UNSW
THE UNIVERSITY OF NEW SOUTH WALES

TARS
Research

Never Stand Still | Science | Transport and Road Safety (TARS) Research

Development of a Motorcycle FE Model for Simulating Impacts into Roadside Safety Barriers

Mongiardini M., Walton B., Mckay M., Grzebieta R., Menictas C., Berg A., Rücker P.

Transport And Road Safety (TARS) – Univ. of New South Wales

1st International Roadside Safety Conference (IRSC 2017)

San Francisco, California – Jun. 12-15, 2017

OUTLINE

- INTRODUCTION
- MODELING
- V&V
- CONCLUSIONS

BACKGROUND

INTRODUCTION

- **Safety Barriers may be a Hazard to Motorcyclists**
  - Highly safe for enclosed vehicles (cars / trucks) (majority of injured & killed road users)
  - Potentially harmful for bikers
    - "Hooking" Posts
    - Sharp edges
    - Ramping effect, etc.
- **Need to Consider Motorcyclist-friendly Barriers**
  - Increasing number of fatalities
  - Safe-system approach

MOTORCYCLIST CRASHES INTO BARRIERS

- **Two Main Crash Typologies**
  - Biker riding into the barrier (upright riding position)
  - Biker sliding into the barrier (separated from bike)

- **Statistics of Crashes into Barriers**
  - NOW: Either crash postures equally distributed (Australia and New Zealand as well as in Europe)
  - PREDICTED : Most crashes in upright position [due to active stability systems (e.g., MABS)]

INTRODUCTION

TESTING OF MOTORCYCLE FRIENDLY BARRIERS

- **European Testing Protocols**
  - ATD sliding into the barrier (EN 1317, Spanish, French, protocols)
  - ATD riding the motorcycle (German protocol - BASt)

- **Computer simulations**
  - Improve knowledge on interaction b/w motorcyclists and barriers in upright crash posture
  - Assess countermeasures to reduce injury risks in motorcyclist crashes into barriers

OBJECTIVE & METHOD

- **<u>Objective</u>: Develop a Motorcycle FE Model**
  (for crashes into barrier in upright riding posture)

- **Method:**
  - Modeling a sport-touring motorcycle
    (touring bikes tend to collide in an upright posture)
  - Model Verification and Validation

SUZUKI GSX-650F

- **Based on a 2008 Suzuki GSX-650F**
  - Major structural components
  - Non-structural parts that may interact w/ barrier or rider

SUZUKI GSX-650F

- **Based on a 2008 Suzuki GSX-650F**
  - Major structural components
  - Non-structural parts that may interact w/ barrier or rider
- **Solid, Shell, and Discrete elements**
  - Most components modeled w/ shells
  - Bulky parts modeled w/ solids (engine, radiator, brake calipers)
  - Lumped mass (inertia of non-modelled components)

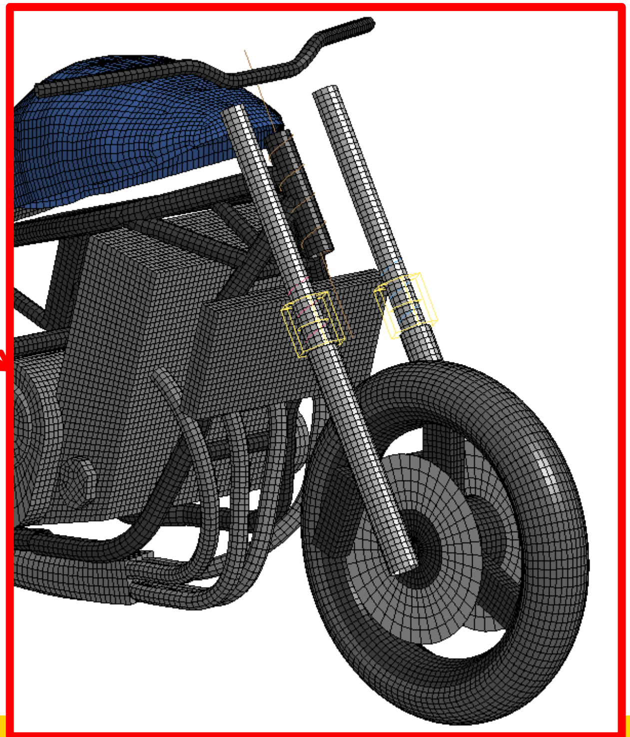
Match CG location of actual motorcycle

- **Rigid Links b/w Frame & Components**

  (Depending on specific degrees of freedom)

