

# SPORTS EQUIPMENT IMPACT ANALYSIS USING MSC.DYTRAN

Mr. Carl J. Poplawsky  
Vice President, Engineering  
Engineering Science Analysis Corp.

Co-Authors:      Dr. Ken Lou (ArmorWorks LLC)  
                         Mr. Martin A. Martinez (ESA Corp.)

PRODUCT DEVELOPMENT CONFERENCE



# INTRODUCTION



ESA Corp. is a mechanical engineering consulting company headquartered in Phoenix, AZ.

- Solid Modeling / Design
- Drafting
- Finite Element Analysis
  - static stress / modal
  - vibration
  - heat transfer / CFD
  - impact
- New Product Development



# INTRODUCTION



ESA Corp. has used MSC.Dytran extensively to predict ball impact performance for sports equipment:

- Golf club driver
  - impact coefficient of restitution (COR) with varying
    - swing speed
    - head face angle
    - head CG location
  - launch angle and spin effects with varying
    - head face angle
    - head CG location



# INTRODUCTION



ESA Corp. has used MSC.Dytran extensively to predict ball impact performance for sports equipment:

- Softball bat
  - impact coefficient of restitution (COR) with varying
    - barrel static stiffness
  - barrel durability (dynamic stress) with varying
    - barrel static stiffness



# BALL PROPERTY PERFORMANCE TUNING



Ball properties (elastic modulus and dynamic viscosity) must be determined first:

- Elastic modulus is determined from static compression data
  - a linear elastic model of the ball is developed in MSC.Patran and solved in MSC.Nastran
    - model must include geometric contact
    - ball is compressed per data
    - Young's modulus is "tuned" until reaction load matches data



# BALL PROPERTY PERFORMANCE TUNING



Ball properties (elastic modulus and dynamic viscosity) must be determined first:

- Dynamic viscosity is determined from ball/wall impact data
  - an MSC.Dytran model is developed for the ball and an “infinitely stiff” wall (typically 1/2” steel plate backed with concrete)
    - multiple ball initial impact speeds are defined
    - predicted COR at each speed is obtained, and compared to data
    - ball dynamic viscosity is “tuned” until XY plot of COR as a function of impact speed matches data plot



# BALL PROPERTY PERFORMANCE TUNING



Coefficient of restitution (COR) is a measure of remaining kinetic energy after impact:

in general

$$COR = \frac{V_{ball}(2) - V_{hit}(2)}{V_{hit}(1) - V_{ball}(1)}$$

for wall impact

$$COR = V_{ball}(2) / V_{ball}(1)$$

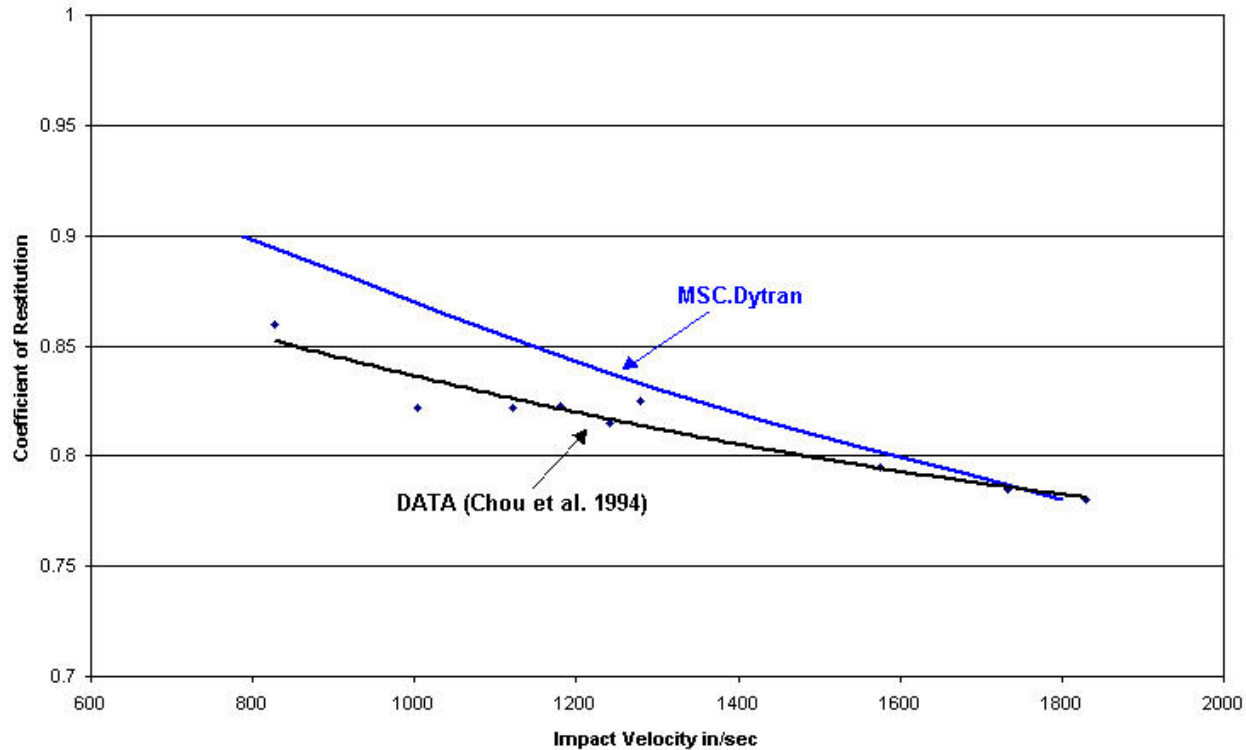
Once the ball properties have been “tuned”, the ball can be used for impact analysis with sports equipment



# BALL PROPERTY PERFORMANCE TUNING



GOLF BALL COEFFICIENT OF RESTITUTION - WALL IMPACT



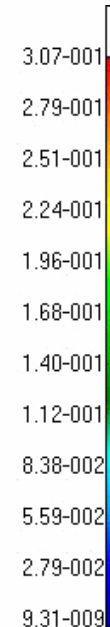
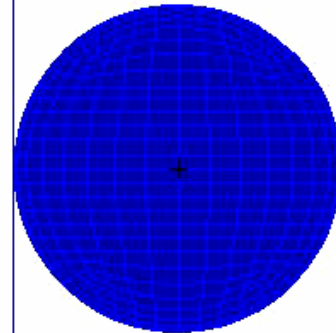
PRODUCT DEVELOPMENT CONFERENCE



# BALL PROPERTY PERFORMANCE TUNING



DISPLACEMENT



default\_Fringe :  
 Max 0. @Nd 126  
 Min 0. @Nd 126  
 default\_Deformation  
 Max 0. @Nd 1  
 Frame: 1

res display anim setup 3d(15, "Linear")

