Motorcycle Finite Element Computer Model to Assist with Roadside Safety Research Efforts

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Roadside Safety Hardware

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How about Motorcycles?

- Limited research to address riders safety when impacting roadside safety hardware
- No US testing standards for motorcycle riders safety when impacting roadside safety devices
- No world testing standards when impacting in upright position
  - Real world crash data showing approximately 50% of motorcycle crashes into barriers occur with the rider in the **upright position**.

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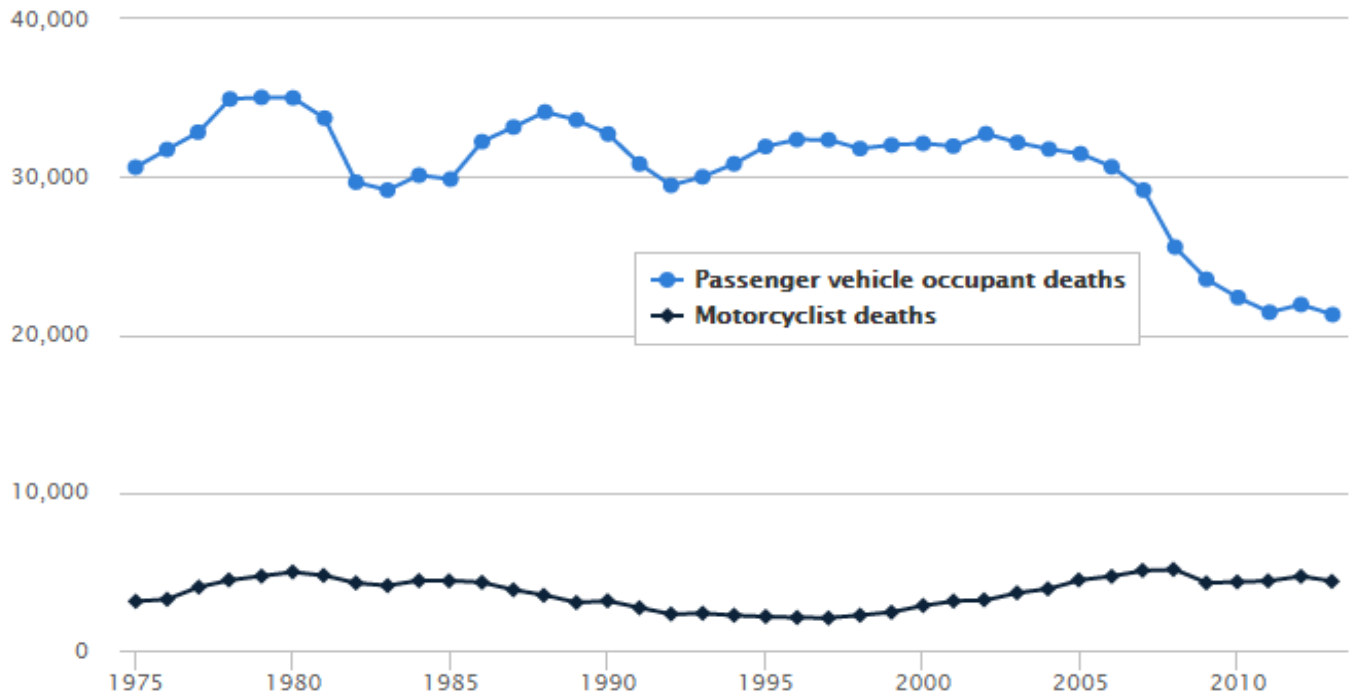
Do We Need Standards for Motorcycles?

- In US, per 100,000 registered motorcycles, 59 bikers are involved in **fatal** road accidents (compared to 10 vehicle fatal accidents)
  - In EU: 11 fatal road accidents for motorcyclists and 5 fatal vehicle occupant accidents
- Over years passenger vehicle deaths have been reduced while motorcyclists deaths have remained constant.



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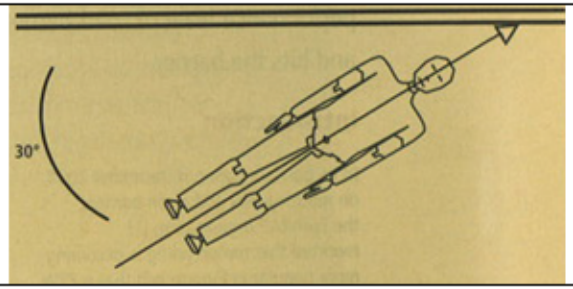
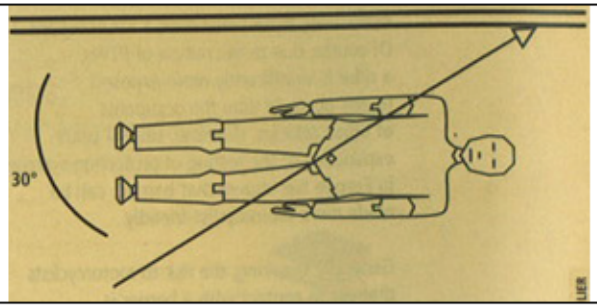
Standards and Technical Specifications

- **1998: LIER-INRETS (France)**
  - Since then, all motorcyclist protection systems must be tested according to this procedure before being approved for use on French roads.