FRONT SUSPENSION

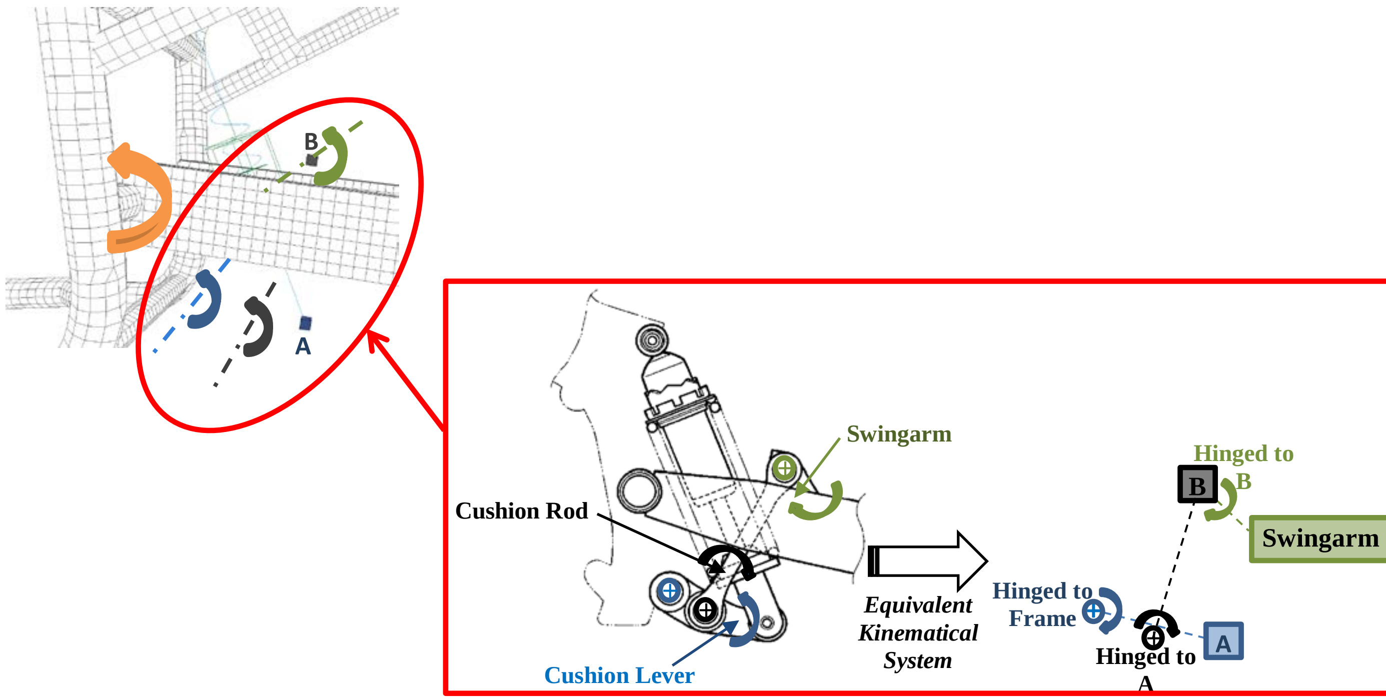
- **Upper and Lower Forks Modeled w/ Shell Elements**
  - Cylindrical joint b/w each pair of forks
  - Spring/damper discrete elements (coil spring & oil damping)
  - Rigid constraint b/w upper forks (triple clamps)



MODELING

REAR SUSPENSION

- ❑ **Swingarm Explicitly Modeled w/ Shell Elements**
- ❑ **Various Links Modeled w/ Kinematical Joints**
  - ➢ Revolute joint b/w swingarm & frame (hinge)
  - ➢ Pairs of revolute joints b/w 2 dummy elements (Cushion-lever-rod assembly)

