatability. These results were compared to the existing pin joint interface and a new three pin coupling that uses elements of the existing interface to create a more deterministic coupling. In static measurements, the canoe ball coupling presented a 64% improvement in repeatability and 35% improvement in repeatability for dynamic measurements. The three pin coupling showed potential of a 44% reduction for dynamic measurement with minimal changes to the interface, however, the critical interface features were damaged during testing. Since the three pin coupling presents the most inexpensive solution, further testing is required to test the true performance of the three pin coupling.

In addition to further testing of the three pin coupling, additional investigation should proceed in several other areas, including friction reduction using coatings, long term dynamic performance, and the effect of off center loads during mounting and operation. Laboratory tests should also be performed to obtain an ideal limit for the repeatability of three pin coupling in comparison to the classic ball and groove coupling. These tests will further the concept of an accuracy design menu, allowing different couplings to be easily compared for repeatability, cost, and other factors.



