Optimal Motion Patterns For Golf Swings

In MSC.ADAMS

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Overview

- **Optimal golf motion pattern is defined as a class of motion patterns to reach highest striking speed with minimum required muscle-generated forces/torques.**

- **Our previous study showed that optimal golf swing motion, like that of the high-speed robot arms, consists of low harmonic motion patterns that are synthesized to require joint torques with low harmonic content.**

- **In the current analysis, MSC.ADAMS is used as a tool to synthesize the optimal motion patterns for golf downswing and obtain the required muscle-generated forces/torques.**

Summary of the Work

- **A nonlinear two-bar link model is created in MSC.ADAMS to analyze the motion of a golfer during striking swing.**

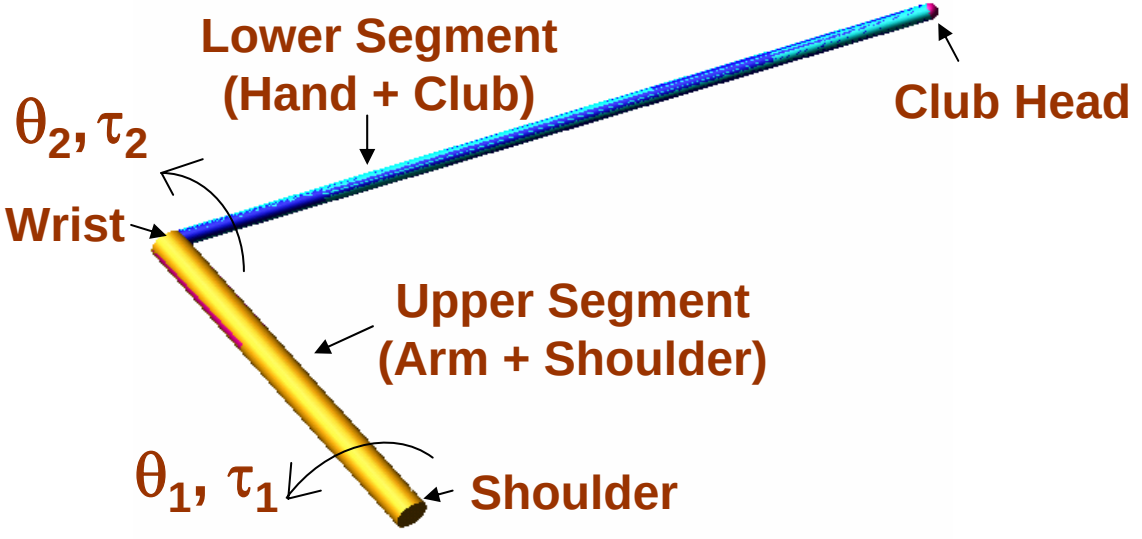
- **The measured shoulder and wrist motions are analyzed. The motion patterns contain significant high harmonics up to the 30^{th}.**

- **The motion patterns are re-synthesized with the modified lowest three harmonics to achieve the same striking speed.**

- **The shoulder/wrist torques are generated using a feed back controller (PID) to achieve the desired motion. The peak torques are reduced significantly with the synthesized motion.**