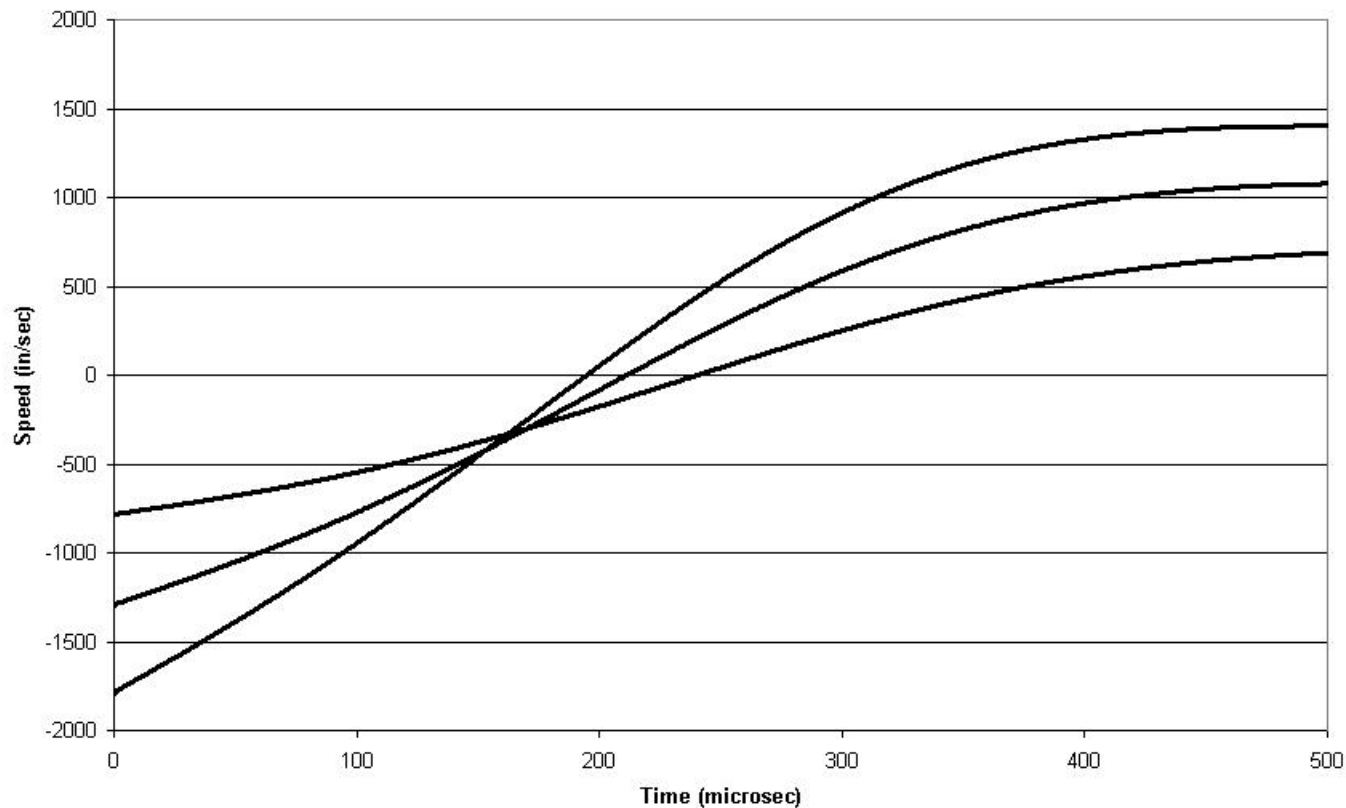
PRODUCT DEVELOPMENT CONFERENCE



# BALL PROPERTY PERFORMANCE TUNING



GOLF BALL SPEED - WALL IMPACT



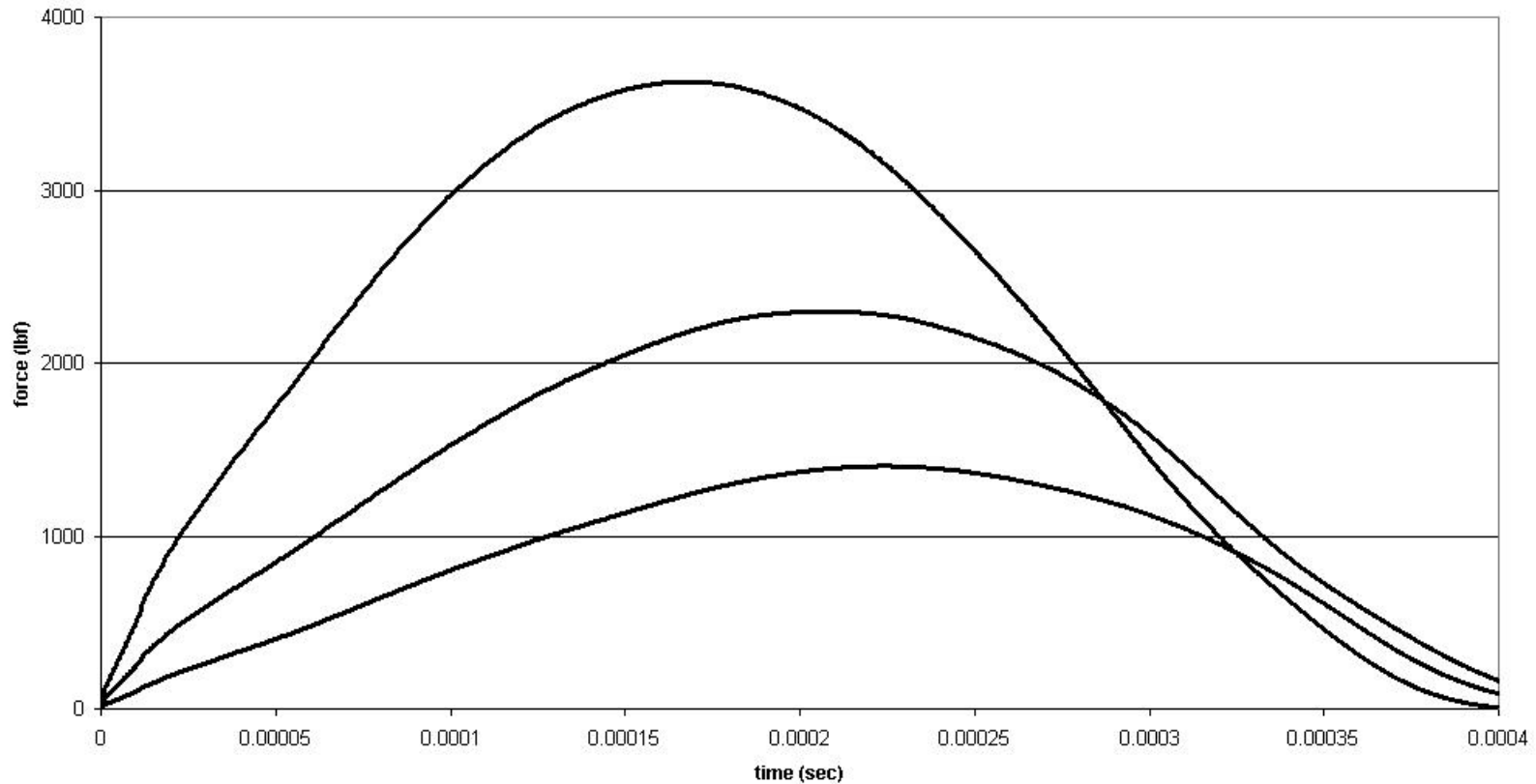
PRODUCT DEVELOPMENT CONFERENCE



# BALL PROPERTY PERFORMANCE TUNING



GOLF BALL CONTACT FORCE - WALL IMPACT



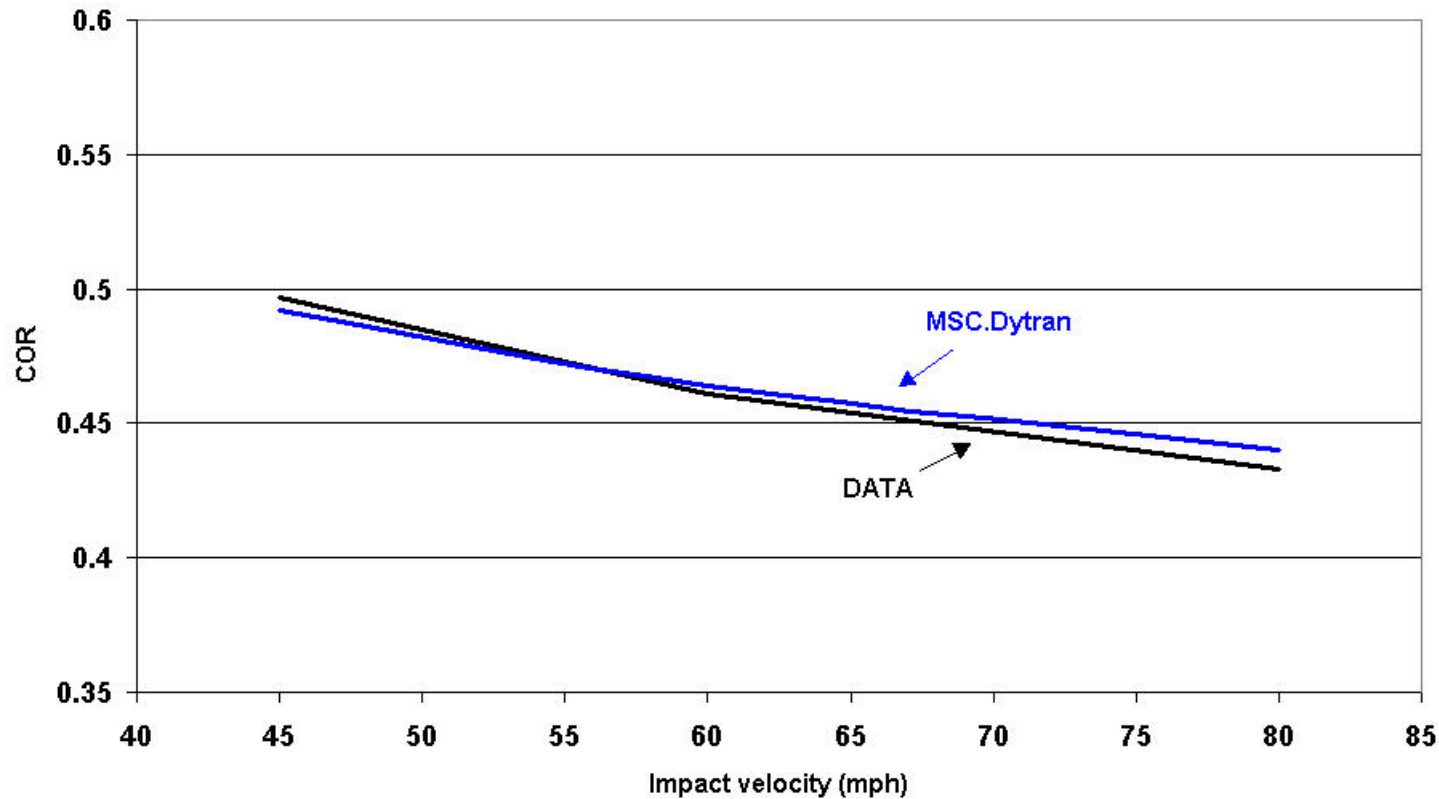
PRODUCT DEVELOPMENT CONFERENCE



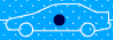
# BALL PROPERTY PERFORMANCE TUNING



SOFT BALL COR - WALL IMPACT



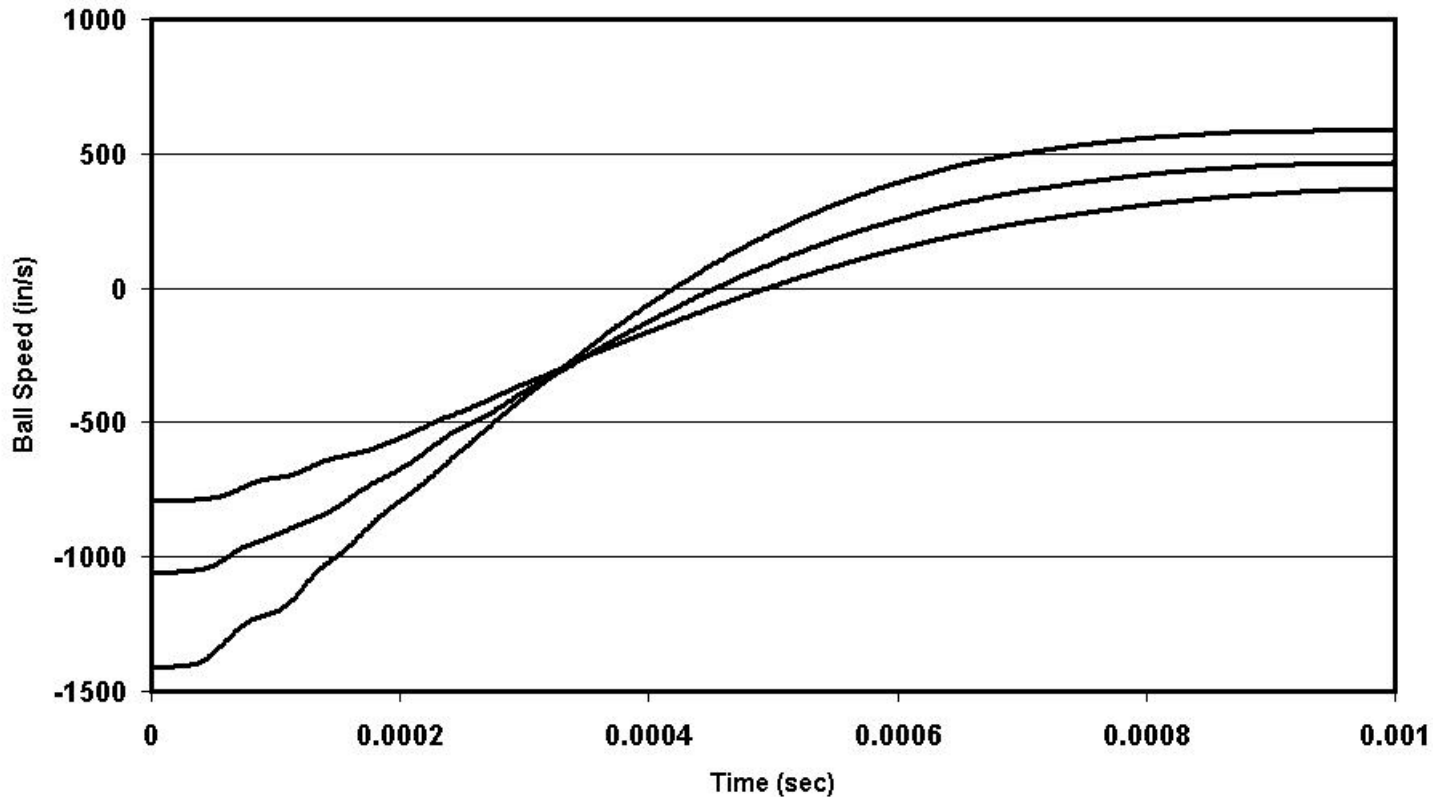
PRODUCT DEVELOPMENT CONFERENCE



# BALL PROPERTY PERFORMANCE TUNING



SOFT BALL SPEED - WALL IMPACT



PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



Generic driver representation developed in solid modeler and MSC.Patran

- Head face geometry parametrically modeled in solid modeler
  - parameters include thickness, bulge, roll, head angle
  - face is meshed with shell elements in MSC.Patran
    - face thickness distribution is easily changed
  - remainder of head is not geometrically modeled



# Golf Club Driver Impact Analysis

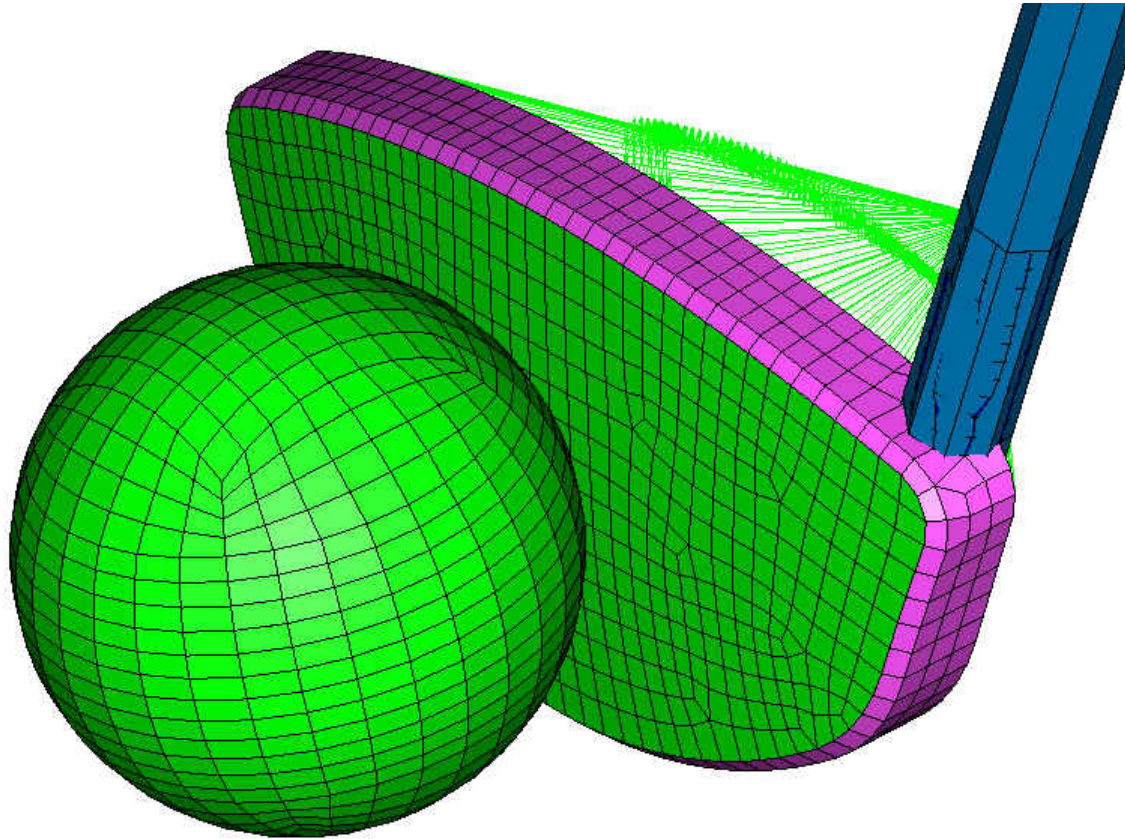


Generic driver representation developed in MSC.Patran

- Correct mass and inertial properties (including CG location)
  - remainder of head is represented with point mass
    - point mass positioned with suitable properties to obtain required CG location, mass and inertial properties
    - connected to face with massless bars
- Resulting parametric head model is simple, can be easily modified, and runs quickly in MSC.Dytran

