

How Does a Baseball Bat Work?

Alan M. Nathan

Department of Physics

University of Illinois at Urbana-Champaign

a-nathan@uiuc.edu

www.npl.uiuc.edu/~a-nathan/pob

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The Ball-Bat Collision

- A violent collision

- ❖ forces large (>8000 lbs!)
- ❖ time is short ($<1/1000$ sec!)
- ❖ ball compresses, stops, expands
 - bat compresses ball
 - ball bends/compresses bat
- ❖ lots of energy dissipated
 - distortion of ball
 - vibrations in bat

- knob end and grip don't matter!

- principal focus:

- ❖ large BBS



BBS: What does it depend on?

- Pitched ball speed v_{ball}
- Bat swing speed v_{bat}
- “Collision Efficiency” E
 - ❖ Property of ball and bat
 - ❖ $\text{BESR} = E + 1/2$
- My only formula:
 - ❖ $\text{BBS} = E v_{\text{ball}} + (1+E) v_{\text{bat}}$

BBS: Some Typical Numbers

- $BBS = E v_{ball} + (1+E) v_{bat}$

- ❖ $E \cong 0.20$ $1+E \cong 1.20$

- MLB: $v_{ball} = 90$ mph $v_{bat} = 70$ mph

- ❖ $BBS = 0.2 \times 90 + 1.2 \times 70 = 18 + 84 = 102$ mph

- Slow-pitch softball: $v_{ball} = 10$ mph $v_{bat} = 70$ mph

- ❖ $BBS = 0.2 \times 10 + 1.2 \times 70 = 2 + 84 = 86$ mph

- Important conclusions:

- v_{bat} the most important factor for BBS

- performance standard needs to account for this

BBS: What does E depend on?

- Energy of bat recoil

- ❖ Depends on bat mass/mass distribution (MOI) and impact location

- Energy dissipated in ball and bat: COR

- ❖ Depends on $v_{\text{ball}} + v_{\text{bat}}$ and impact location

E maximized when recoil & dissipation minimized

Ball-Bat COR

- Depends on “ball-wall” COR

...which depends on

- $v_{\text{rel}} = v_{\text{ball}} + v_{\text{bat}}$
- mass of ball

- Depends on “BPF” (ball-bat COR/ball-wall COR)

...which may depend on

- impact location
 - vibrations minimized at “sweet spot”
- ball-wall COR and compression
- v_{rel}

Mass and Mass Distribution

- For large E

- ❖ more mass in barrel of bat is better
- ❖ mass in handle plays little role
- ❖ physics of this is very well understood