Impact Configuration	Impact Speed	Impact Angle
 **Test 1.** Dummy aligned w/ launch path	60 km/h 37.3 mi/h	30°
 **Test 2.** Dummy parallel to the test item	60 km/h 37.3 mi/h	30°

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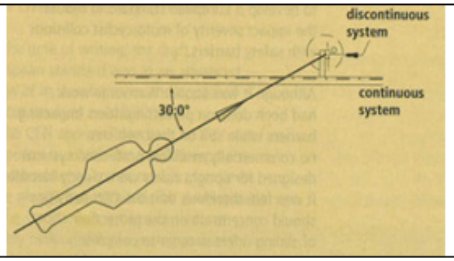
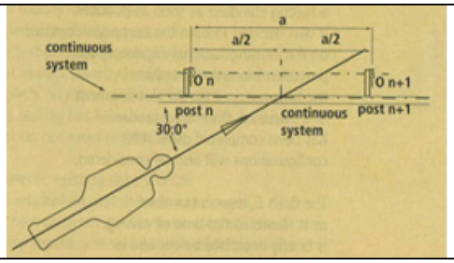
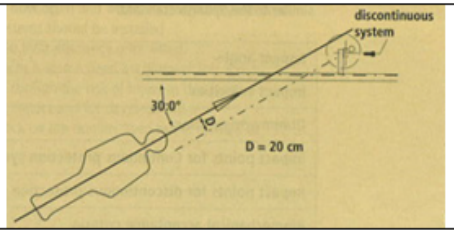
 **Test 1.** Dummy aligned w/ launch path - Post centered	60 km/h 37.3 mi/h	30°
 **Test 2.** Dummy aligned w/ launch path - Mid-Span	60 km/h 37.3 mi/h	30°
 **Test 3.** Dummy aligned w/ the launch path - Post Offset	70 km/h 43.5 mi/h	30°

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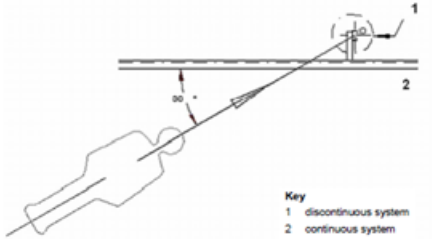
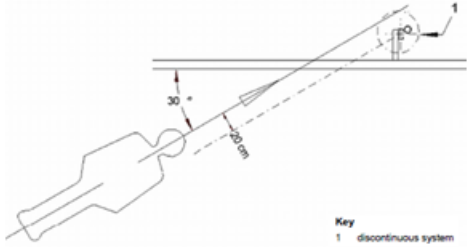
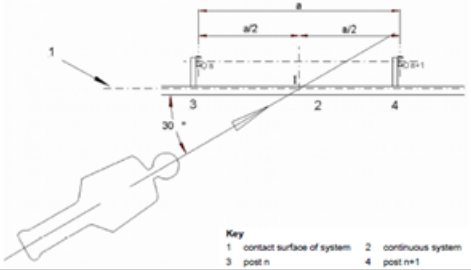
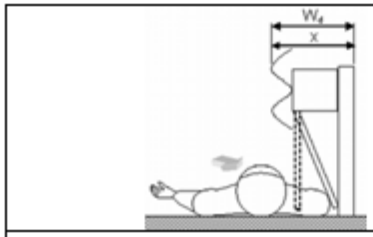
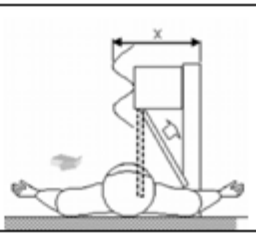
 **Test 1.** Launch Configuration1: Post-Centered Impact	60 km/h 37.3 mi/h or 70 km/h 43.5 mi/h	30°
 **Test 2.** Launch Configuration 2: Post-Offset Impact	60 km/h 37.3 mi/h or 70 km/h 43.5 mi/h	30°
 **Test 3.** Launch Configuration 3: Mid-Span Impact	60 km/h 37.3 mi/h or 70 km/h 43.5 mi/h	30°

	
(a) Example: barrier + MPS	**(b) Example: barrier + MPS**
No protrusions rearward of complete system	Arm protrudes rearward of complete system
-> ACCEPTABLE PERFORMANCE	-> SYSTEM FAILS TEST

Severity Level	Maximum Admissible Values							
		Neck						
	Head	F_x (N)	$F_{z\ tension}$ (N)	$F_{z\ compression}$ (N)	M_{OCx} (Nm)	$M_{OCy\ extension}$ (Nm)	$M_{OCy\ flex}$ (Nm)
	HIC_{36}							
I	650	See Table	See Table	See Table	134	42	190	
II	1,000	See Table	See Table	See Table	134	57	190	