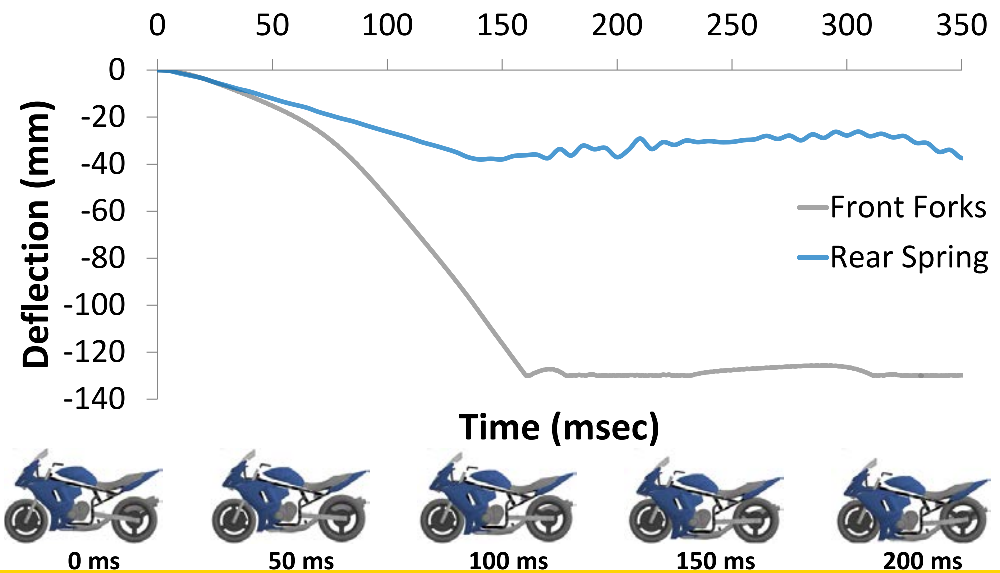


MODEL VERIFICATION

V&V

❑ Front/Rear Suspensions

- ➢ <u>Static behavior</u>: compression/extension up to the limit
  - o Stiffness & damping zeroed
    (to speed up process)
  - o Bike frame constrained in the vertical plane
    (to prevent tilting)
  - o Model settled under gravity (onto rigid plane)



MODEL VERIFICATION

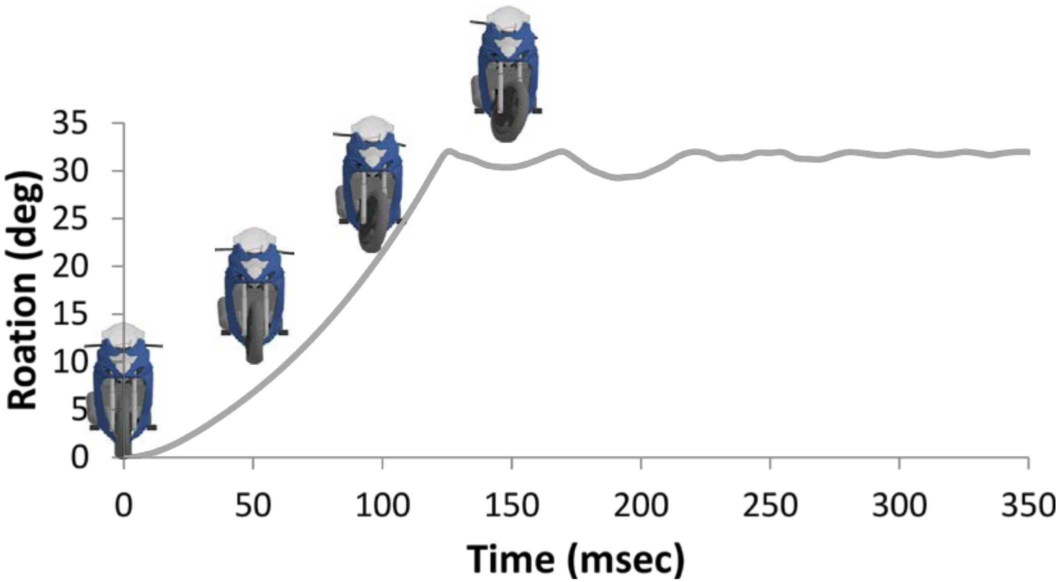
V&V

❑ Front/Rear Suspensions

- Static behavior: compression/extension up to the limit
- Dynamic behavior: riding over a bump
  - o Bump height: 200 mm
  - o Initial speed: 10 km/h

MODEL VERIFICATION

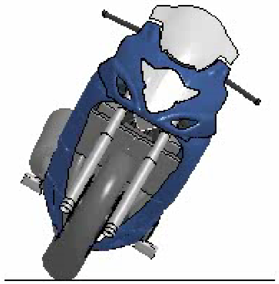
- **Steering**
  - Static behavior: Steering up to limit angle (32 deg)
    - Steering input: 50-N (applied @ outer rim)