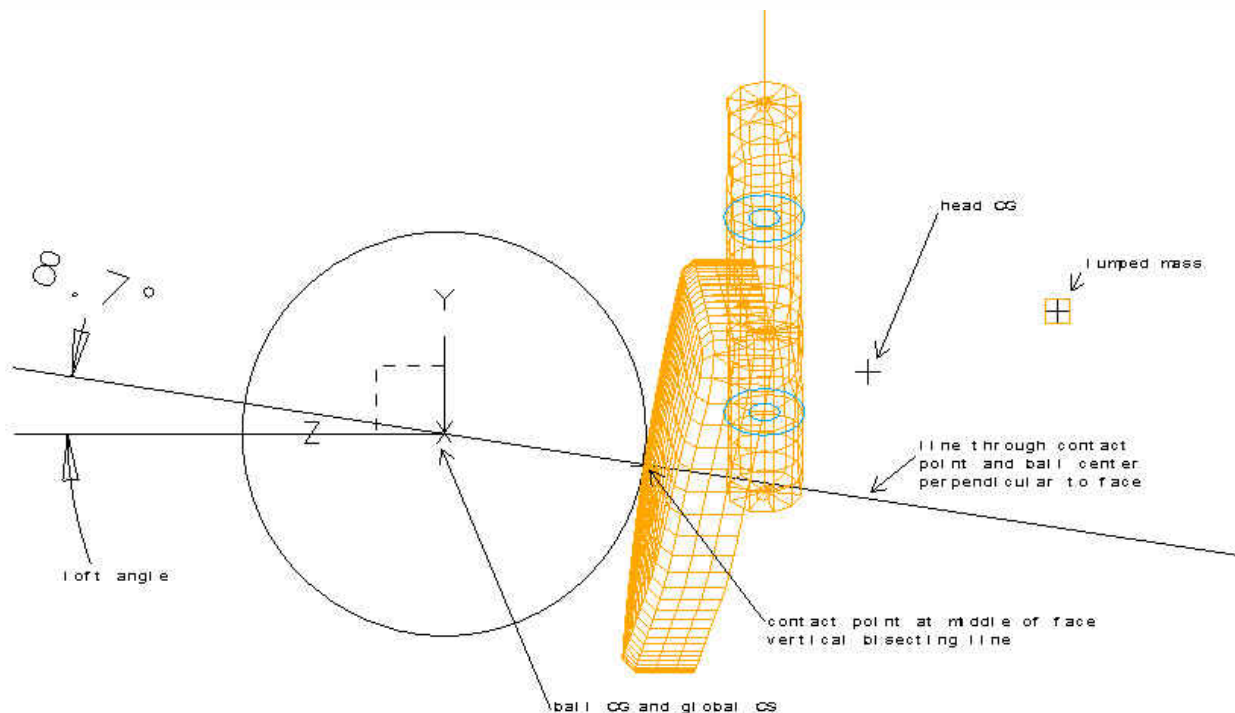


# Golf Club Driver Impact Analysis





# Golf Club Driver Impact Analysis



PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



MSC.Dytran model used to determine dependency of performance parameters on initial swing speed

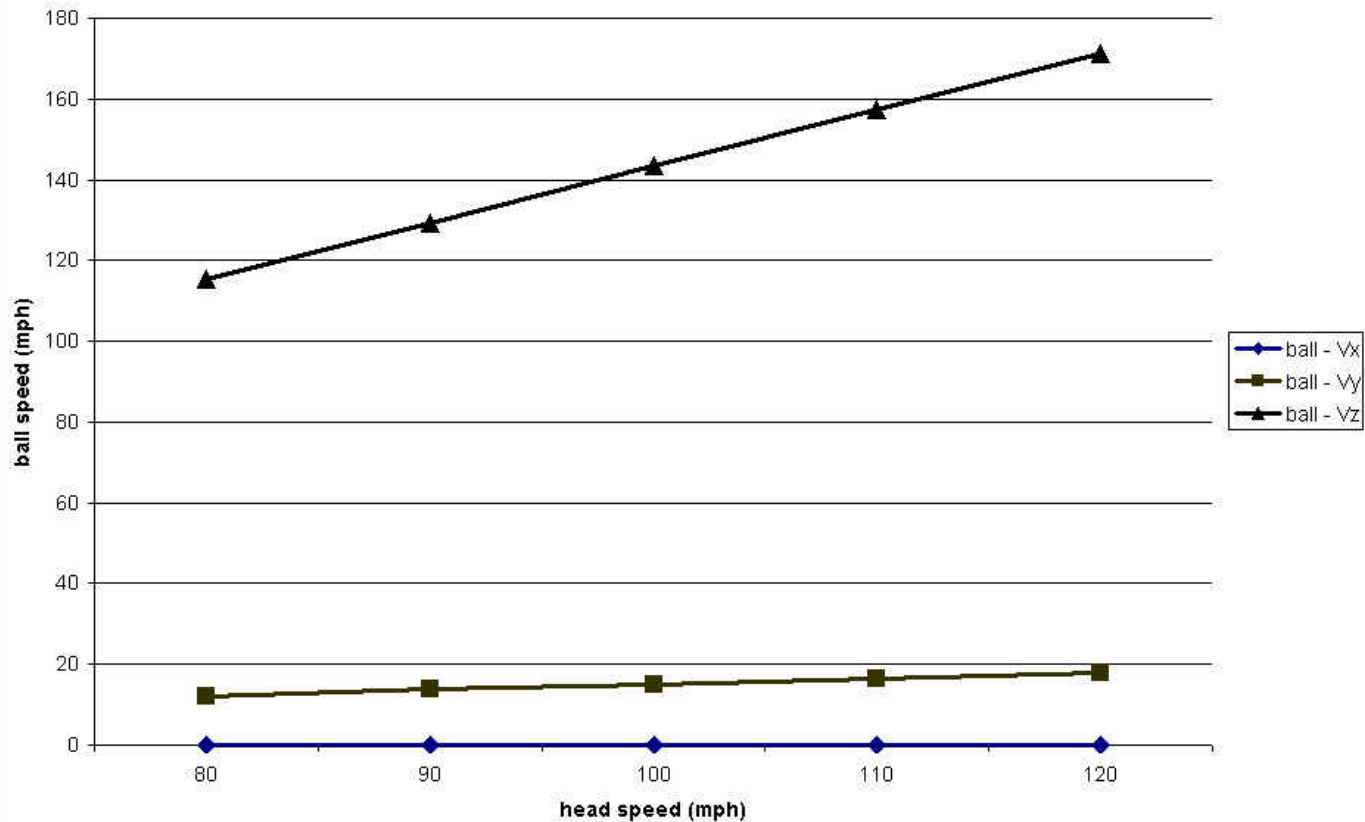
- Performance parameters
  - final ball speeds
  - ball departure angles
  - ball spin rates
  - club head stress
  - contact force
  - impact COR



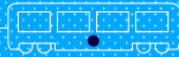
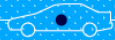
# Golf Club Driver Impact Analysis