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Standards and Technical Specifications

- **TRL Ltd. (Transport Research Laboratory) (UK)**
  - "TRL have not, and will not be testing to this standard (EN 1317-8) due to the costs involved (…)" (Gavin Williams, Technical Specialist)
- **2005 International Standard**
  - **ISO 13232** "Motorcycles - Test and Analysis Procedures for Research Evaluation of Rider Crash Protective Devices Fitted to Motorcycles" (8 parts) **(Motorcycle vs. car)**
- **DEKRA Crash Test Center (Germany)**
  - Motorcycle crash tests (ISO 13232)
- **BASt (Federal Highway Research Institute) (Germany)**
  - Has defined an homologation procedure for impact protector

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Why Computer Simulation?

- Computer simulations are quick and inexpensive compared to full-scale crash tests
- Several different motorcycle crash scenarios can be simulated to observe motorcycle rider behavior and injury risk

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Selection of Motorcycle

- A 2005 Kawasaki Ninja 500R Motorcycle was selected to be modeled
  - Popular motorcycle for beginner riders
  - Rider posture is more forward
  - Dimensions of the motorcycle

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3D Scanners

- Surphaser HSX
- Used for larger parts and entire motorcycle

- FARO Edge
- Used for majority of the parts of the motorcycle

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Software

- Geomagic Design X
- SurphExpress
- HyperMesh
- LS-DYNA

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Scanning Process

- Developed global scans of entire motorcycle

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Scanning Process

- Develop individual part scans

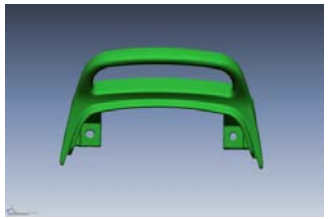
Scan part using FARO Edge scanner to generate point cloud. Align point cloud to global anchor scan.

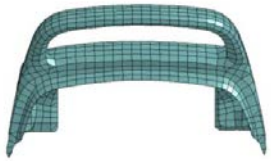
↓

Generate surface or solid from point cloud of part.

↓

Create FE mesh of part by breaking down into elements.





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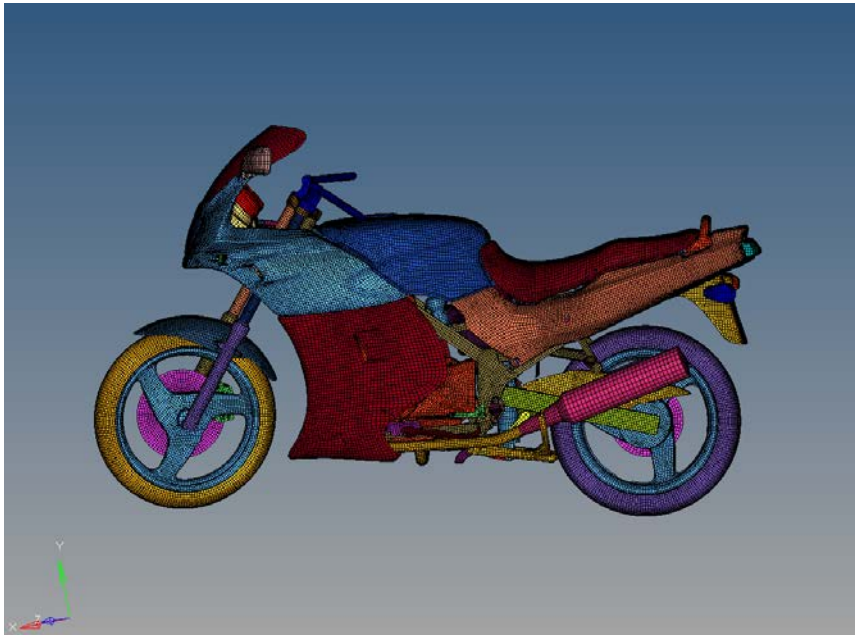
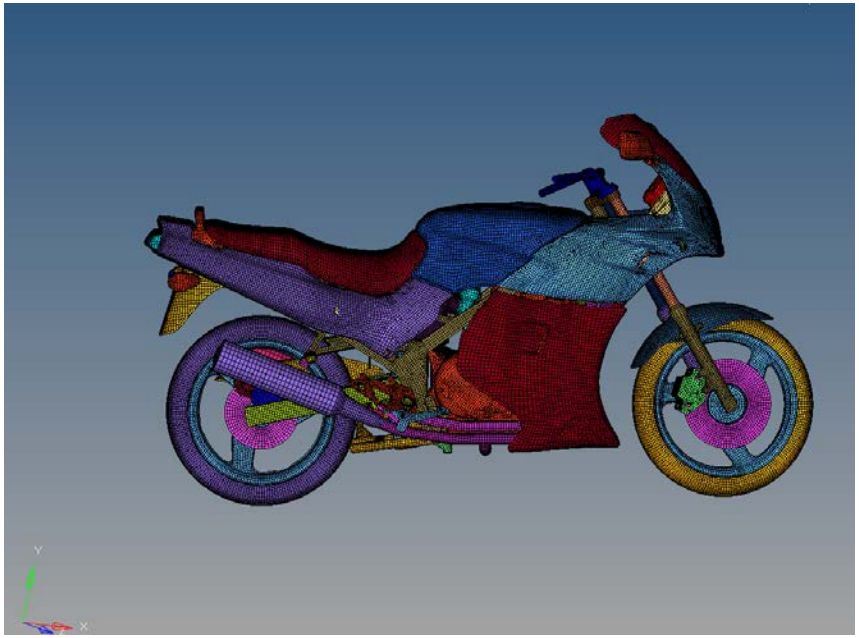
Scanning Process