V&V

MODEL VERIFICATION

- **Steering**
  - Static behavior: Steering up to limit angle (32 deg)
  - Dynamic behavior: induce turn when bike is travelling
    - Steering input: 50-N (applied @ outer rim)
    - Initial speed: 10 km/h
    - Initial bike roll angle: 30 deg (to center of curvature)



V&V

MODEL VALIDATION

❑ Response to Sloped Obstacles

- ➢ Validated against experimental tests
  - o Slope height: 200-mm (7.9-in)
  - o Initial speeds: 15 km/h (9.3 mph) - 20 km/h (12.4 mph)
  - o Slope steepness: 20 deg / 45 deg
  - o Approach angle: 90 deg / 45 deg

Test No.		Impact Speed * (km/h) [mph]	Ramp Angle (deg)	Approach Angle (deg)
20° Slope	20/90-1	20.1 [12.5]	20	90
	20/90-2	20.6 [12.8]		
	20/90-3	19.7 [12.2]		
	20/45-1	14.4 [8.9]	20	45
	20/45-2	18.0 [11.2]		
	20/45-3	18.2 [11.3]		
	20/45-4	19.3 [12.0]		
45° Slope	45/90-1	15.6 [9.7]	45	90
	45/90-2	17.0 [10.6]		
	45/90-3	17.9 [11.1]		

* Speed determined at time front suspension begins compressing upon contact w/ ramp

MODEL VALIDATION

❑ Response to Sloped Obstacles

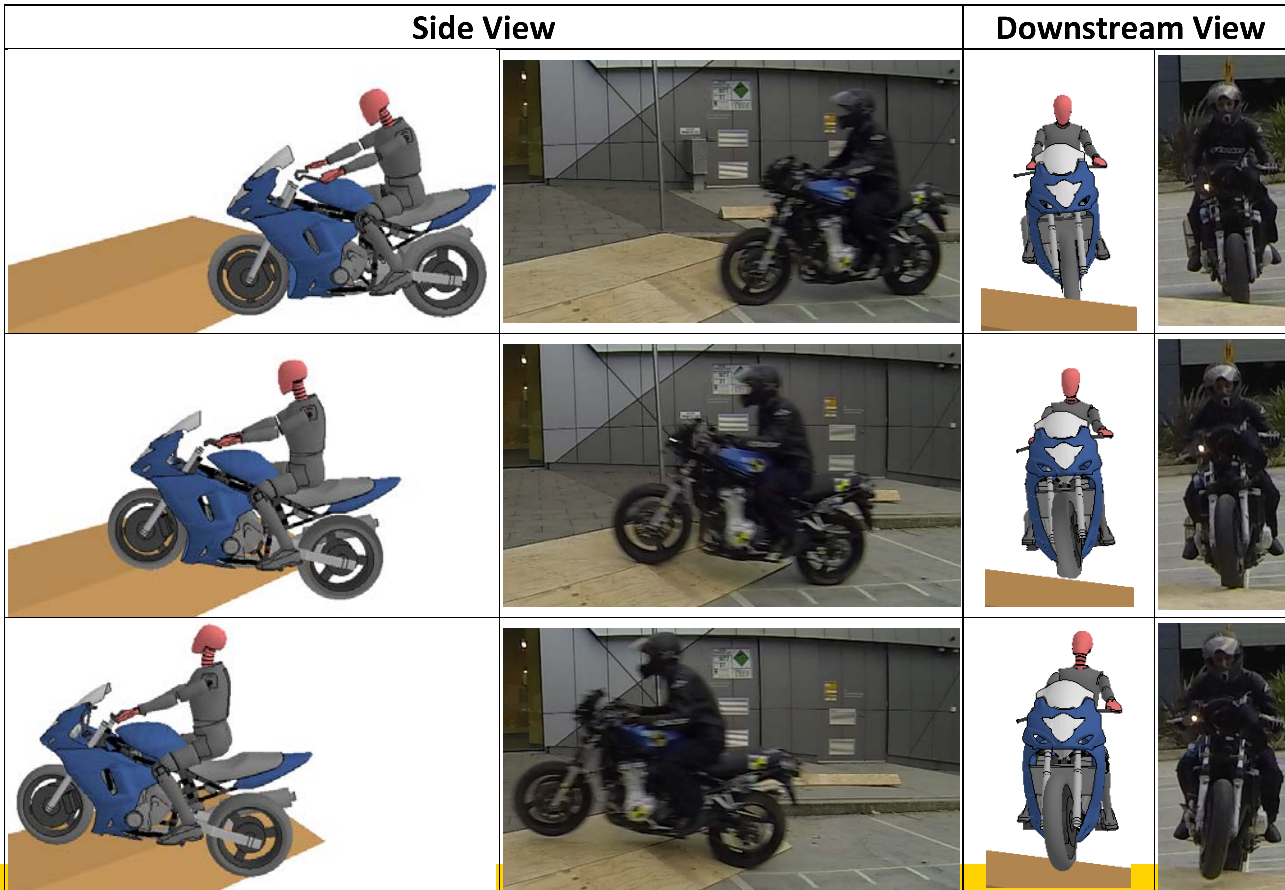
- Validated against experimental tests
  - ***MOTORCYCLE KINEMATICS***
    (Example: 20-deg slope & 45-deg approach angle)