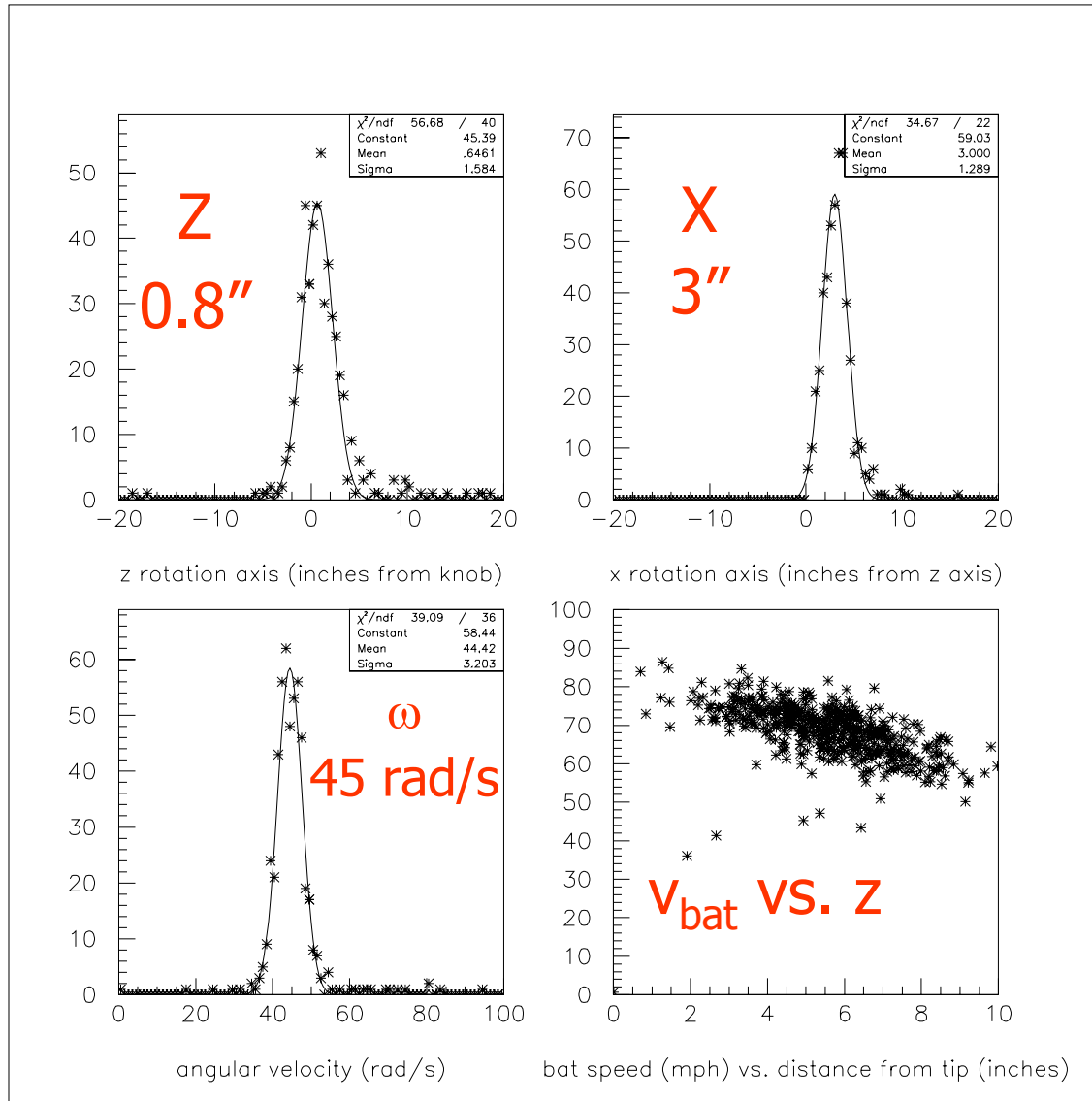
- For large v_{bat}

- ❖ less mass in barrel of bat is probably better
- ❖ mass in handle probably plays little role
- ❖ not as well understood as we would like

- So, what to do?

- ❖ assume two effects cancel and ignore
 - Base performance on BPF only
 - **NOT** my recommendation
- ❖ do more field studies of bat speed