- Entire motorcycle was disassembled and parts were scanned as they were removed
- Documentation of each part was conducted for the following categories:
  - Mass
  - Thickness
  - Connections
  - Material type

Motorcycle FE Mesh

- Average element size was 7.5 mm





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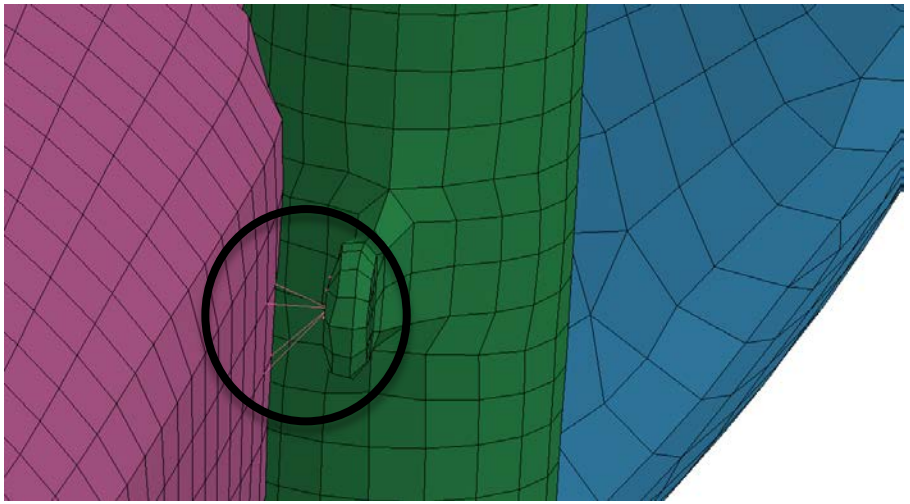
FE Motorcycle Connections

- A majority of the motorcycle connections consisted of simple bolt connections
- CNRBs were used to model this



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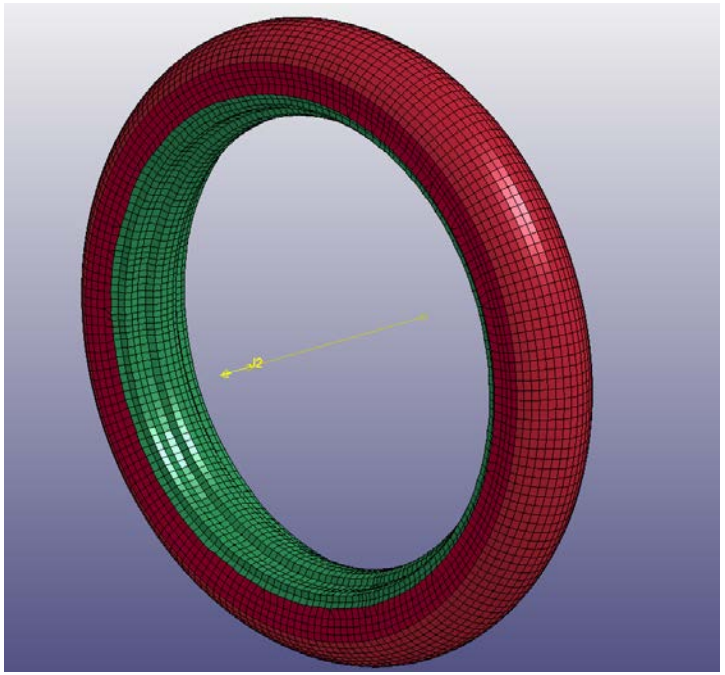
FE Motorcycle Axle Connections

- An axis of rotation was defined for front and rear wheel using Constrained_Joint_Revolute