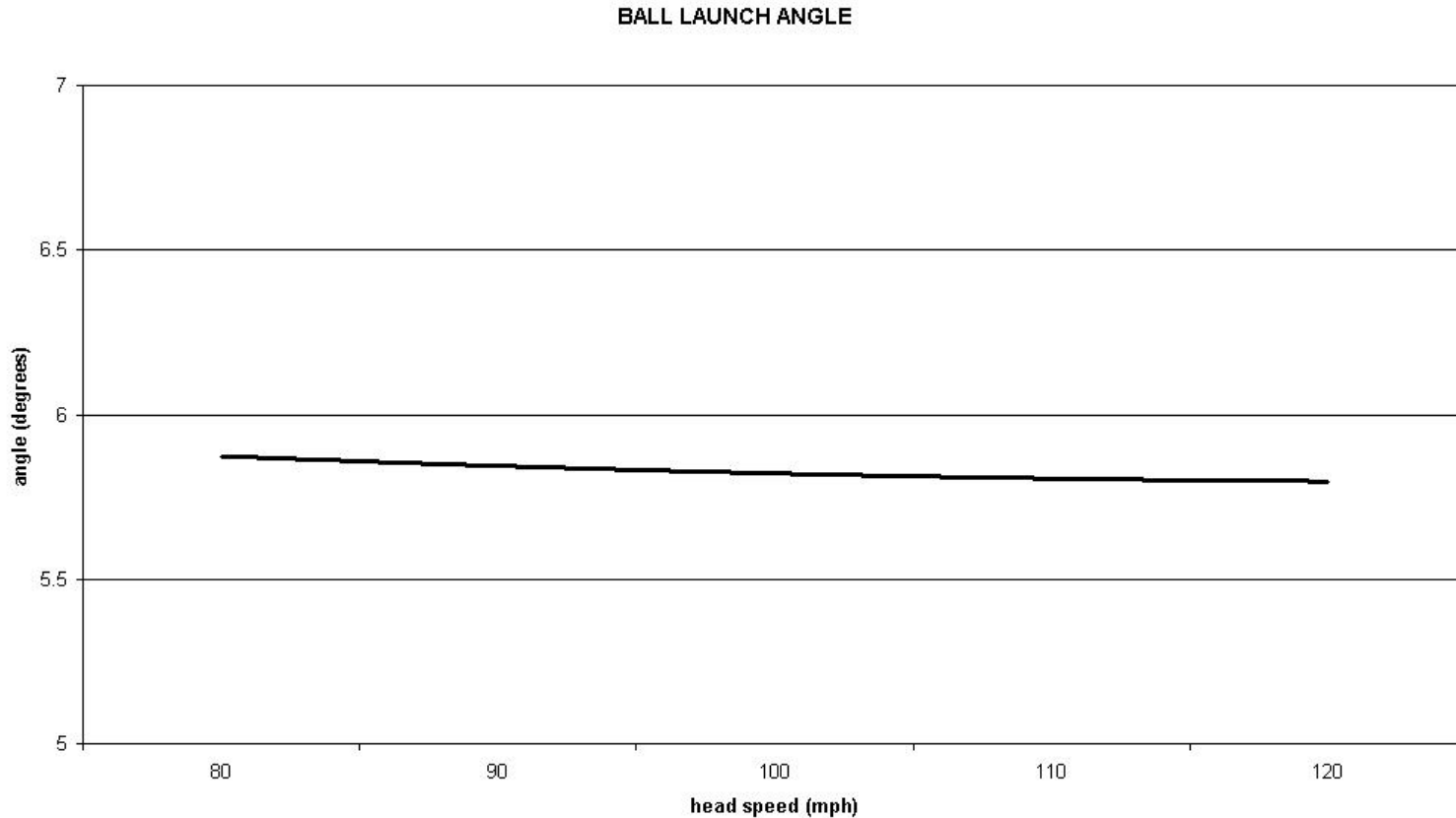
BALL FINAL SPEED COMPONENTS



PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis

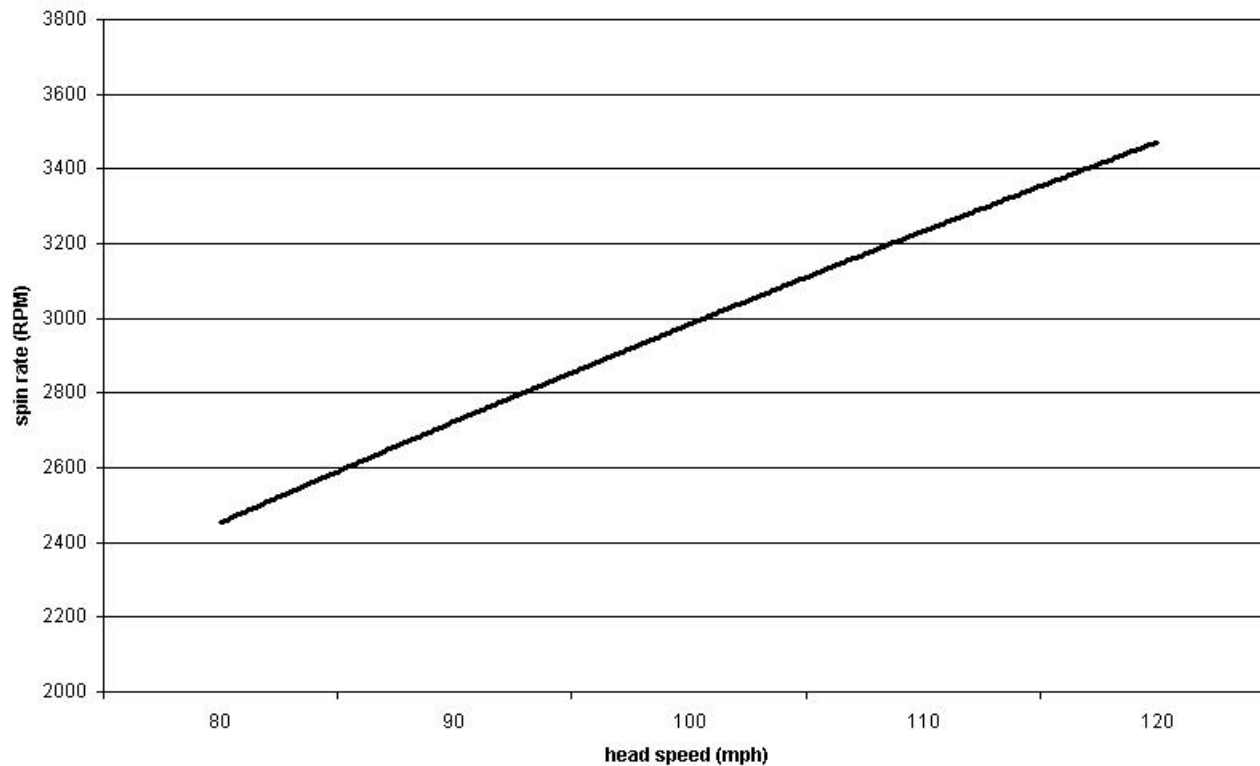




# Golf Club Driver Impact Analysis

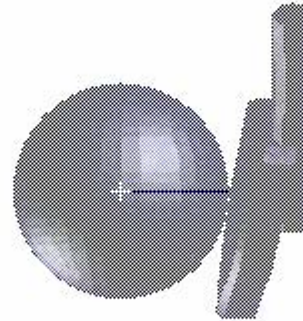


BALL SPIN RATE (X)





*ir logo*  
e-



default\_Deformation  
Max 0. @Nd 1  
Frame: 1

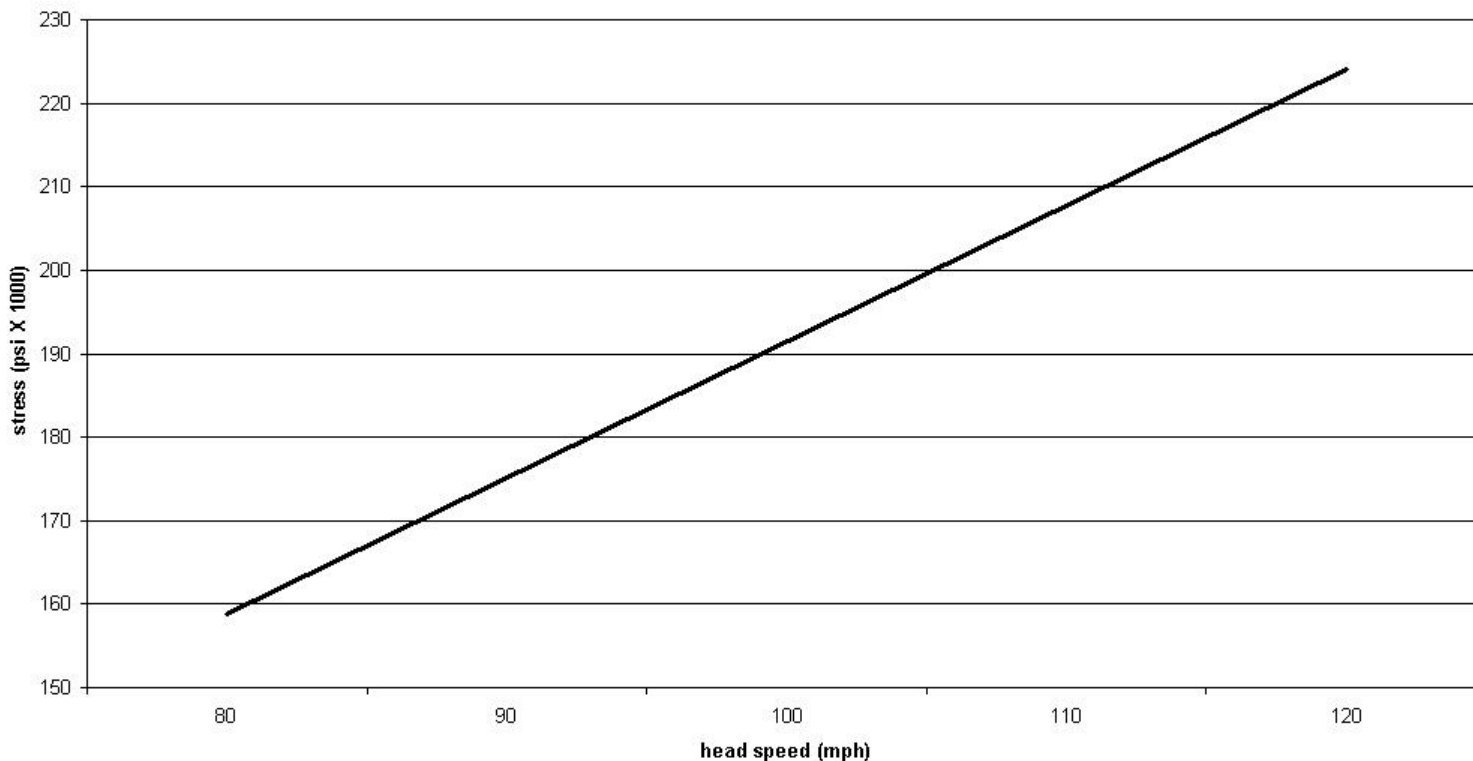
# PRODUCT DEVELOPMENT CONFERENCE



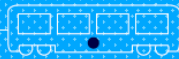
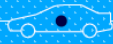
# Golf Club Driver Impact Analysis



HEAD FACE MAXIMUM VON MISES STRESS



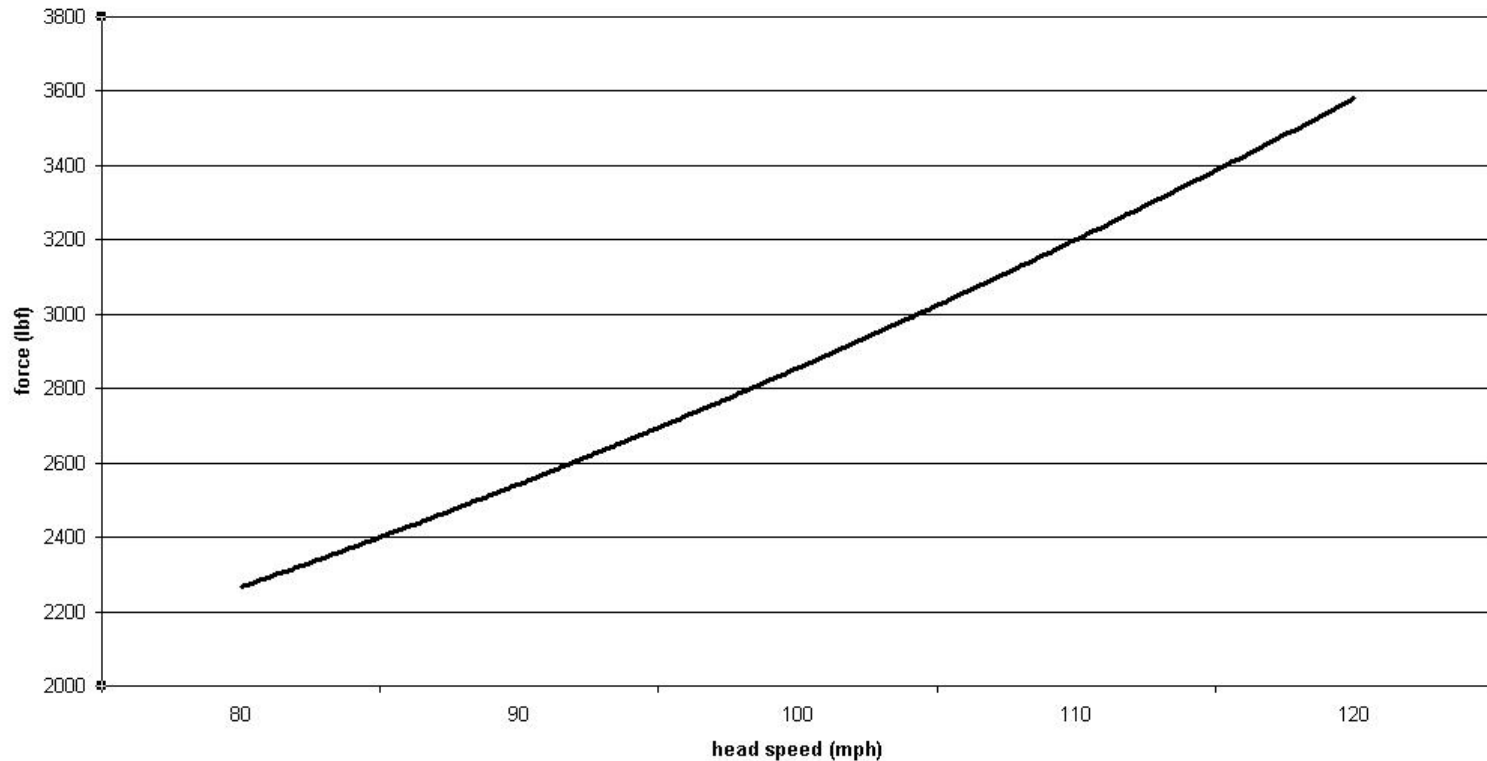
PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