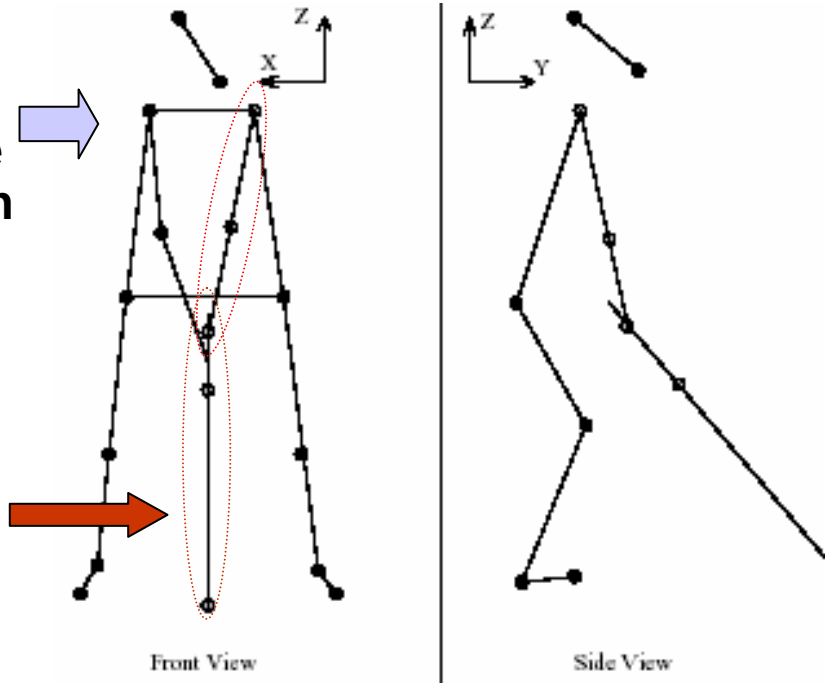
Dynamic Model of Golf Downswing

- **The downswing in golf (left segment) has been modeled by the 3-D motion of a nonlinear two-bar link space model in MSC.ADAMS.**
  - ***Upper segment (arm + shoulder) pivoted at the shoulder and connected to the lower segment (club + hand) at the wrist.***
    - **Shoulder motion is applied by a 3-D translational motion generator.**
    - **Upper/lower segments are modeled with effective links connecting the shoulder to the wrist, and the wrist to the club head. Each link consists of two sliding segments with the total Link length controlled to equal the measured shoulder/wrist or wrist/club head distances.**
    - **3-D rotational motions θ_1 and θ_2, and the net muscle-generated torques, τ_1 and τ_2, are obtained about the shoulder and the wrist joints.**



Measured Motion Simulation

- **The swing motion of a golfer was measured using 120 Hz high resolution video cameras and the retro-reflective markers placed on the subject and the golf club.**
- **The measured motion at the left shoulder/wrist/club head during downswing is simulated in MSC.ADAMS using 3-D translational motion generators.**

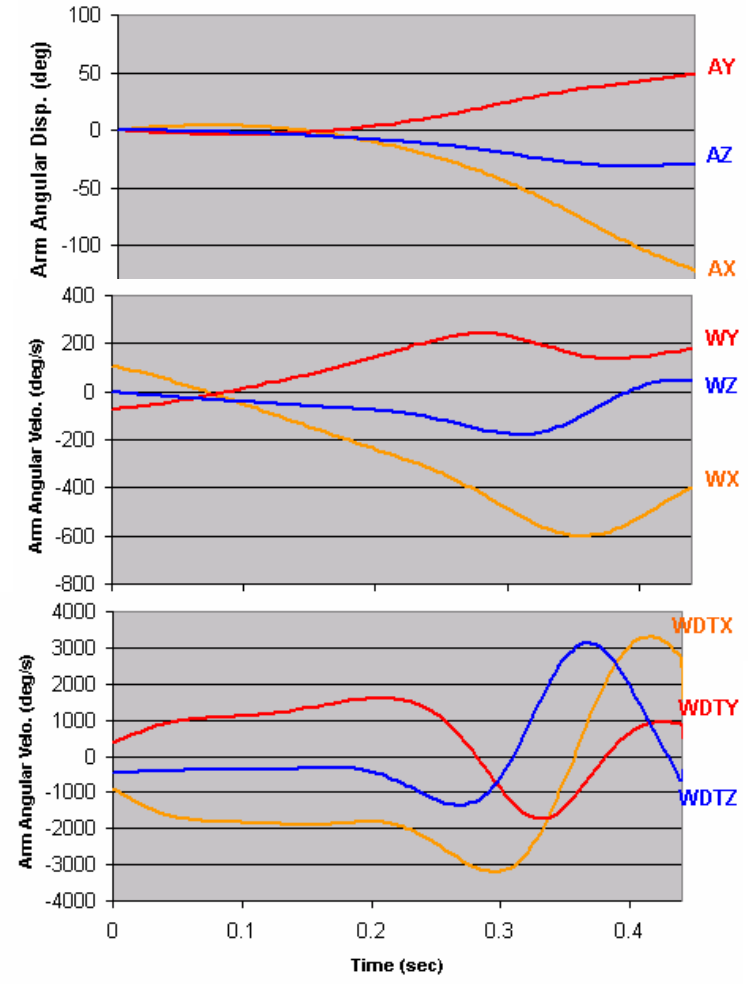


- **The point motions of the shoulder/wrist/club head determine the motions of the upper and lower segments and their effective lengths. The rotational motions at the shoulder and the wrist joints are then measured in MSC.ADAMS.**
- **The required muscle-generated torques are obtained using a feed back PID controller for the measured rotational motions about the shoulder/wrist joints.**