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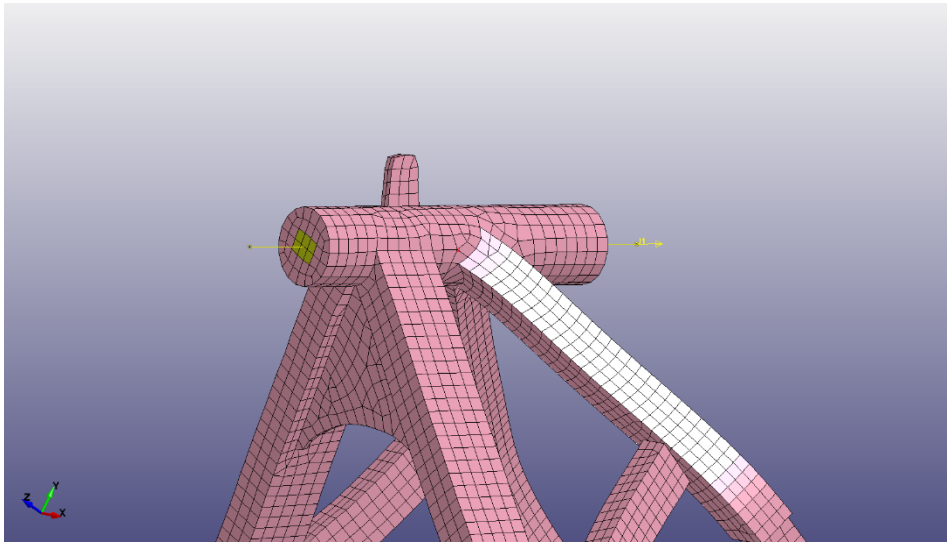
FE Motorcycle Main Frame Connection



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FE Motorcycle Part Contact

- Contact_Automatic_Single_Surface was used in DYNA to define contact between all the different parts

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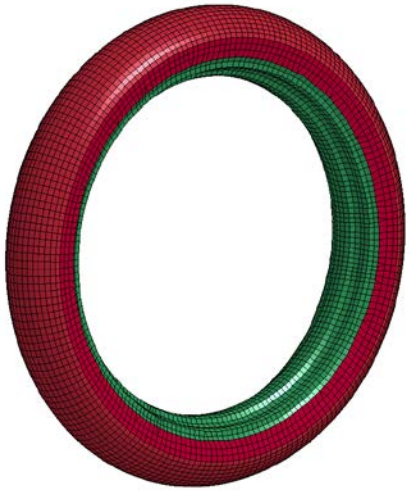
FE Motorcycle Tire Model

- For Kawasaki Ninja 500R specified tire pressure is 0.28 MPa (41 psi)
- Airbag_Simple_Pressure_Volume was used to model pressure input for specified volume



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FE Motorcycle Section and Material Properties

- Default Belytschko-Tsay element formulation used
- Thickness defined based on measurements taken during disassembly of motorcycle
- Material properties were not based on testing. General parameters were used for material type

	E (MPa)	ν	Sigy (MPa)	Etan (MPa)
Steel	20,000	0.3	-	-
Plastic	10,000	0.3	20	10
Rubber	300	0.3	-	-

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FE Motorcycle Summary

Number of Parts	102
Number of Nodes	193,170
Number of Elements	194,120
Nodal Rigid Body Connections	174
Joint Connections	3

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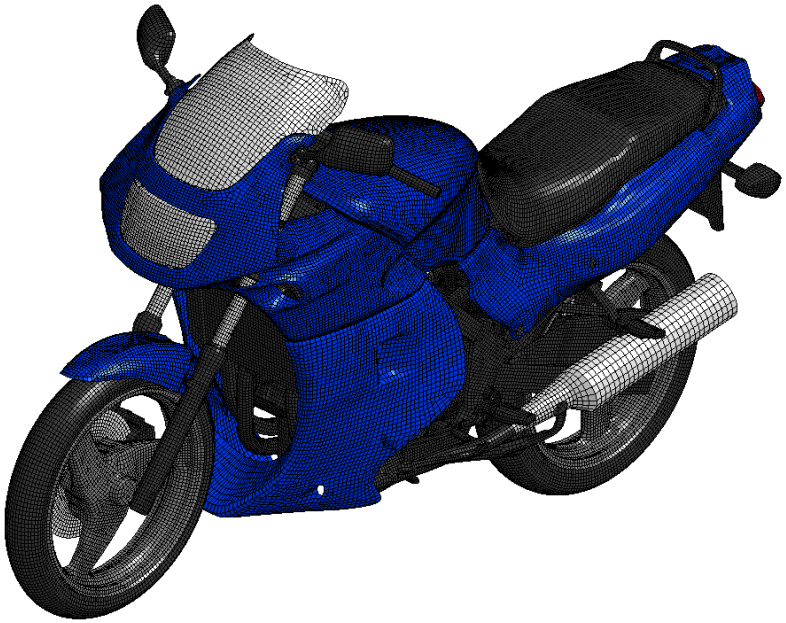
FE Motorcycle Summary