MODEL VALIDATION

V&V

❑ Response to Sloped Obstacles

- ➢ Validated against experimental tests
  - o ***MOTORCYCLE KINEMATICS***
    (Example: 20-deg slope & 45-deg approach angle)

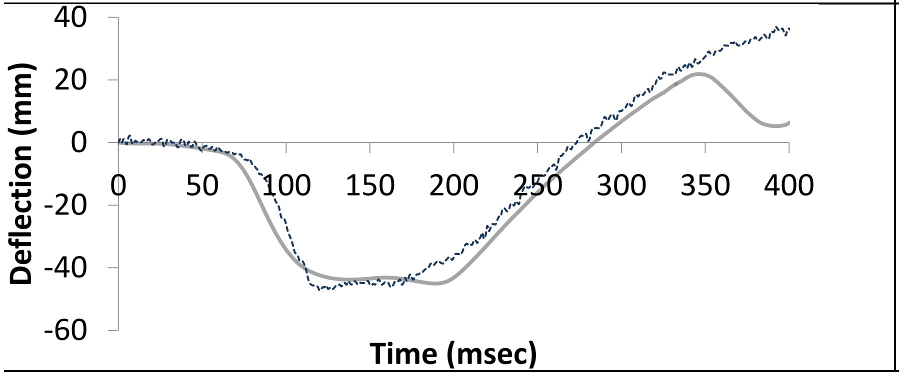


MODEL VALIDATION

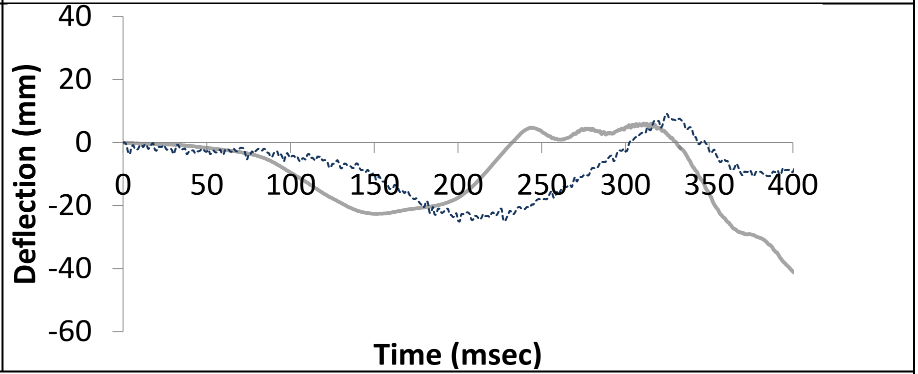
❑ Response to Sloped Obstacles

- Validated against experimental tests
  - ***SUSPENSION COMPRESSION***
    (Example: 20-deg slope & 45-deg approach angle)

Front Suspension



Rear Suspension



—Simulation ---Test 20/45-4

Sprague&Geers	Anova	Sprague&Geers	Anova
M = -4.4; P = 10.5; C = 11.4	Avg = -10.8; Std = 15.4	*M = 26.9; P = 29.6; C = 40.0*	*Avg = -4.2; Std = 49.3*