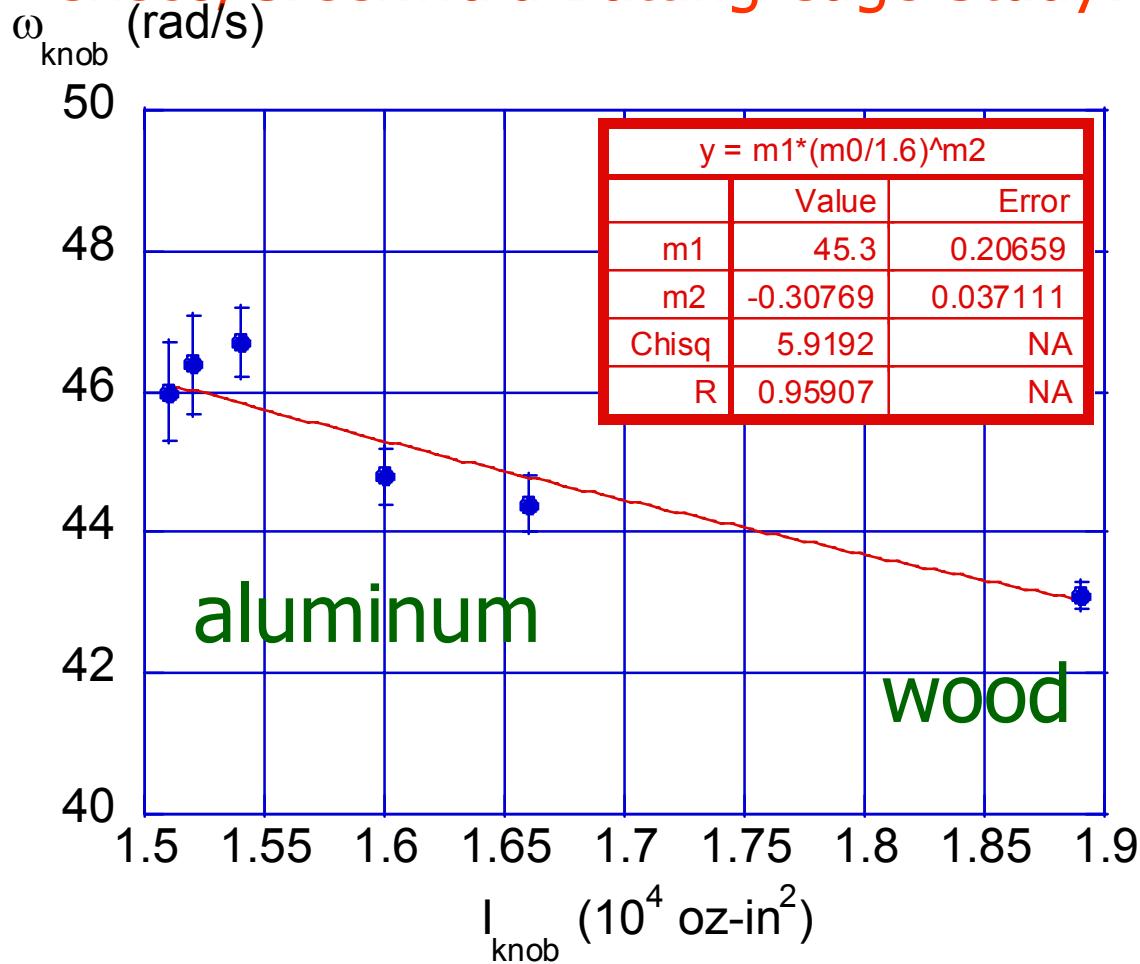
Crisco/Greenwald Batting Cage Study



Conclusion: at impact, bat is rotating about knob

Bat Speed vs. MOI

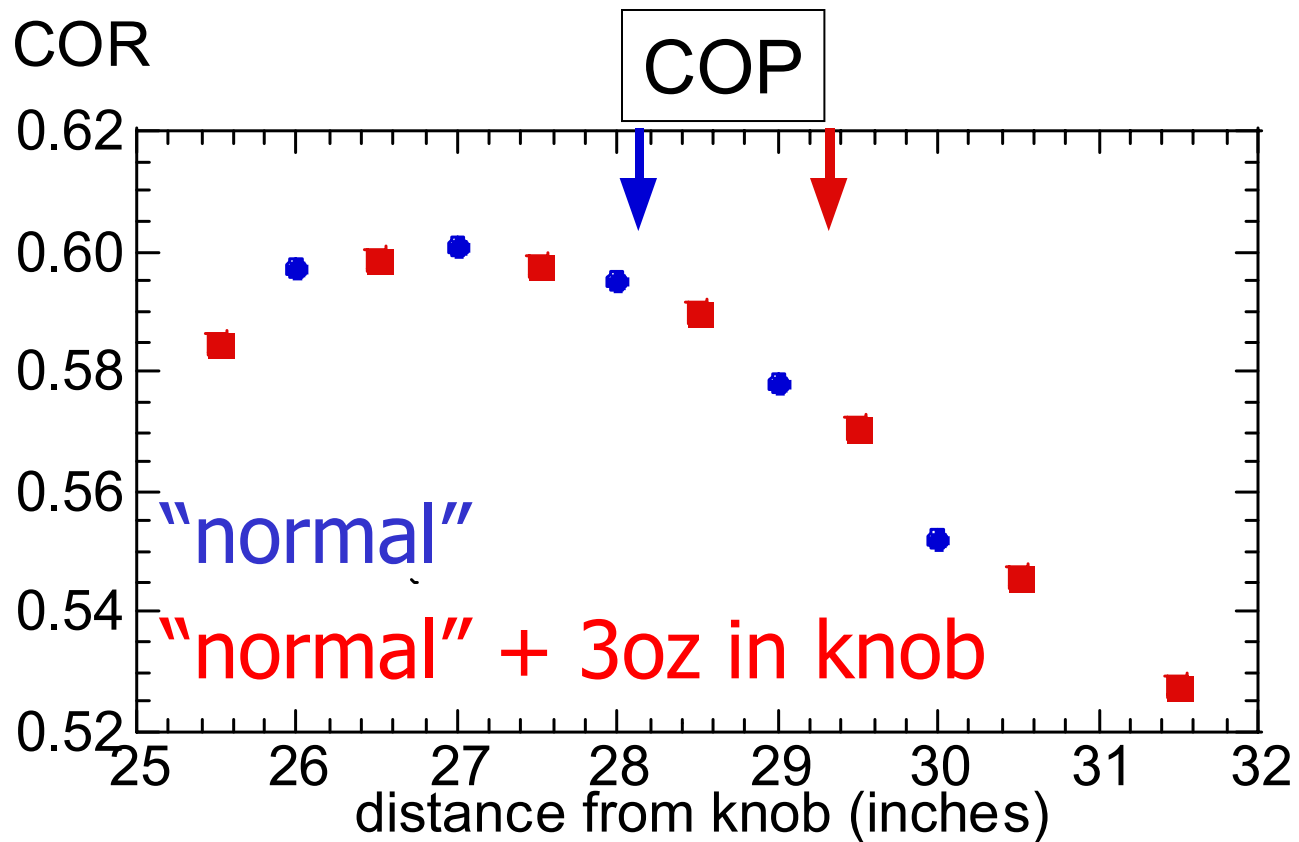
Crisco/Greenwald Batting Cage Study:



Conclusion: bat speed scales with $(1/I_{\text{knob}})^{0.3}$

Conclusions for lab performance testing

- Want v_{rel} that closely replicates field
- Want impact location that maximizes BBS in field
 - ❖ NOT COP!
- Want ball-wall COR and compression representative of field conditions



Conclusion: COP is completely irrelevant

A Possible Testing Procedure

- Decide on “standard field conditions”:
 - ❖ ball (ball-wall COR; compression)
 - ❖ $v_{\text{ball,field}}$ and $v_{\text{bat,field}}$ (which depends on bat!)
 - $v_{\text{rel,field}} = v_{\text{ball,field}} + v_{\text{bat,field}}$
- Measure $v_{f,\text{lab}}$ for $v_{\text{ball,lab}} = v_{\text{rel,field}}$
- Calculate $\text{BBS} = v_{f,\text{lab}} + v_{\text{bat,field}}$
- Repeat at different impact locations until maximum BBS obtained

Note: procedure based on sound science except for selection of $v_{\text{bat,field}}$

Summary of Important Points

- Performance (BBS) depends on
 - ❖ Bat swing speed
 - ❖ Bat mass and mass distribution
 - ❖ Ball-bat COR
- For laboratory testing, careful attention must be paid to
 - ❖ Parameters of ball (COR, compression)
 - ❖ Selection of impact location(s)
 - ❖ Relative ball-bat speed
- More field tests needed to elucidate bat swing speed