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FE Motorcycle Summary

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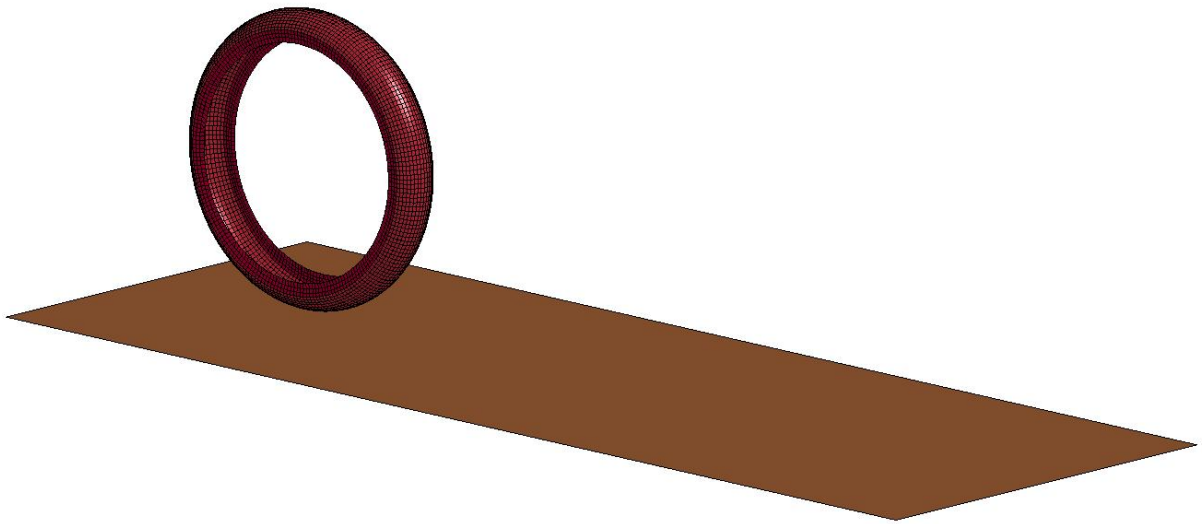

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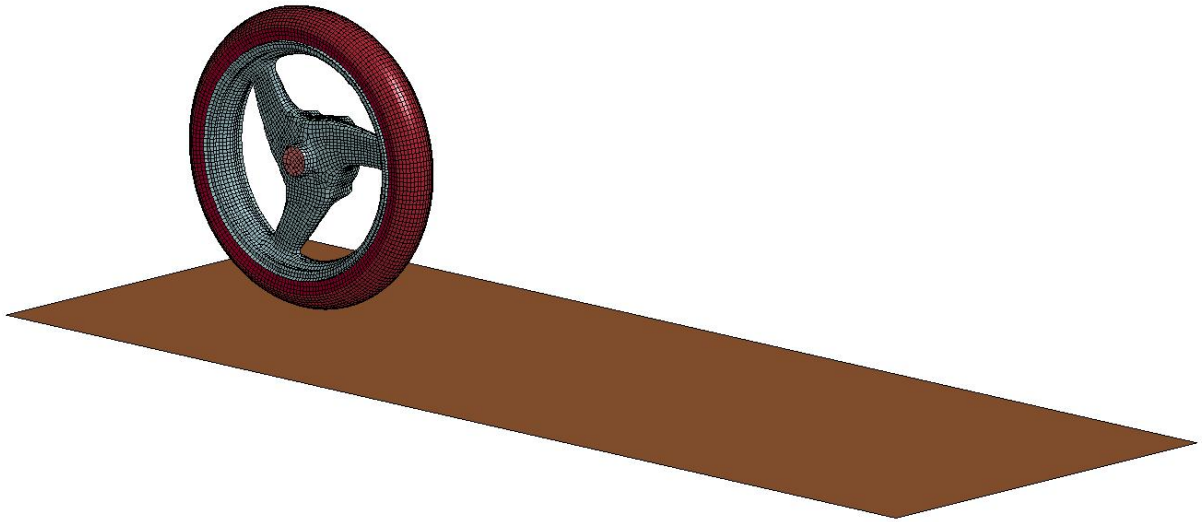

