OPTIMIZING ROWING PERFORMANCE

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BME 473 - NOVEMBER 17, 2016
GOALS

• IMPROVE ROWING PERFORMANCE
• IDENTIFY THE OPTIMAL RATIO BETWEEN OAR SHAFT STIFFNESS AND OAR LENGTH
• DECREASE POWER LOST AT THE OAR BLADE
ROWING EQUIPMENT
ROWING TECHNIQUE

THE ROWING STROKE SEQUENCE:

A.  B.  C.  D.

BLADE PATH THROUGH THE WATER:
EVOLUTION OF OAR AND BLADE DESIGNS

1847 - SQUARE BLADE
1960 - MACON BLADE
1977 - INTRODUCED CARBON FIBER
1991 - ULTRA LIGHT CARBON FIBER
1991 - CLEAVER (BIG BLADE)
1996 - INTRODUCED THE ADJUSTABLE LENGTH SYSTEM FOR OARS
1997 - SMOOTHIE BLADE
2006 - FAT2 BLADE
THE MODERN OAR

- Composite oar shafts made up of carbon fiber reinforced polymers
- Stiffer and 60% lighter than wooden oars
  - Extra soft - 20% High Modulus Carbon Fiber
  - Medium - 40% High Modulus Carbon Fiber
    - Heavily loaded near oar sleeve
- Cleaver blade
  - Asymmetrical shape
  - Minimizes vertical movement
HYDRODYNAMICS OF ROWING

- **HYDRO-LIFT FORCE**
  - Increases with greater catch angle of attack
  - Contributes ~56% of blade propulsive forces

- **DRAG FORCES**
  - Stabilizes blade in water
  - Middle of drive phase
  - Contributes ~44% of blade propulsive forces

- **FORCE COEFFICIENTS**
  - Oar blade shape
  - Angle of attack between chord line and fluid flow

- **ANGLE OF ATTACK (AOA)**
  - Drag coefficient increases with AOA close to 90°
    - Middle of drive phase
  - Lift coefficient reaches max around 40-45°
    - Catch angle of attack

\[
\text{Drag: } F_{BD} = \frac{1}{2} \rho A c_D v_B^2
\]

\[
\text{Lift: } F_{BL} = \frac{1}{2} \rho A c_L v_B^2
\]
PREVIOUS STUDIES

VOLKER NOLTE (2009)

• ARE SHORTER OARS MORE EFFECTIVE?
  
  • ORIGINAL THEORY. LONGER OAR PRODUCES LARGER BLADE FORCE
  
  • HANDLE FORCE, BLADE FORCE, OAR LENGTH, AND POWER
    
    • $F_H \propto F_B$
    
    • $F_B \propto (L_1/L_2)$
    
    • $F_H \propto P \Rightarrow$ INCREASES STRESS ON ROWER
      
      • SCULLING OARLOCK FORCES AVERAGE BETWEEN 465-600 N OVER 500 M AT RACE PACE
    
    • $\uparrow F_B$ WHILE MAINTAINING $F_H$
    
    • HIGHER BOAT VELOCITY ONLY ACHIEVED WITH HIGHER BLADE FORCE
      
      • DECREASE OUTBOARD LENGTH AND INCREASE LIFT COEFFICIENT OF THE BLADE
PREVIOUS STUDIES

HOFFMIESTER ET AL. (2010)

• ENERGY LOSS AT THE BLADES
  • HIGH POWER LOSS (>30%) DUE TO PROPULSIVE FORCE ON BLADE

• ENERGY LOSS UNDERESTIMATIONS
  • ASSUMING OAR RIGIDITY AND NEGLECTING PARALLEL BLADE FORCE
  • NON-ZERO PARALLEL BLADE FORCE WHEN BLADE IS PERPENDICULAR TO BOAT

• NEED TO OPTIMIZE OAR DESIGN TO DECREASE POWER LOSS
  • DO NOT ASSUME OAR RIGIDITY
  • PARALLEL BLADE FORCE
  • “DELTA WING” BLADE DESIGN
PREVIOUS RESEARCH