MAXIMUM CONTACT FORCE



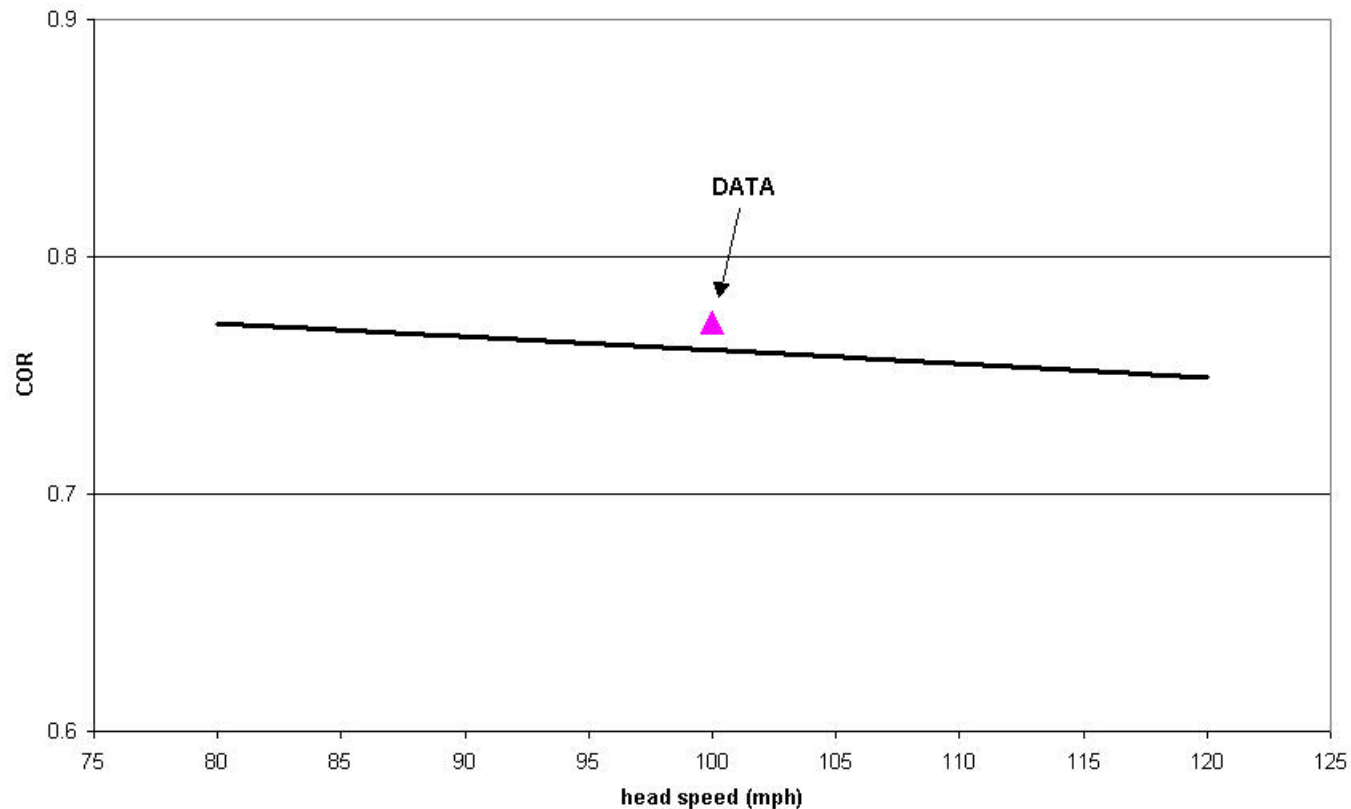
PRODUCT DEVELOPMENT CONFERENCE



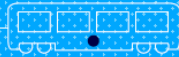
# Golf Club Driver Impact Analysis



BALL / HEAD IMPACT COR



PRODUCT DEVELOPMENT CONFERENCE

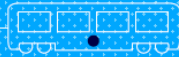


# Golf Club Driver Impact Analysis



MSC.Dytran model used to determine dependency of performance parameters on initial head loft angle

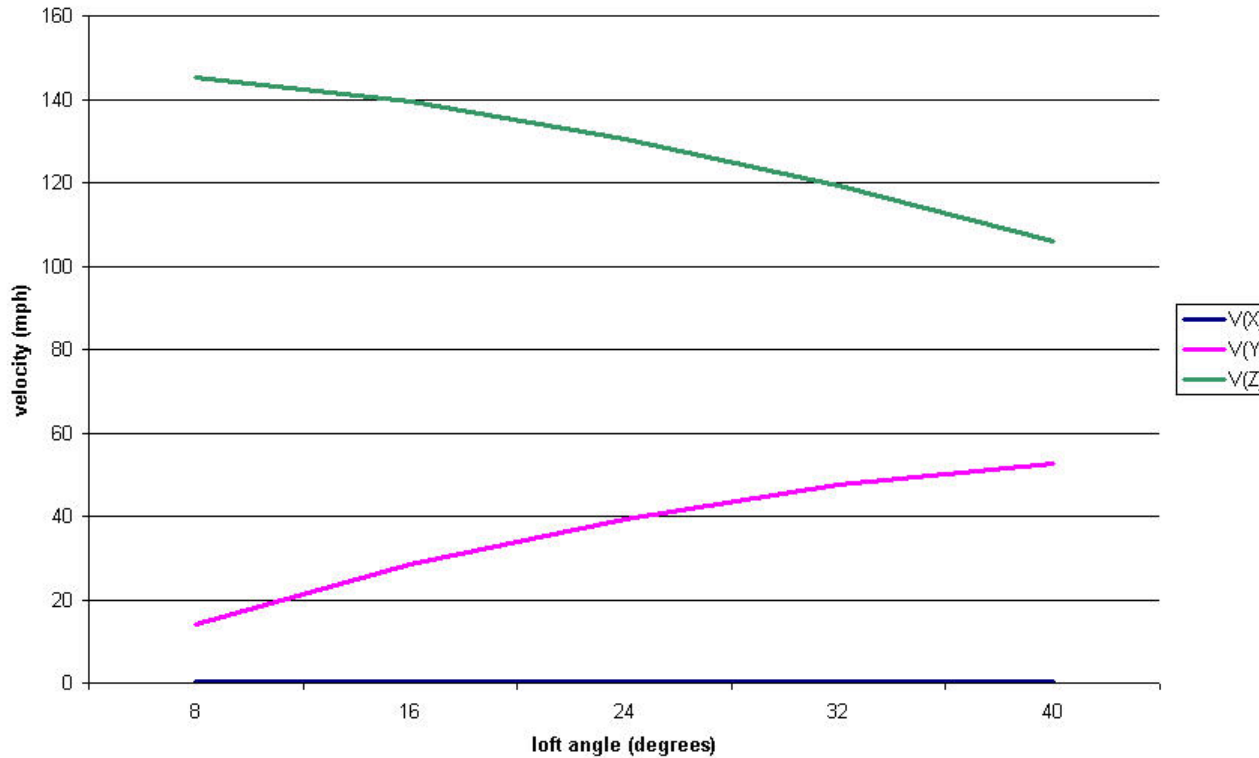
- Performance parameters
  - final ball speeds
  - ball departure angles
  - ball spin rates
  - head face stress
  - impact COR



# Golf Club Driver Impact Analysis



BALL VELOCITY COMPONENTS



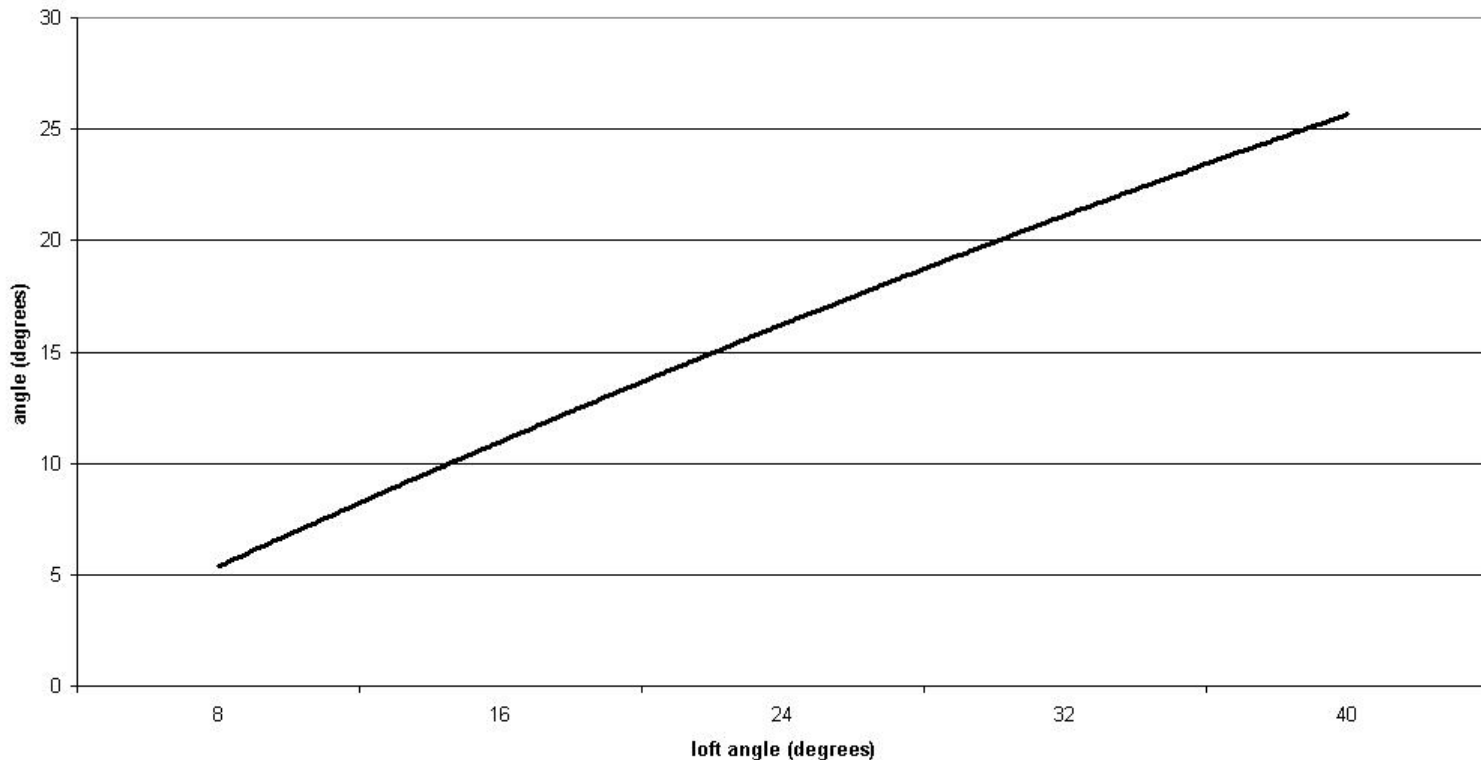
PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



BALL LAUNCH ANGLE



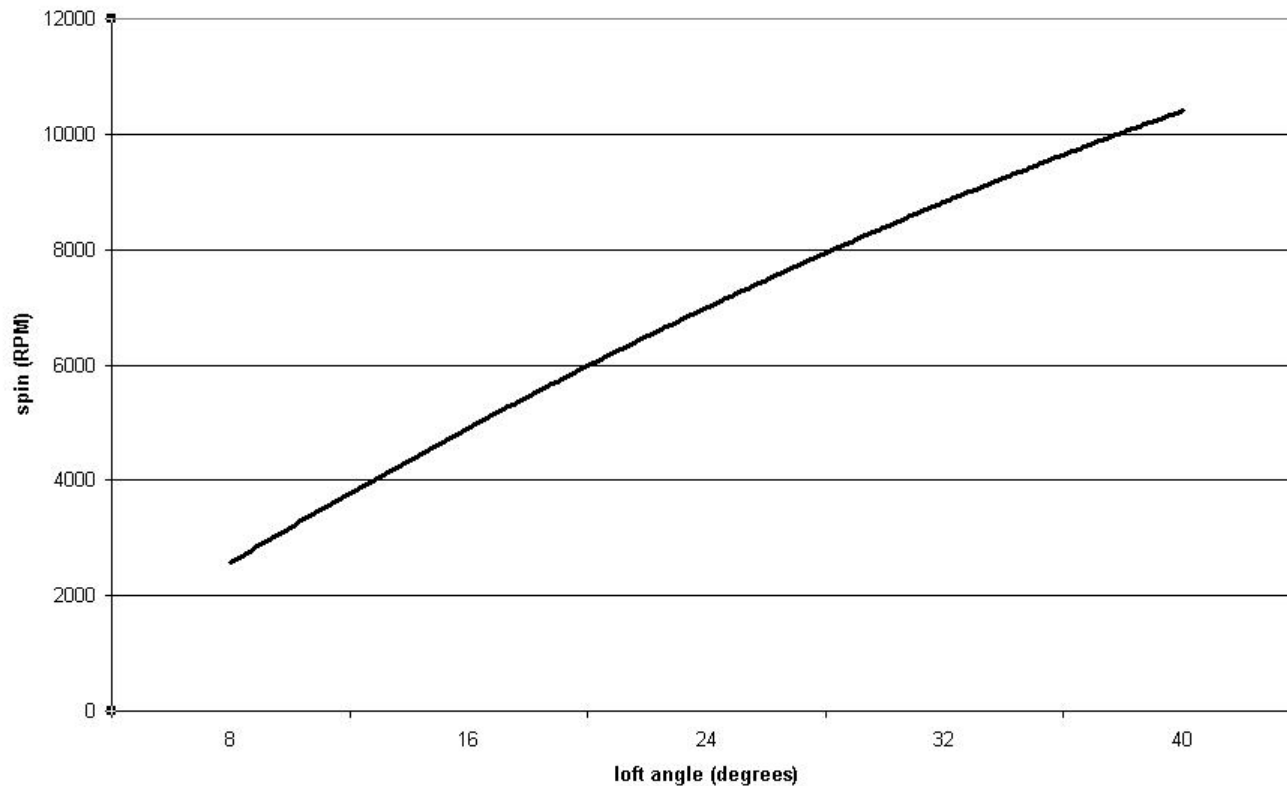
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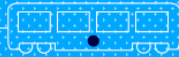
# Golf Club Driver Impact Analysis