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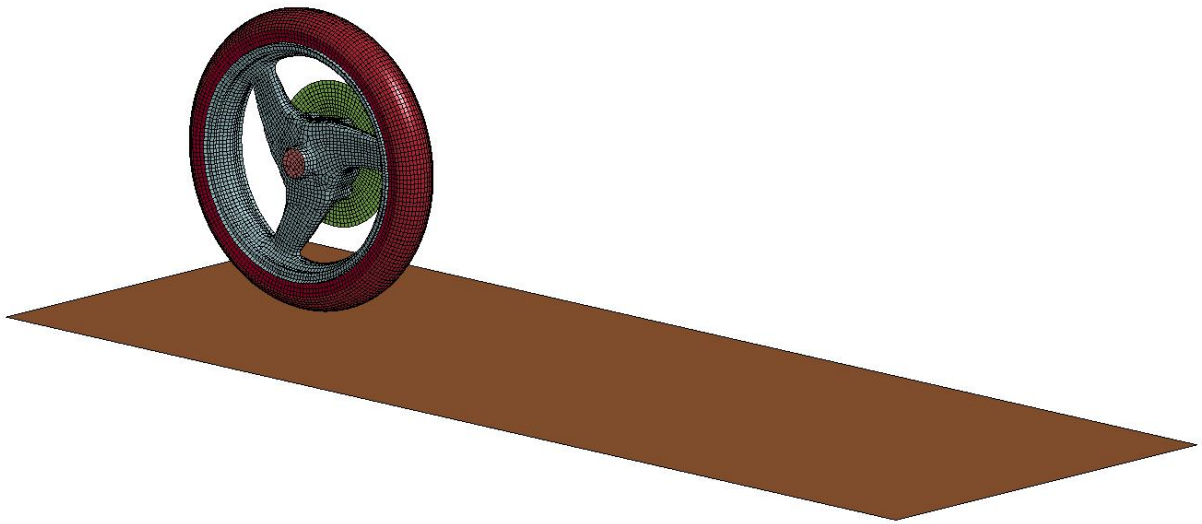

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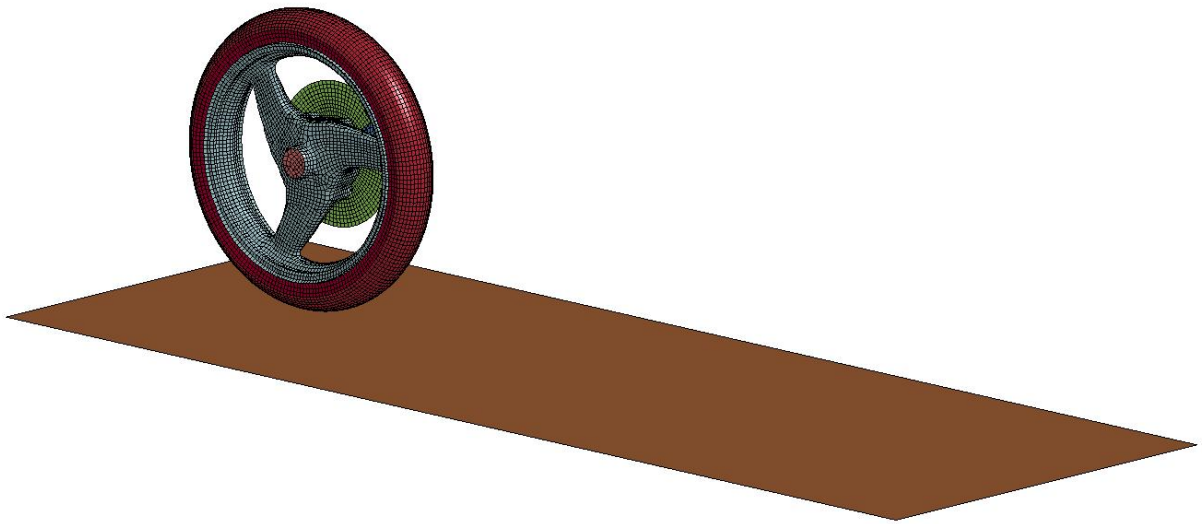

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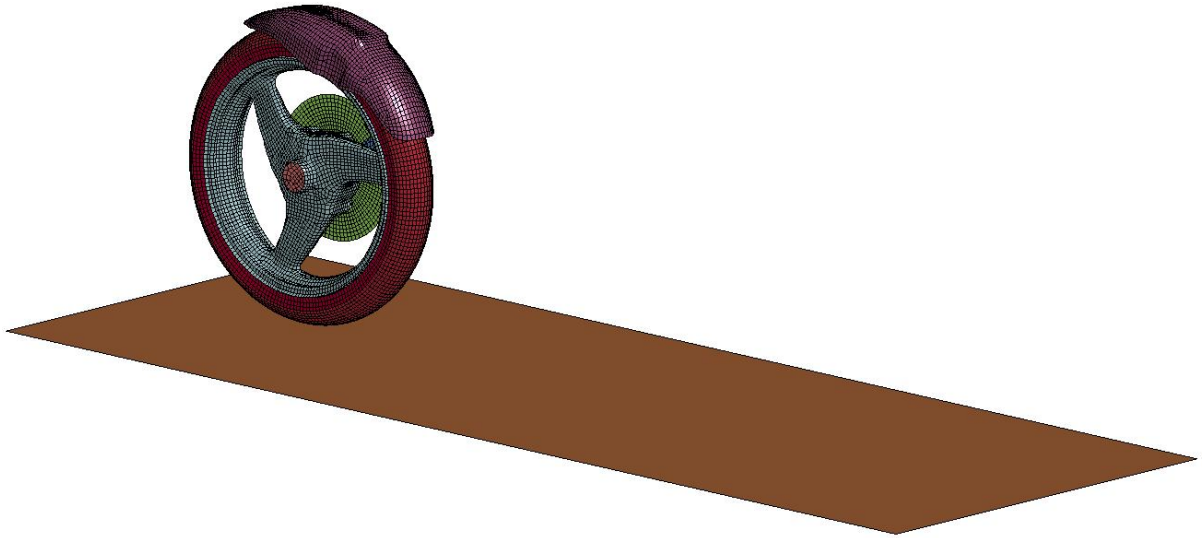