MODEL VALIDATION

- **Full-Scale Crash into Jersey Barrier**
  - Test conducted by DEKRA on a Kawasaki ER-5
    - Barrier Type: Jersey [810-mm (32-in) tall]
    - Impact speed: 58.5 km/h (36.4 mph)
    - Impact and angle: 12 deg

MODEL VALIDATION

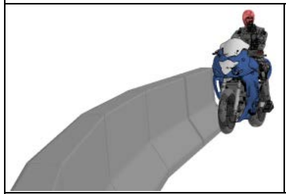
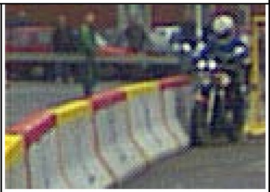
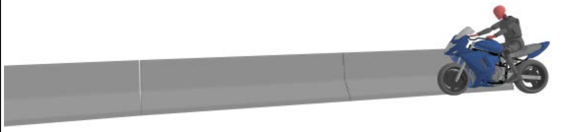
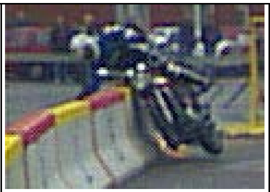
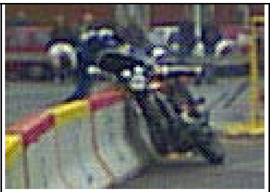
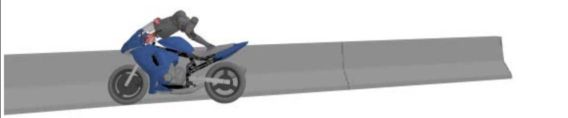
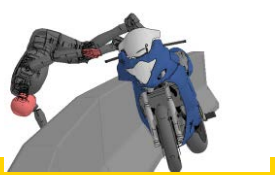
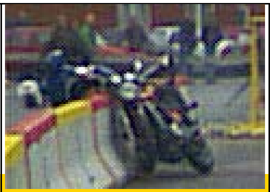
- **Full-Scale Crash into Jersey Barrier**
  - Test conducted by DEKRA on a Kawasaki ER-5
    - ***MOTORCYCLE KINEMATICS***

V&V

MODEL VALIDATION

❑ Full-Scale Crash into Jersey Barrier

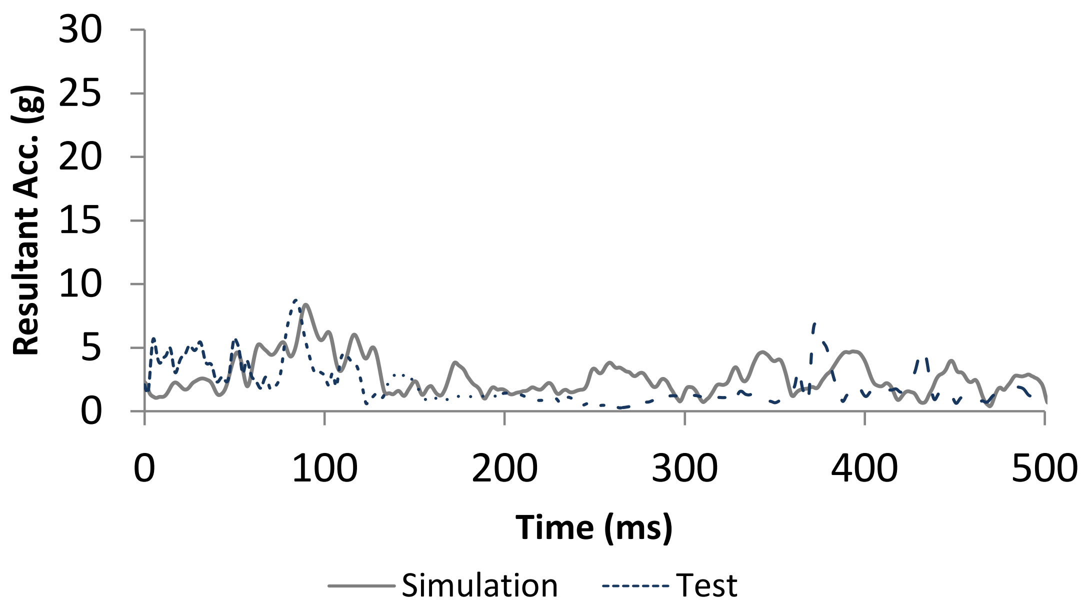
- ➢ Test conducted by DEKRA on a Kawasaki ER-5
  - o ***MOTORCYCLE KINEMATICS***