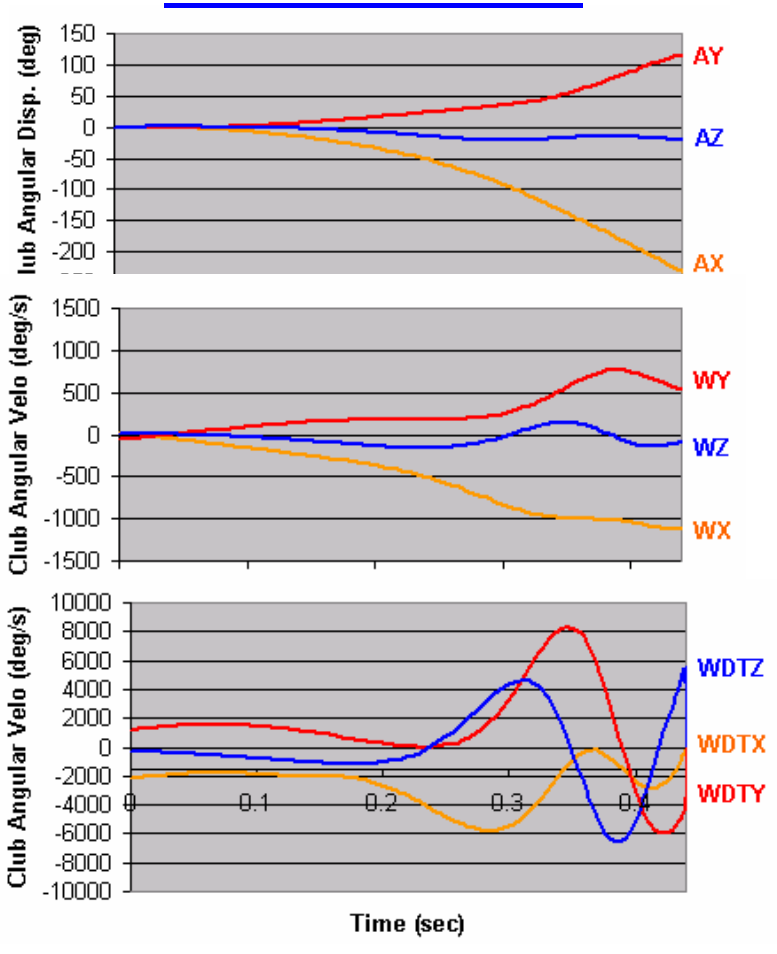
Measured Motion Time History at Shoulder/Wrist Joints

- **The 3-D angular disp/velo/acce about the shoulder/wrist obtained from MSC.ADAMS for the measured downswing motion after zeroing the start time.**

Shoulder Joint Motion



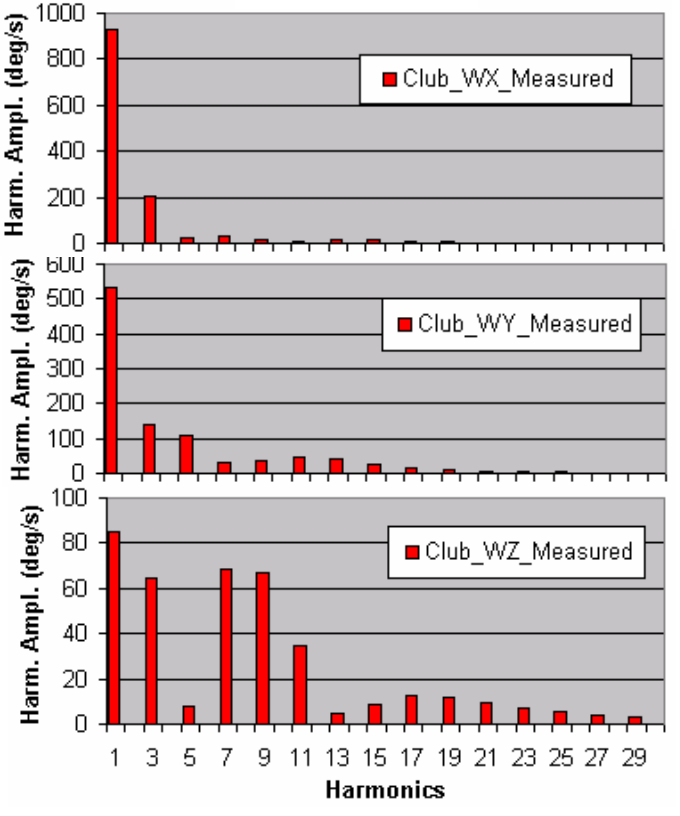
Wrist Joint Motion



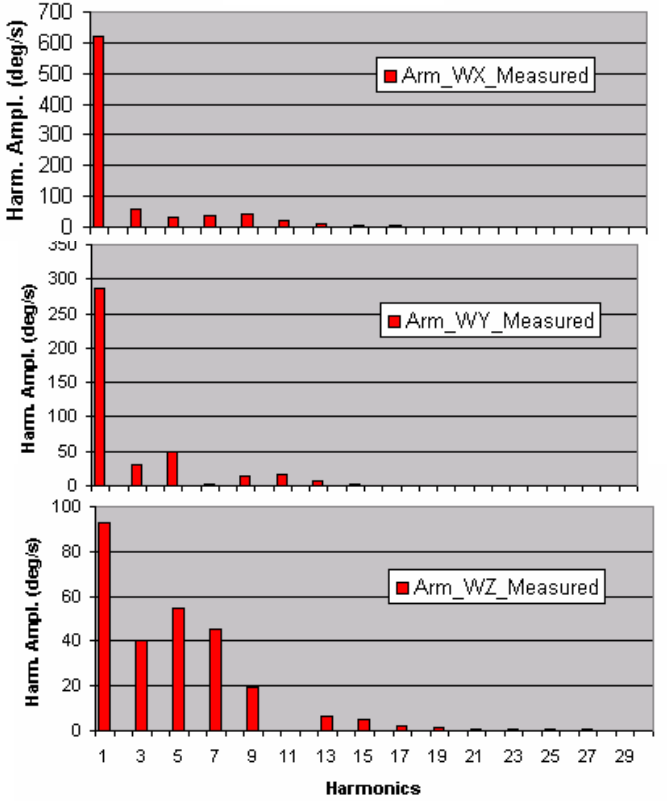
Measured Motion Pattern at Shoulder/Wrist Joints