CAPLAN & GARDNER (2007C)

• OPTIMIZING OAR BLADE DESIGN
  • MAXIMIZE BLADE’S ABILITY TO GENERATE LIFT THROUGHOUT ROWING STROKE
  • BLADE CURVATURE
    • INCREASING CIRCULATION OF FLUID BOUNDARY LAYER
    • ACTING AS A “DELTA WING”
  • BIG BLADE SIGNIFICANTLY GREATER LIFT COEFFICIENT

\[ F_{\text{lift}} = F_T \sin \alpha + F_N \cos \alpha \]
\[ F_{\text{Drag}} = F_N \sin \alpha - F_T \cos \alpha \]
OUR PROPOSAL

• TAKE WHAT IS KNOWN ABOUT:
  • OAR LENGTH
  • INFLUENCES ON LIFT AND DRAG FORCES
  • BLADE DESIGN AND LIFT COEFFICIENT
  • ENERGY LOSS AT BLADES

• FIND THE OPTIMAL RATIO BETWEEN OAR STIFFNESS, OAR LENGTH, AND BLADE DESIGN THAT WILL INCREASE PERFORMANCE IN ROWING

• INTRODUCE “MATCHING” OAR LENGTH TO INDIVIDUAL ROWER
PROPOSED HYPOTHESES

• OPTIMAL COMBINATION WILL BE MATCHED OAR LENGTH AT MEDIUM STIFFNESS
  • BLADE FORCE WILL INCREASE
  • LIFT COMPONENT WILL INCREASE
  • POWER LOST AT BLADES WILL DECREASE
PROPOSED RESEARCH

• EIGHT ELITE FEMALE ROWERS, PROFICIENT IN SCULLING
• COMBINATION OF OAR SHAFT STIFFNESS AND OAR LENGTH
  • STIFFNESS LEVELS
    • SOFT, MEDIUM, STIFF
  • OAR LENGTH
    • SHORT, MEDIUM, LONG
    • MATCHED
  • HATCHET BLADE
• DEFLECTION ANGLE
  • MEASURES THE DEGREE OF DEFLECTION THE BLADE BENDS RELATIVE TO THE OAR SLEEVE
  • STATIC LOAD OF 98.1 N PLACED AT THE BLADE AND SHAFT JUNCTION
  • CLAMPS AT HANDLE AND SLEEVE
  • MEASURE DEFLECTION ANGLE
PROPOSED PROTOCOL

• SINGLE-BLINDED
  • OAR CONFIGURATIONS UNKNOWN TO ROWER

• OAR SETUP AND CALIBRATION
  • TWO CUSTOM OAR SHAFT STRAIN GAUGES (LOCATED AT Y1 & Y4)
  • CUSTOM OARLOCK STRAIN-GAUGE FORCE TRANSDUCERS
  • CABLE ATTACHED TO BLADE
  • EXTERNALLY APPLIED FORCE (0-150N) BY EXPERIMENTER

• ON-WATER EXPERIMENT
  • 500M DISTANCE ROWED (30-32 STROKES PER MINUTE)
  • INSTRUMENTED RACING SINGLE SCULL
    • BLADE VELOCITY
    • LIFT AND DRAG FORCES (FROM BLADE FORCE VECTOR)
    • POWER LOSS TO WATER
EXPECTED RESULTS

• WHAT OAR SHAFT STIFFNESS VALUE INCREASES PERFORMANCE?
  • MEDIUM STIFFNESS WILL PRODUCE OPTIMAL PERFORMANCE
  • WILL OPTIMIZE THE LIFT FORCE THROUGHOUT THE STROKE

• DOES “MATCHING” OARS IMPROVE PERFORMANCE?
  • FOR SCULLING, “MATCHING” OARS WILL INCREASE PERFORMANCE
    • LIFT FORCE INCREASED
    • DRAG FORCE DECREASED
  • NEED TO RECONSIDER FOR LARGER TEAMS (4 & 8)
QUESTIONS??
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