Downstream View		Side View	
			
t = 0 ms (Beginning of Impact)			
			
t = 300 ms			
			
t = 400 ms			
			
t = 500 ms			

MODEL VALIDATION

❑ Full-Scale Crash into Jersey Barrier

- Test conducted by DEKRA on a Kawasaki ER-5
  - ***RES. ACCELERATION* @ Top Steering Column**

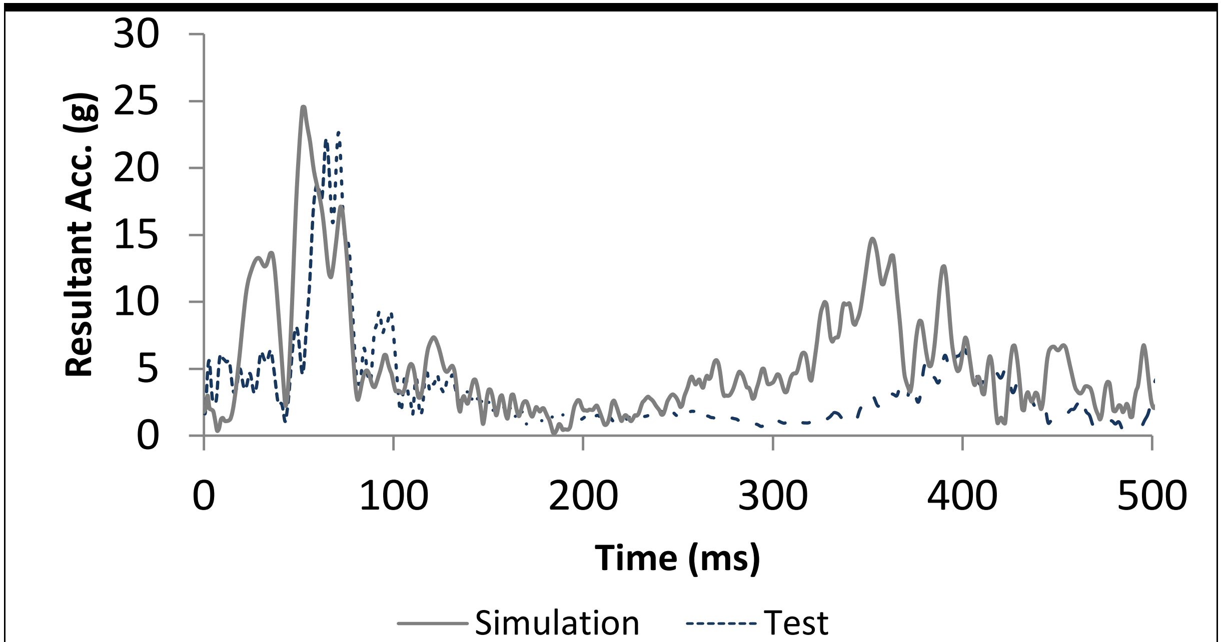


Sprague&Geers	Anova
M = 18.6; P = 22.2; C = 29.0	*Avg = 7.6; Std = 21.4*

MODEL VALIDATION

❑ Full-Scale Crash into Jersey Barrier

- Test conducted by DEKRA on a Kawasaki ER-5
  - **RES. ACCELERATION @ Seat**



Sprague&Geers	Anova
M = 41.5; P = 20.6; C = 46.4	*Avg = 9.2; Std = 16.6*

CONCLUSIONS

- **FE Model to Simulate Upright Motorcyclist Impacts**
  - Reliable kinematics of steering and suspensions
    - Verified functionality
    - Validated response against slope tests (suspensions only)
- **Promising Results when Coupled w/ ATD Model**
  - Reliable kinematics of both motorcycle and ATD
  - Differences w/ full-scale test likely due to geometric differences w/ tested bike
- **Next, Further Validation...**
  - Against ATD loads (w/ better ATD Model ?)
  - Against crashes into semi-rigid and flexible barriers

ACKNOWLEDGMENTS

Experimental Testing

- Dept. of Mechanical Engineering at UNSW (Mechanical shop)
- Road & Maritime Services CrashLab (Test instrumentation)
- Mr. Cameron Peacock (Manufacturing of ramps)

QUESTIONS?