- **The harmonic component of the joint motions are analyzed by Fourier Transformation of the measured downswing motion extended to the full cycle of the angular displacement motion.**
- **The measured motion pattern shows significant higher harmonic contents up to the 30th.**

Shoulder Joint Motion Pattern



Wrist Joint Motion Pattern



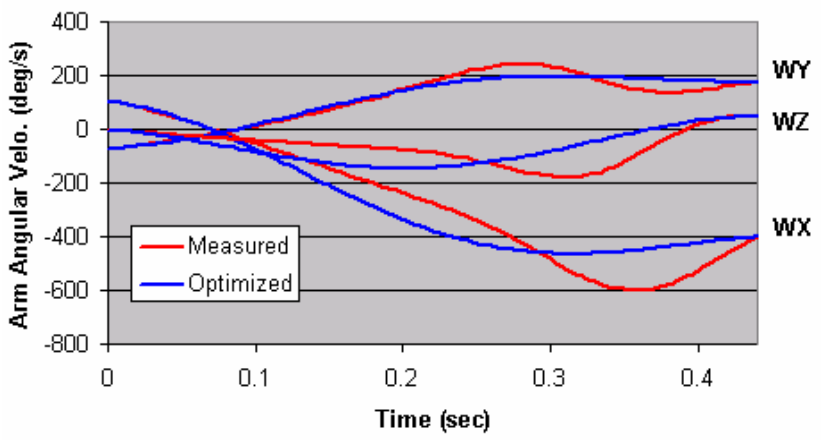
Optimal Motion Pattern Synthesis

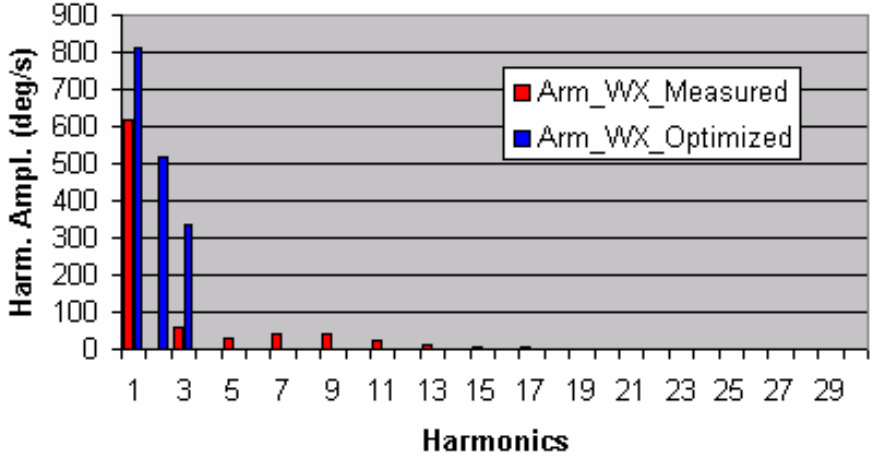
- **Optimal shoulder/wrist joint motions are synthesized with the first three harmonic contents of the measured motion modified such that the synthesized optimal motion starts from the same over-head position and attains the same striking speed.**
  - ***The shoulder 3-D translational motion and the effective lengths of the upper and lower segments are kept the same as in the measured motion.***
  - ***The ball location relative to the golfer can change to allow for continuous human motion.***

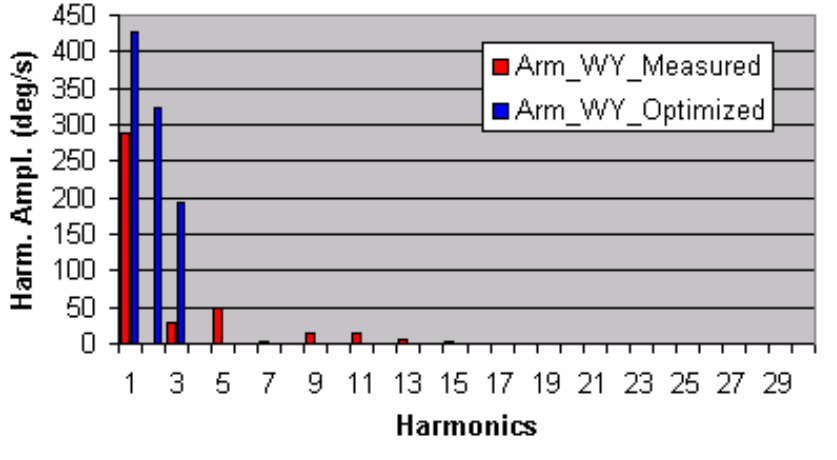
- **The required muscle-generated torques are obtained using a feed back PID controller for the synthesized motion about the shoulder/wrist joints.**