BALL BOTTOM SPIN



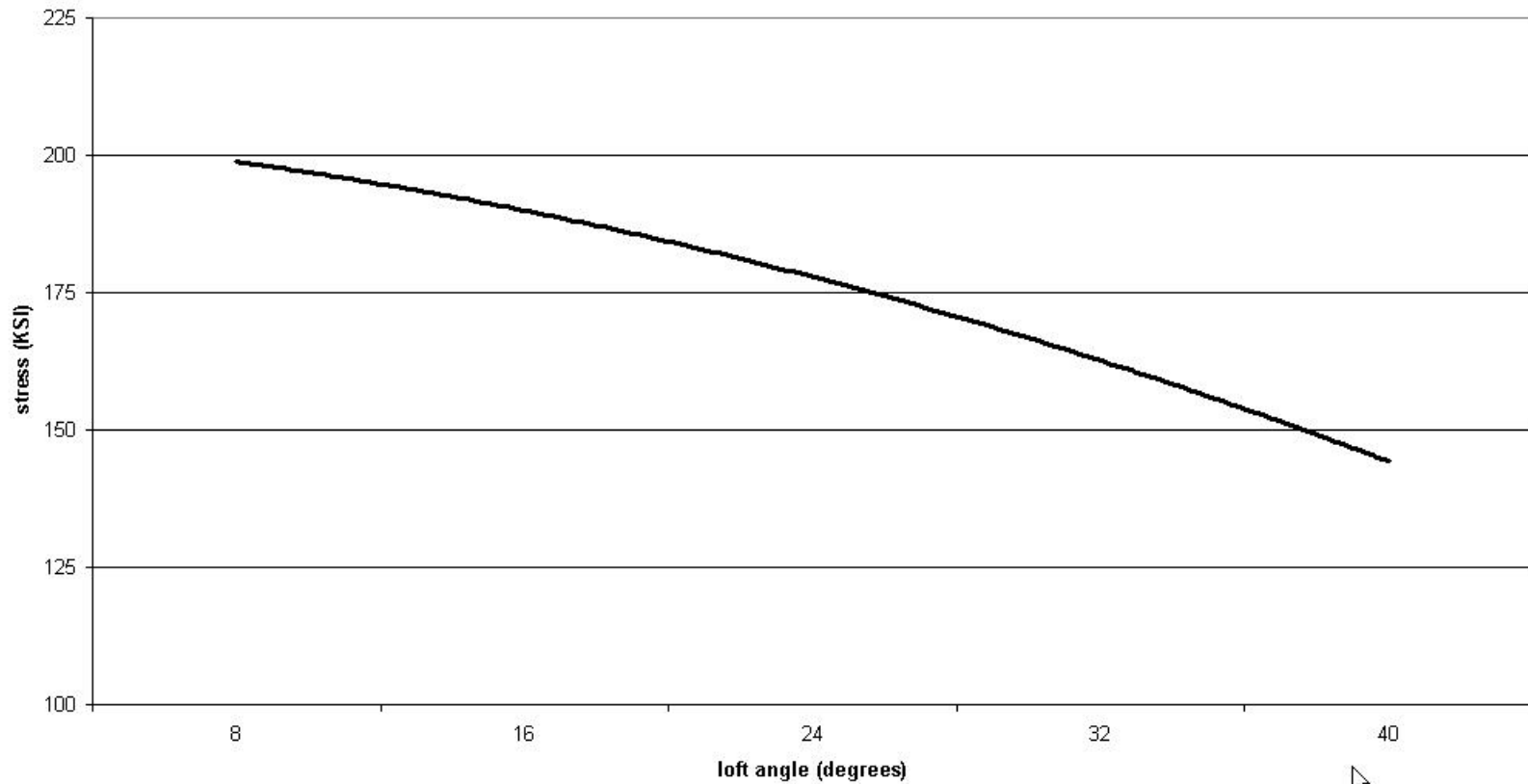
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# Golf Club Driver Impact Analysis



HEAD FACE VON MISES STRESS



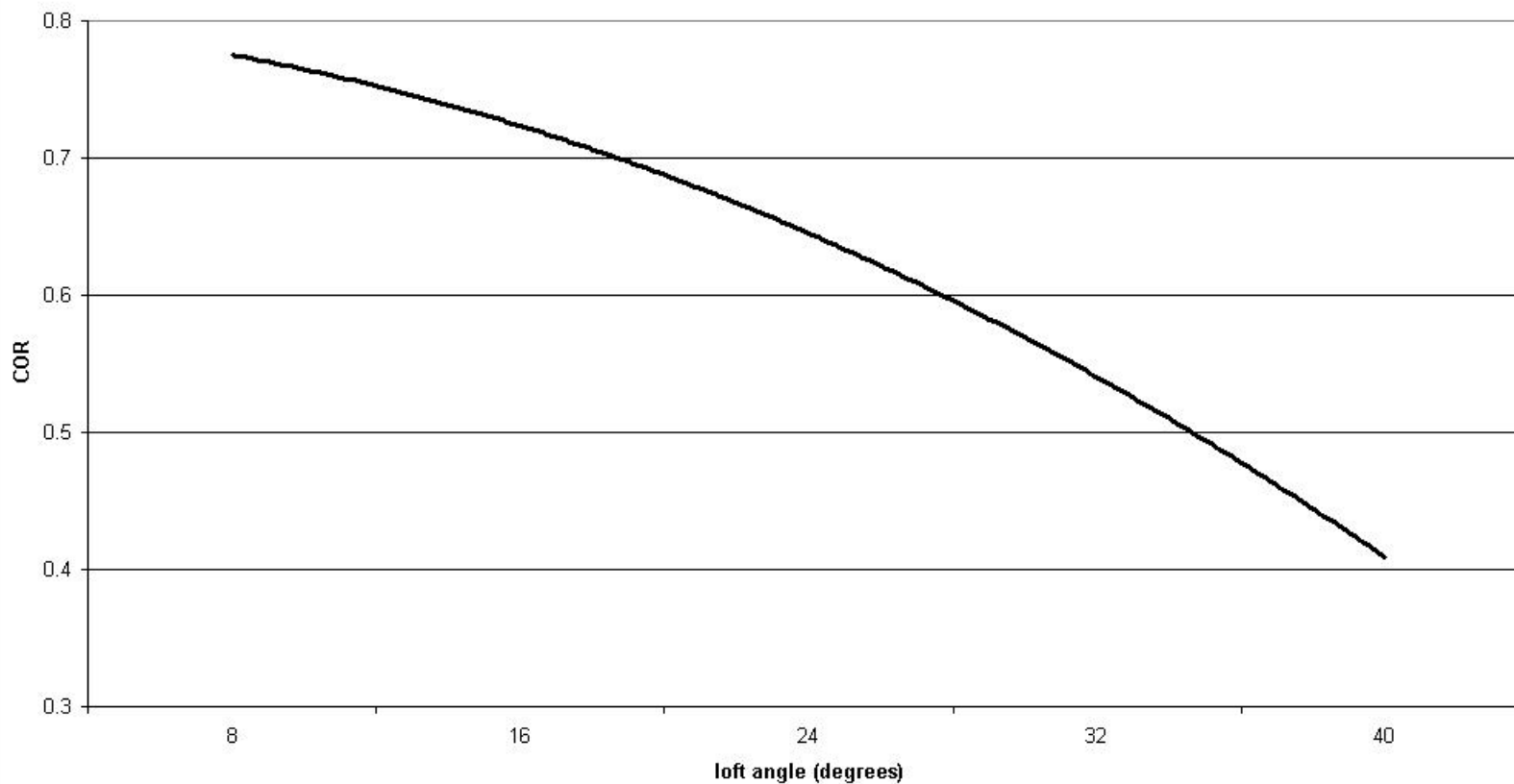
PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



COR FOR VARIOUS LOFT ANGLES AT 100 MPH



PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis

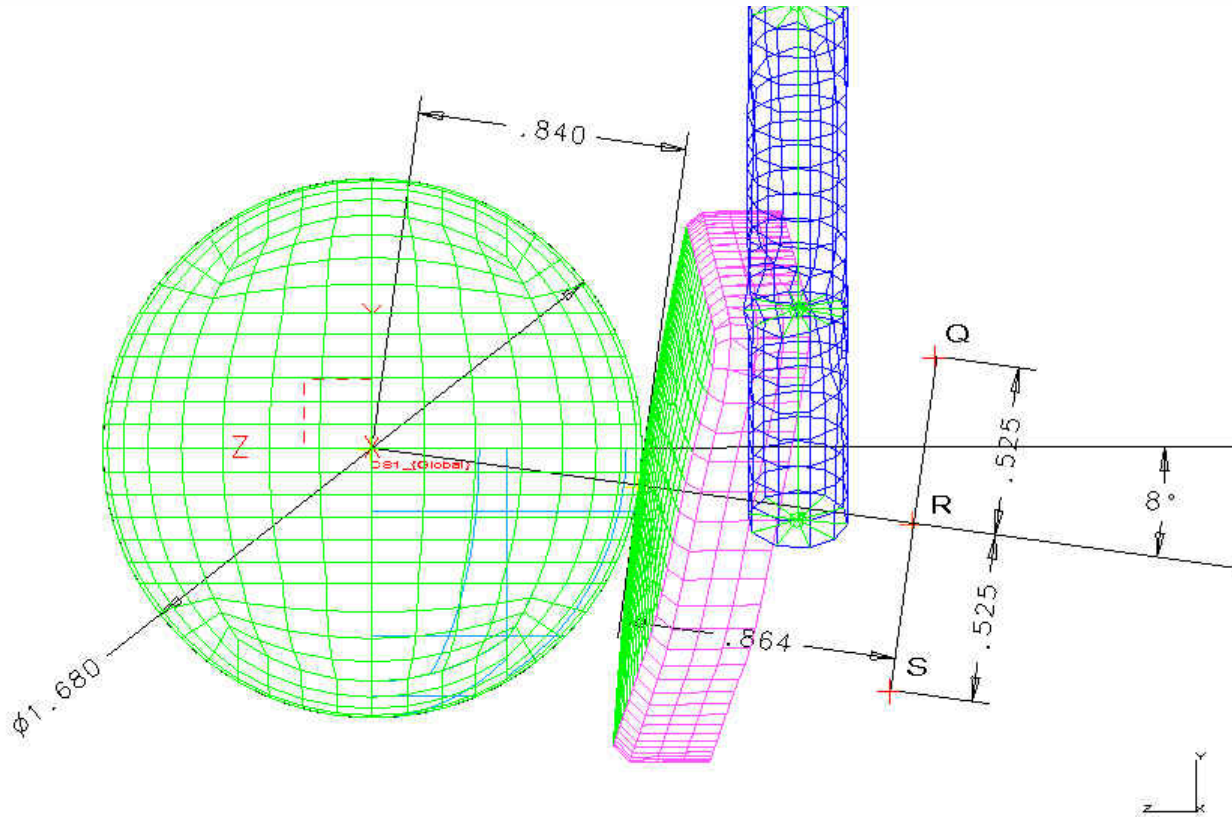


MSC.Dytran model used to determine dependency of performance parameters on head CG location (vertical offset)

