MECH 577 Optimum Design

Project # 3 Inequality-constrained Optimization: Optimum Structural Design of a Spherical Link

Assigned: November 3rd, 2010 Due: December 3rd, 2010

Project Statement

Intelligent Robotics Inc. (IRI) is now ready to use a spherical four-bar linkage as a *quasi-homokinetic* joint in its robot currently under development. To this end, it is engaging in the structural design of the various links of the linkage that you designed in Project 2. The crucial elements here are the input and output links. Although their mid curves are usually sketched as spherical arcs on one and the same sphere, interference issues require that the end points of their proximal and distant joint "centres"—the joint centre is defined as the point at which each pin-joint axis intersects an imaginary sphere—lie on concentric spheres of different radii.

More concretely, let the mid curve of the link be $C'D'$, as sketched in Fig. 1, α_2 indicating the optimum link dimension found in Project 2—if you could not find a reasonable value, use 47.7°. The curve has two straight segments at the end, subtending equal angles $2\alpha_0$ that you will specify according to the dimensions needed to accommodate one input shaft of axis OA, rigidly fastened to the link, and a pin-joint defined by a bearing of axis OB, to couple this link with the coupler link. The bearing must be specifed from a catalogue, indicating catalogue ID number.

The main purpose of the project is to determine the intermediate segment Γ, defined so that the whole curve $C'D'$ be G^2-*continuous*. G^2-*continuity* means that Γ is tangent to segments CC' and DD' at points C and D, respectively, at which points the curvature of Γ vanishes. The space available to place the linkage allows for $\overline{OA} = 116.8$ mm and $\overline{OB} = 92.2$ mm. A practical method to obtain G^2-continuous curves as results of optimization problems is outlined in (Teng, Bai and Angeles, 2008). A complete case study is given in (Bidault, Teng and Angeles, 2001).

Your report must contain the rationale behind the definition of the mid curve, a CAD image of the optimum link and a finite element analysis, under a unit input torque, with its results showing the *von Mises stress distribution* along the optimum link, illustrated with a map of von Mises contours on the boundary of the link. Make sure that **your report includes a description of the meaning of the von Mises stress**, as this concept is not common among B.Eng. graduates. For concreteness, use a uniform circular cross-section of the appropriate radius. Choose aluminum as the material for the link. Your optimum link should be close to obeying Venkayya's criterion (Venkayya, 1971) for an optimum structural element.

References

Bidault, F., Teng, C.P. and Angeles, J., 2001, "Structural optimization of a spherical parallel manipulator using a two-level approach," *Proc. ASME 2001 Design Engineering Technical Conferences*, Pittsburgh, PA, Sept. 9-12, CD-ROM DETC 2001/DAC-21030. Available at

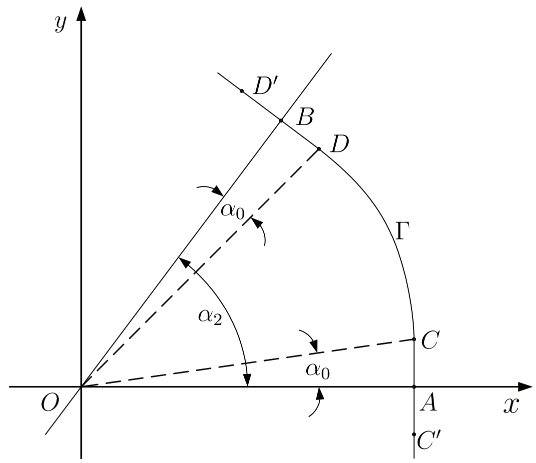

Figure 1: A sketch of the mid curve of the input link of a quasihomokinetic spherical linkage

`http://www.cim.mcgill.ca/~rmsl/Index/index.htm` under "Full-Length Papers in Refereed Conference Proceedings."

Teng, C.P., Bai, S. and Angeles, J., 2008, "Shape synthesis in mechanical design," *Acta Polytechnica*, Vol. 47, No. 6, pp. 56–62. Available on the course CIM website.

Venkayya, V.B., 1971, "Design of the optimum structure," *Computers and Structures*, Vol. 1, pp. 263–309.