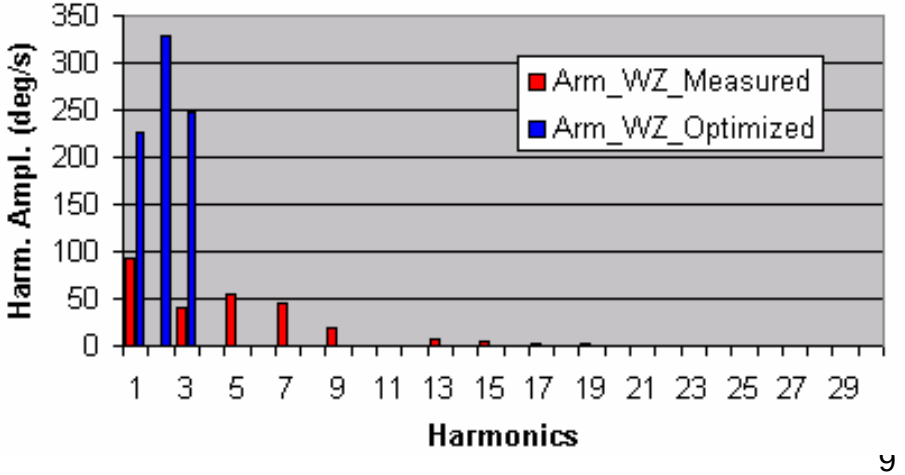
Synthesized Motion Pattern vs Measured at Shoulder Joint

- Shoulder Joint Angular Velocity Time History and Harmonic Contents.