- Performance parameters
  - final ball speeds
  - ball departure angles
  - ball spin rates
  - impact COR

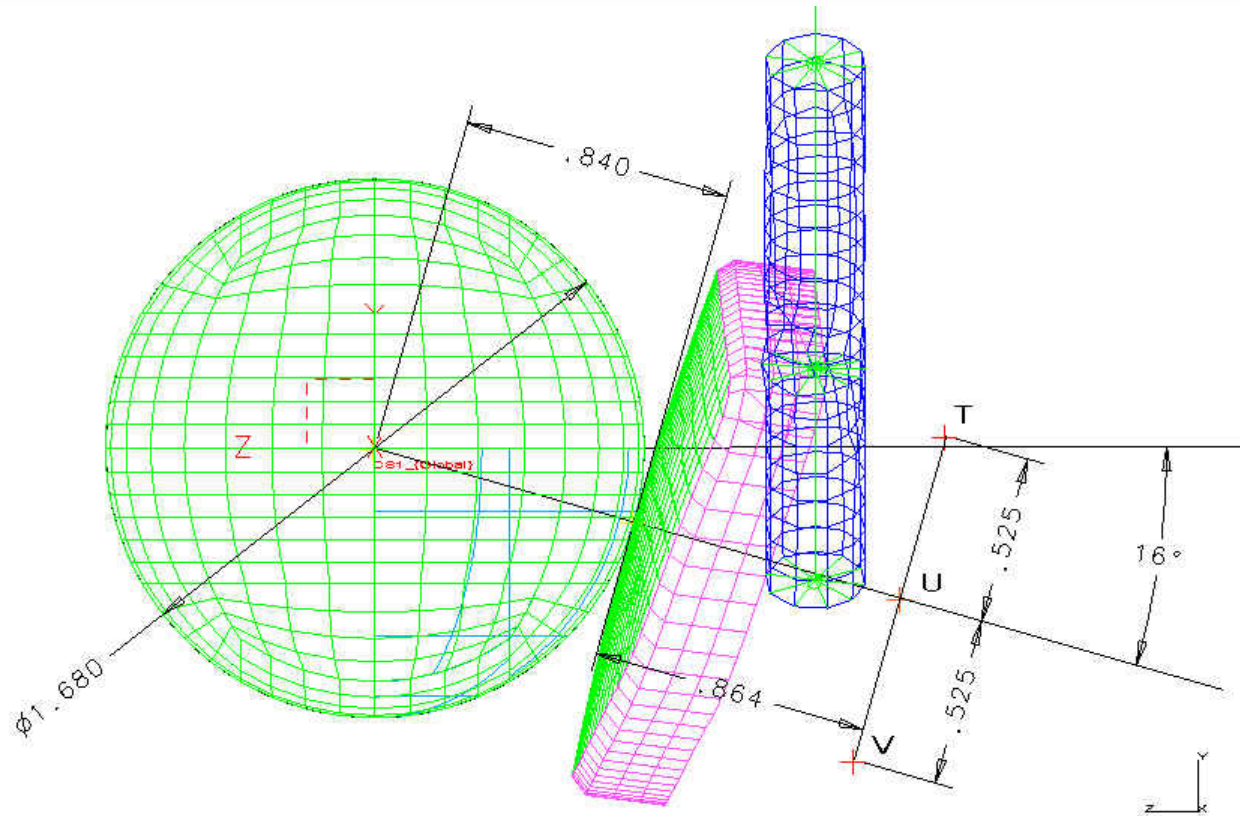


# Golf Club Driver Impact Analysis

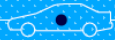




# Golf Club Driver Impact Analysis



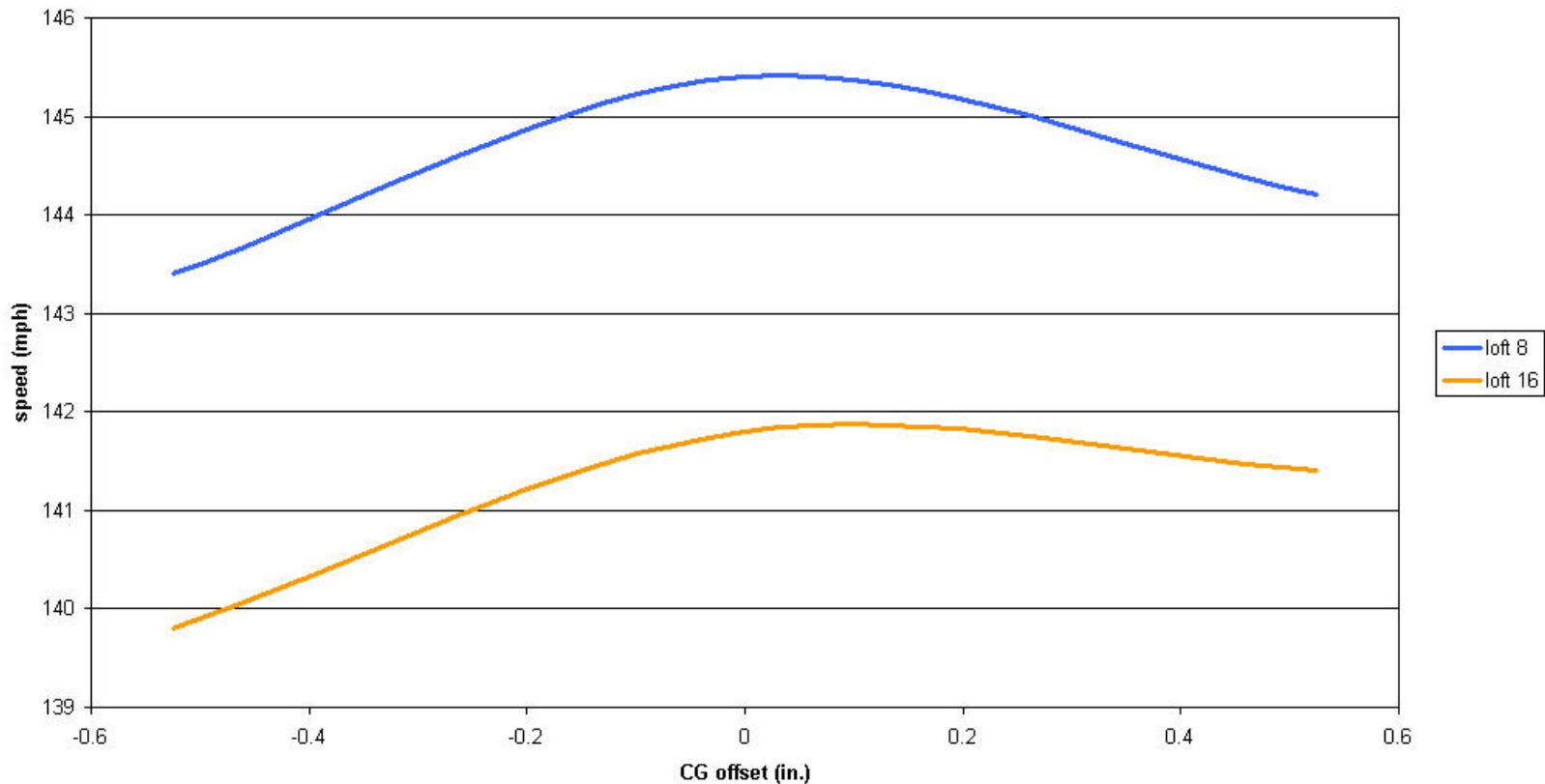
PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



BALL ABSOLUTE SPEED



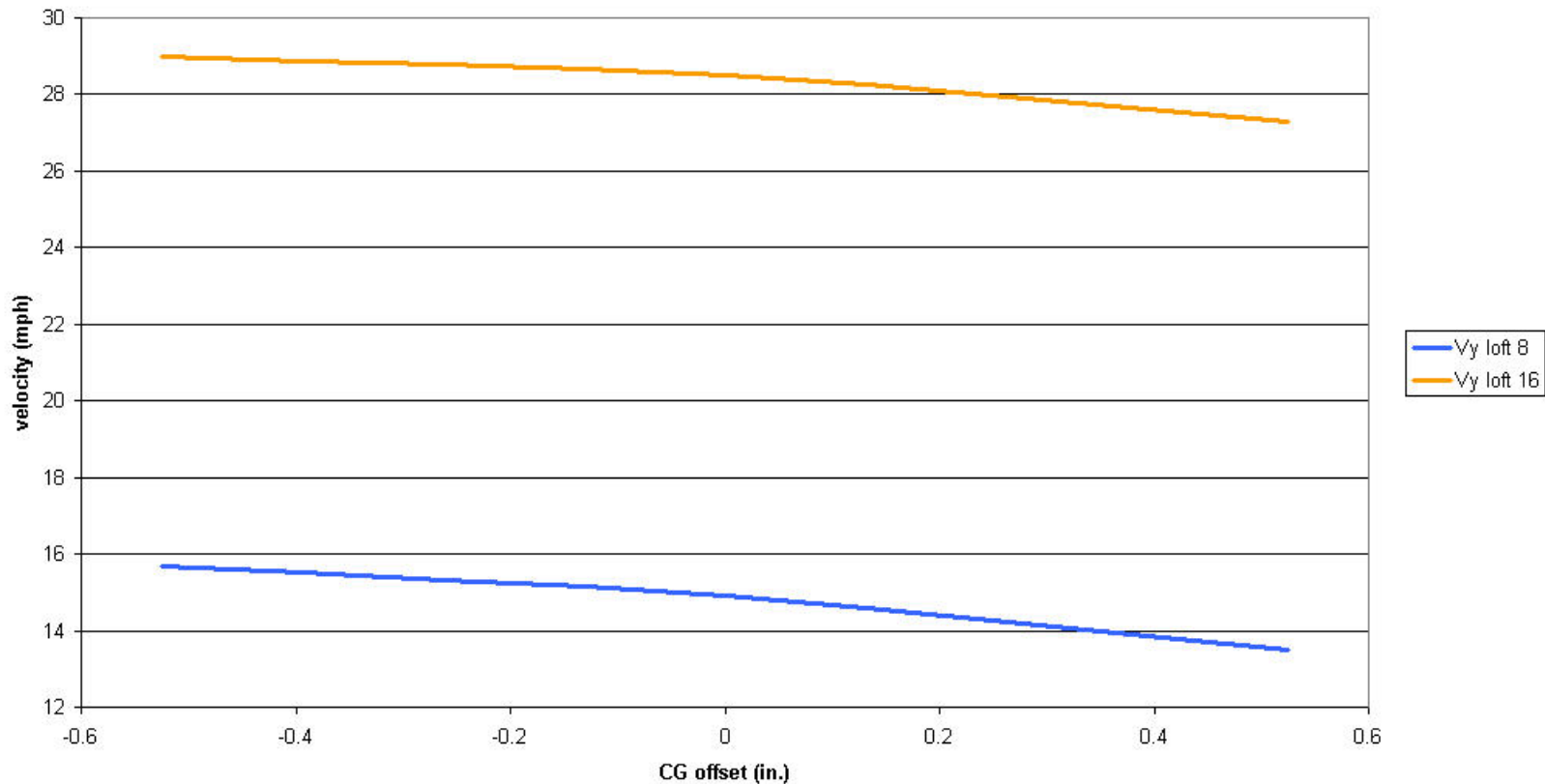
PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