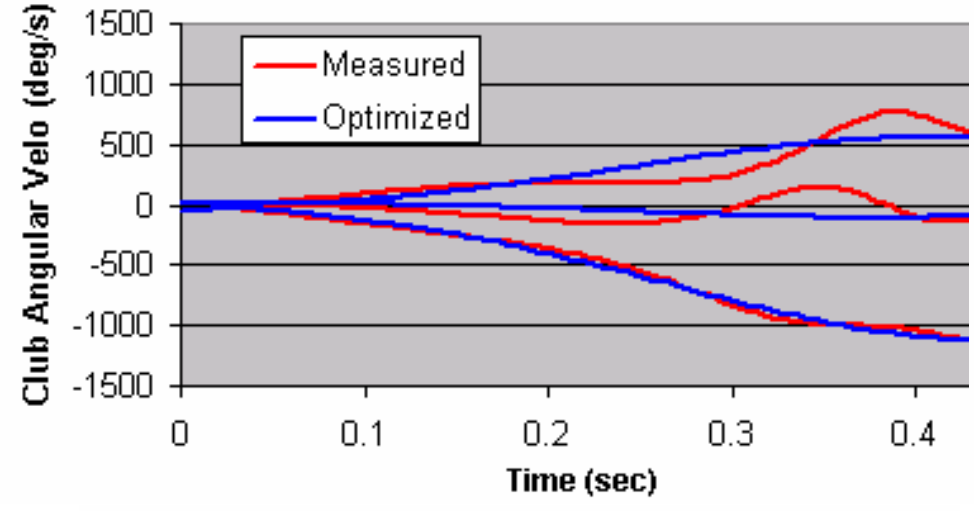


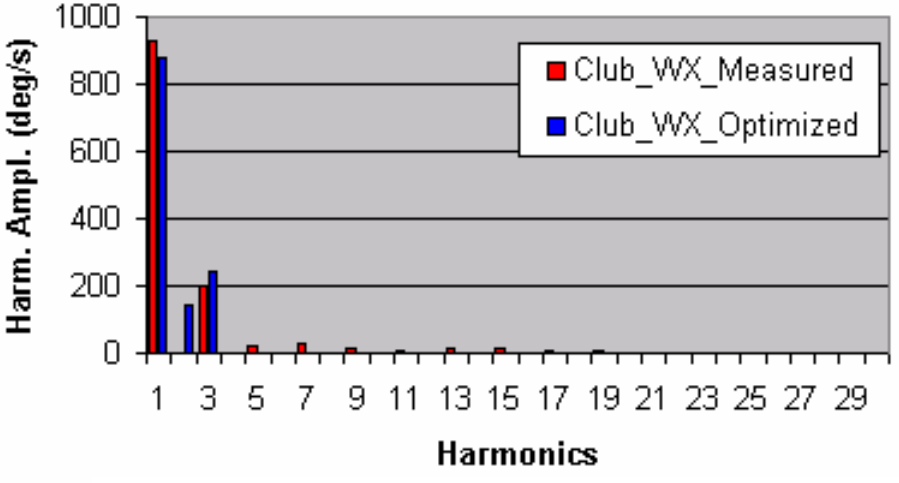


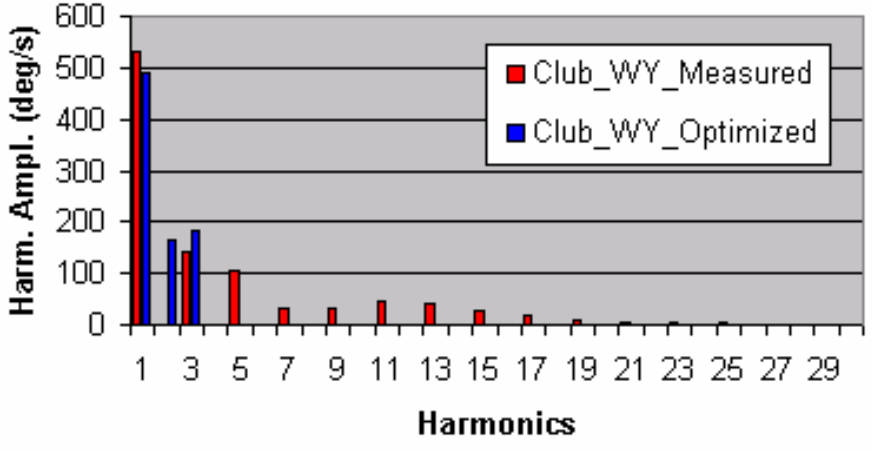


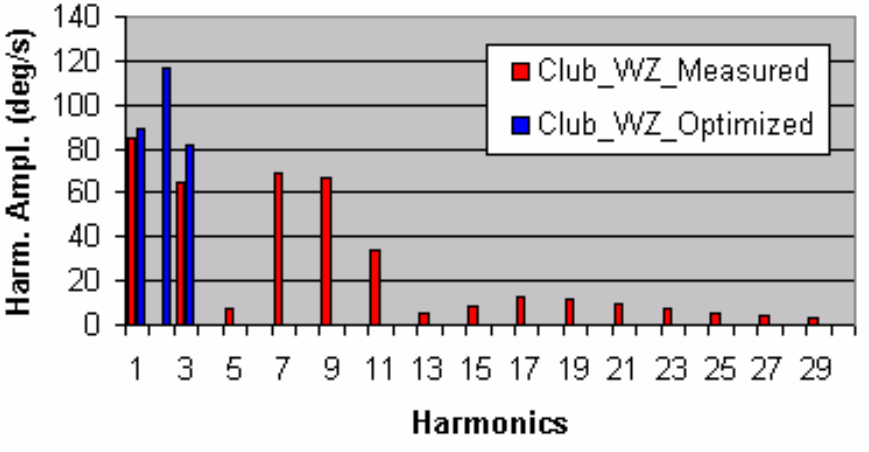
Synthesized Motion Pattern vs Measured at Wrist Joint

- Wrist Joint Angular Velocity Time History and Harmonic Contents.