BALL VELOCITY - Y

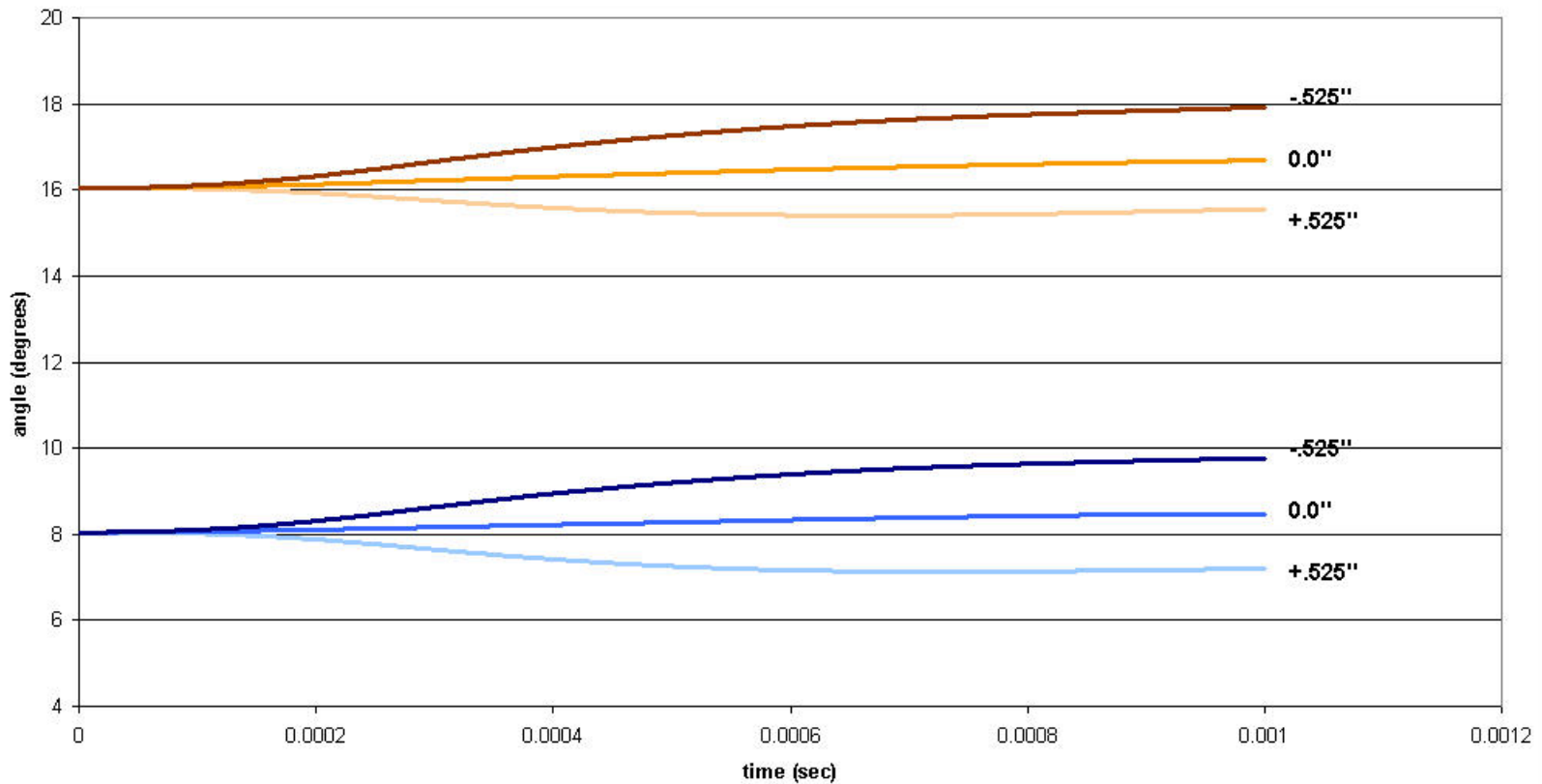




# Golf Club Driver Impact Analysis



EFFECTIVE LOFT ANGLE



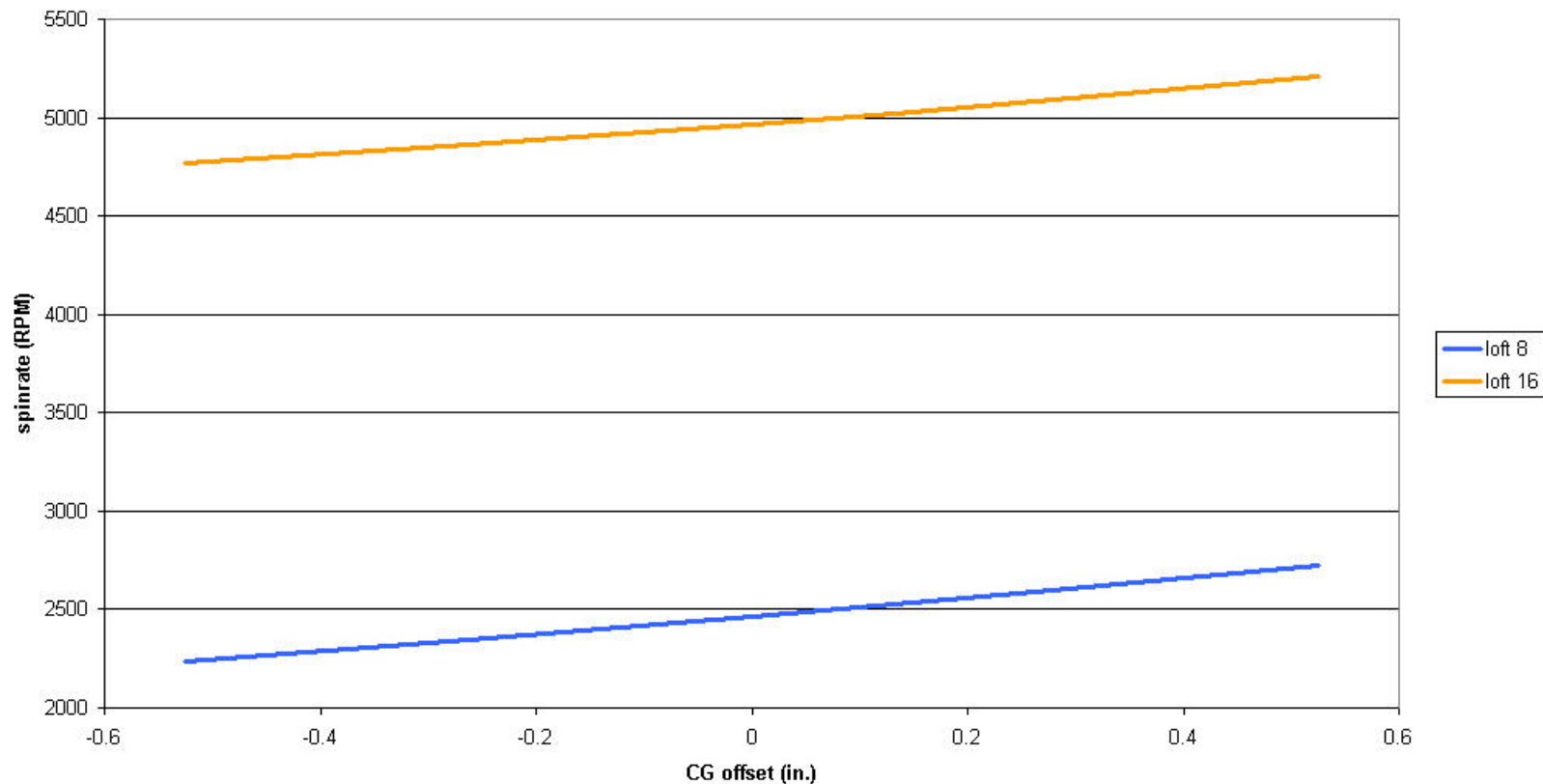
PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



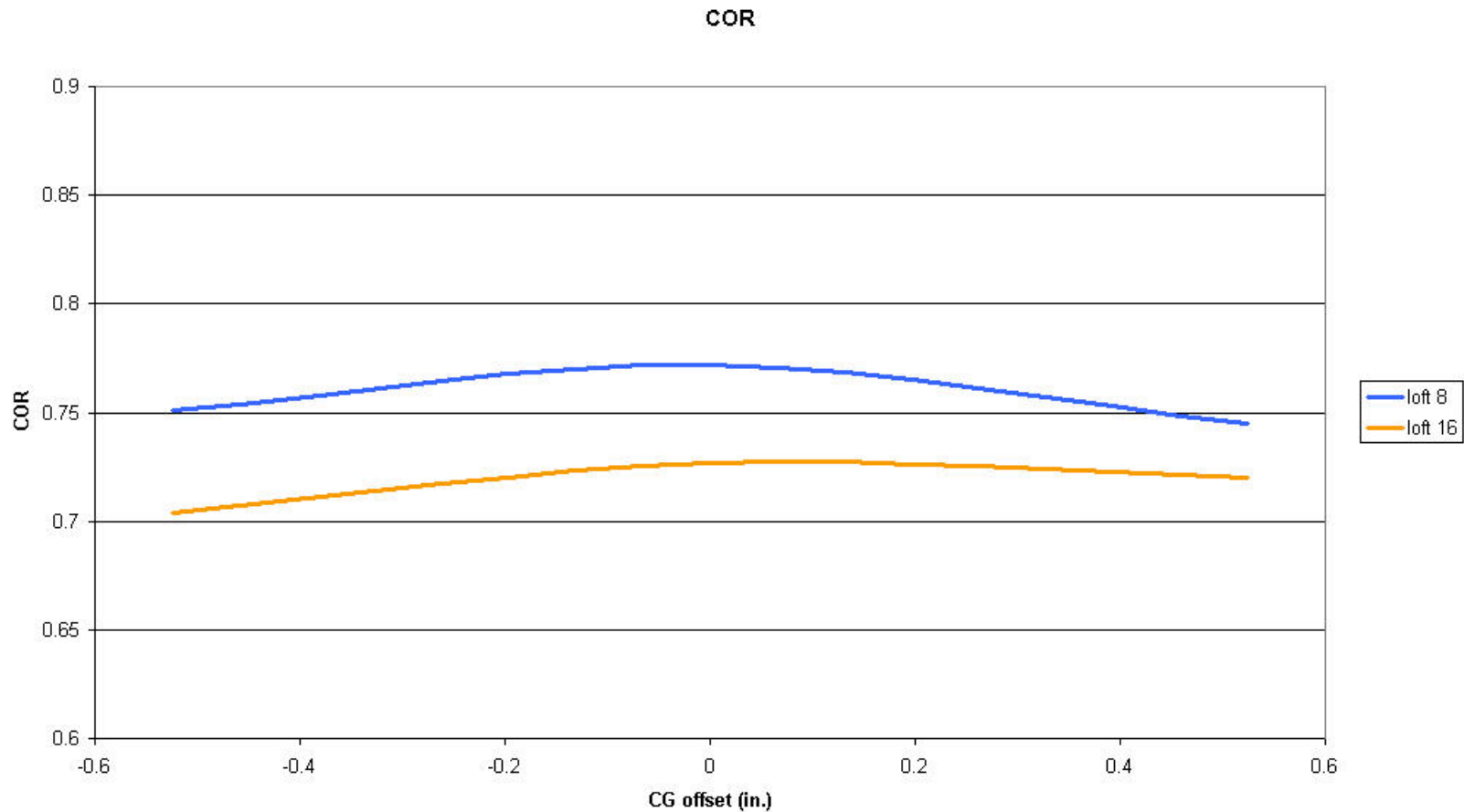
BALL BOTTOM SPIN RATE



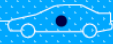
PRODUCT DEVELOPMENT CONFERENCE



# Golf Club Driver Impact Analysis



PRODUCT DEVELOPMENT CONFERENCE

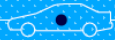


# Golf Club Driver Impact Analysis



## CONCLUSIONS:

- MSC.Dytran can be used effectively for impact sports equipment design
- It is essential to “tune” ball material properties with static force/deflection data and ball/wall impact data at multiple speeds before equipment impact analysis is performed
- ESA has successfully correlated both golf ball and soft ball wall impact COR data
- The ESA generic golf club driver model correlates well with data



# Golf Club Driver Impact Analysis



## CONCLUSIONS:

- The ESA generic driver model is an effective tool, able to provide design guidance quickly and efficiently
  - effect of *any and all* design parameters on
    - ball launch speed
    - ball impact efficiency (COR)
    - ball launch angle(s)
    - ball spin(s)
    - face dynamic stress levels