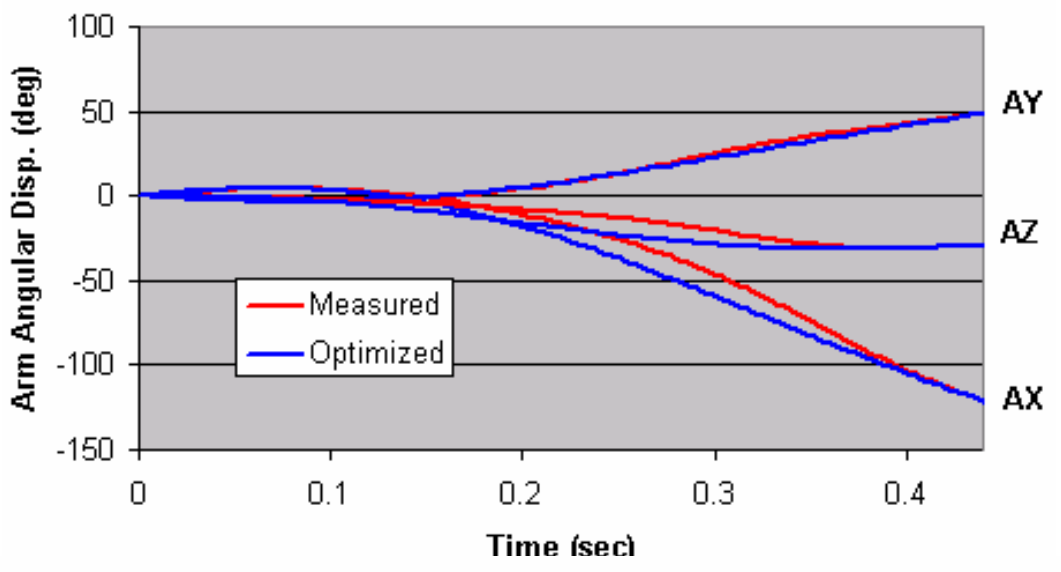




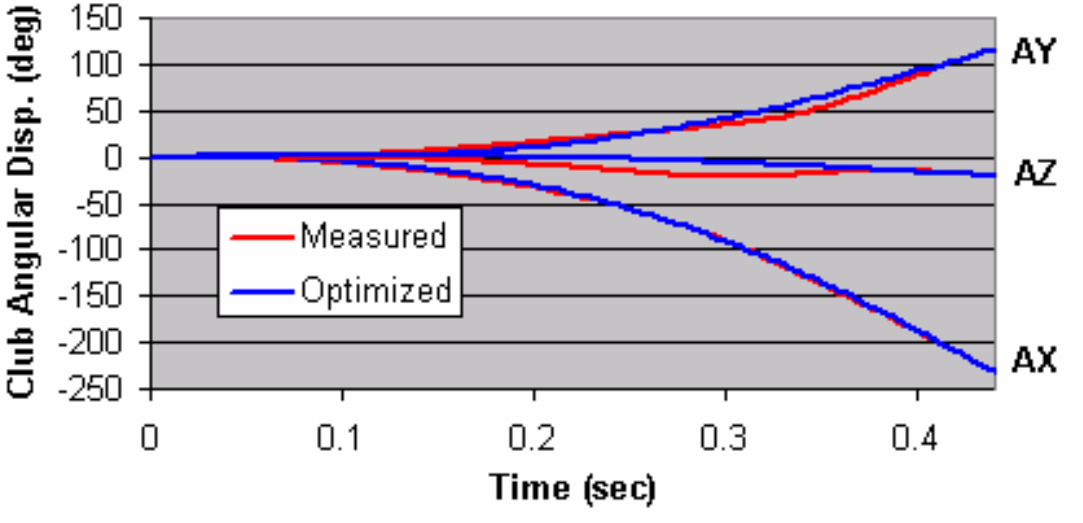


Synthesized Motion Time History vs Measured

- Shoulder Joint Angular Displacement Time History

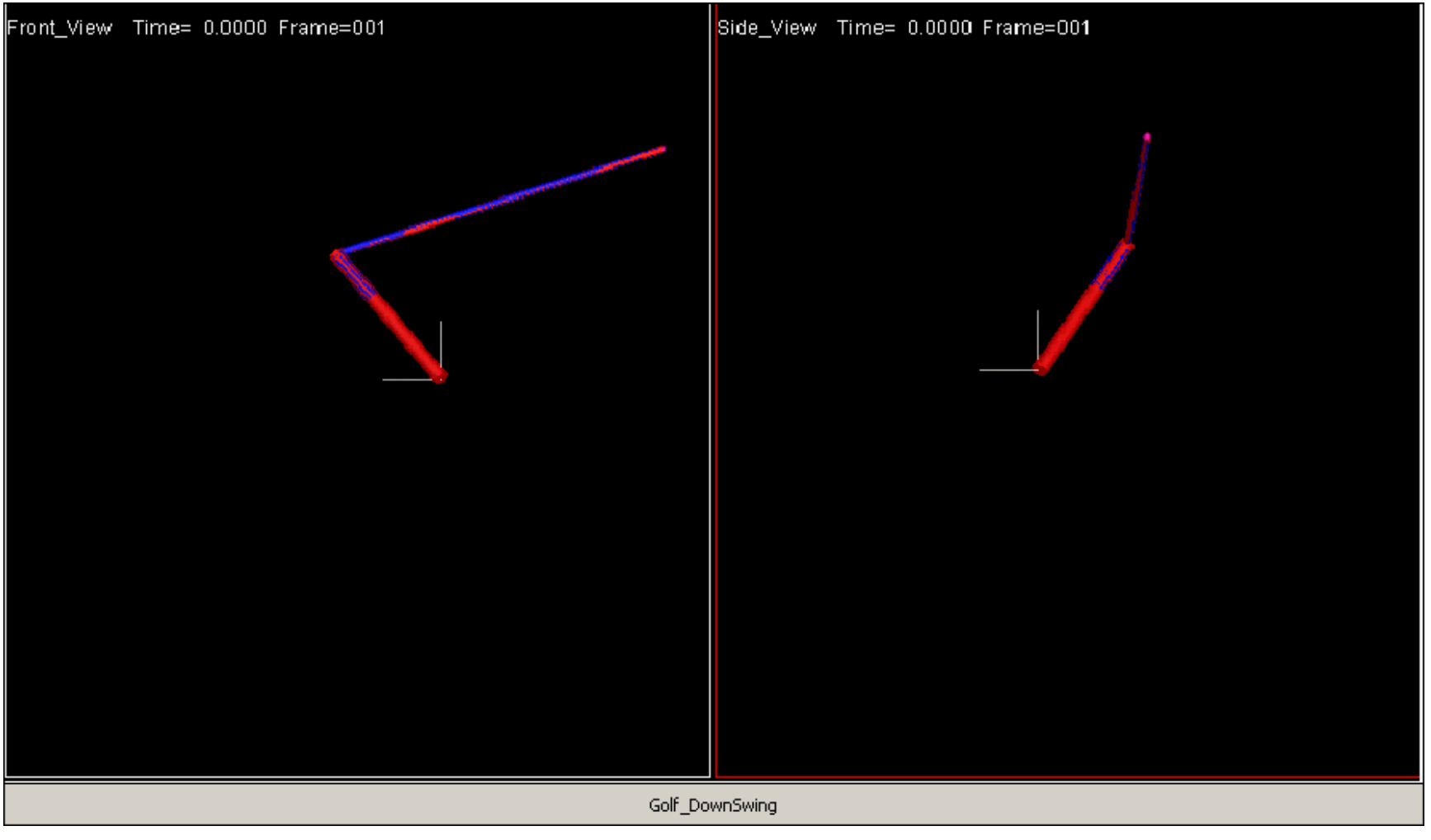


- Wrist Joint Angular Displacement Time History



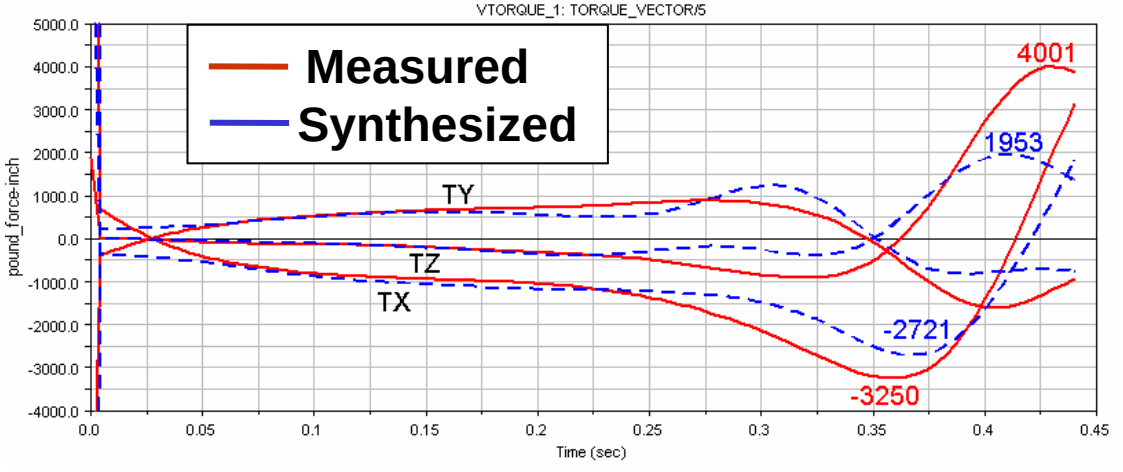
MSC.ADAMS Model Animation Video

- **Synthesized Downswing Motion (in blue) VERSUS Measured (in red)**



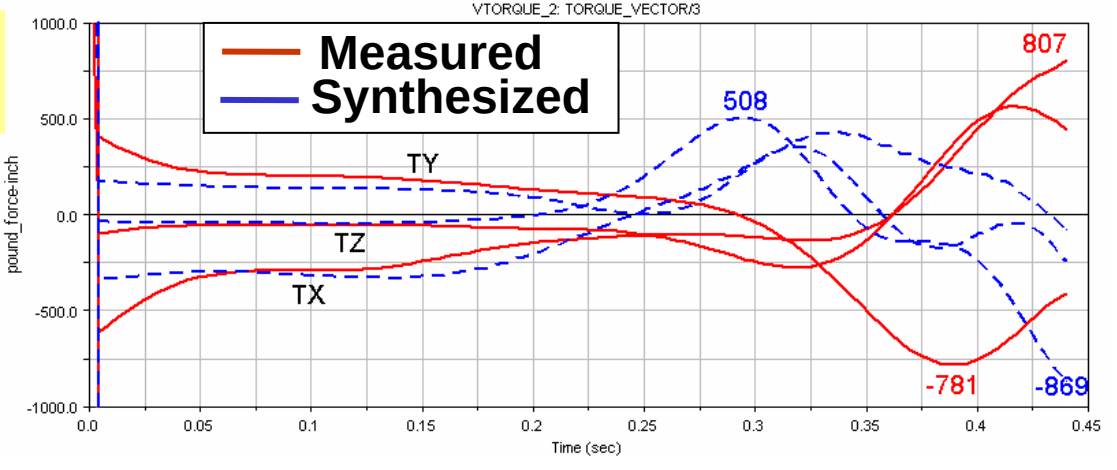
Required Muscle-generated Torques - Synthesized vs Measured

τ_1



- Peak torque around the shoulder reduced significantly with the synthesized motion.

τ_2



- Slight change in the peak torque around the wrist with the synthesized motion.

Discussion and Conclusions

- **A dynamic model has been created in MSC.ADAMS to simulate the golf downswing motion and obtain the required muscle-generated torques.**

- **It has been shown that the synthesized golf downswing motion with only low harmonic contents require significantly less muscle-generated torques to achieve comparable striking speed.**

- **One can expect that with the same muscle strength/torque, using the synthesized downswing motion pattern would achieve higher striking speed than the measured motion pattern.**