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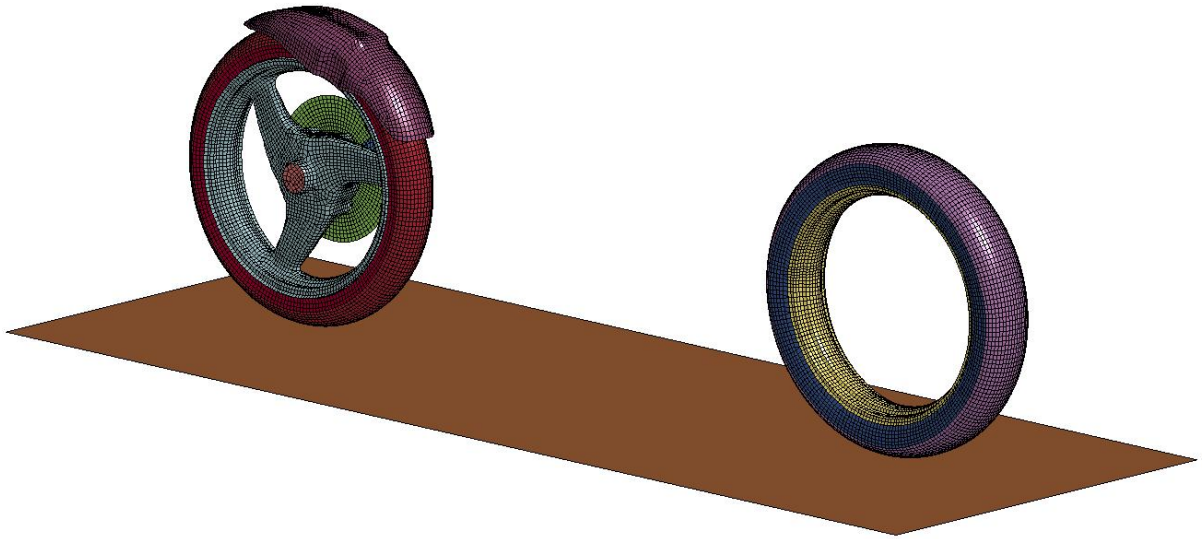

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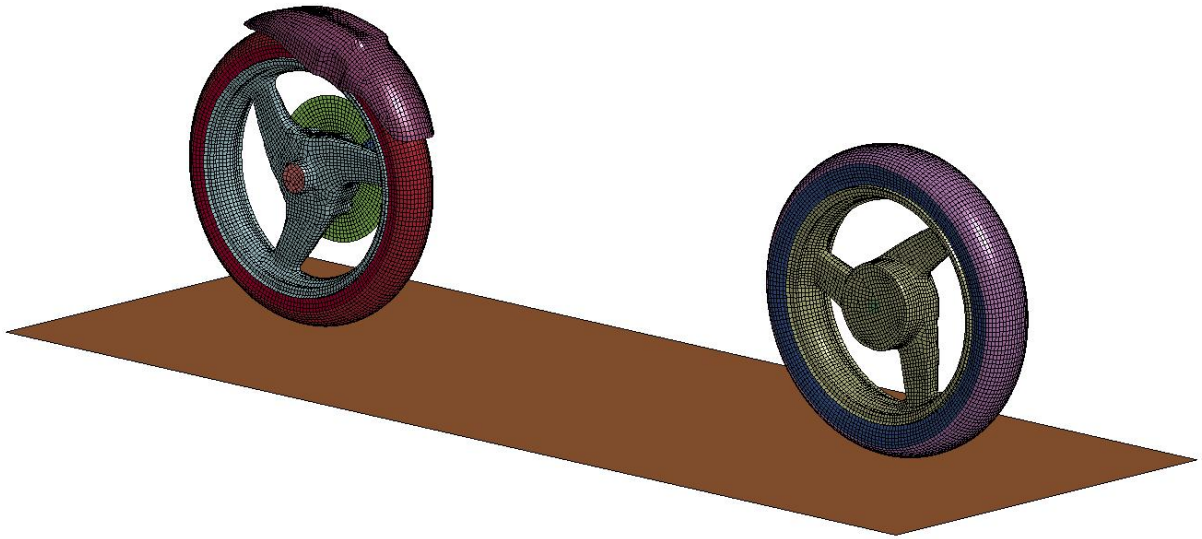

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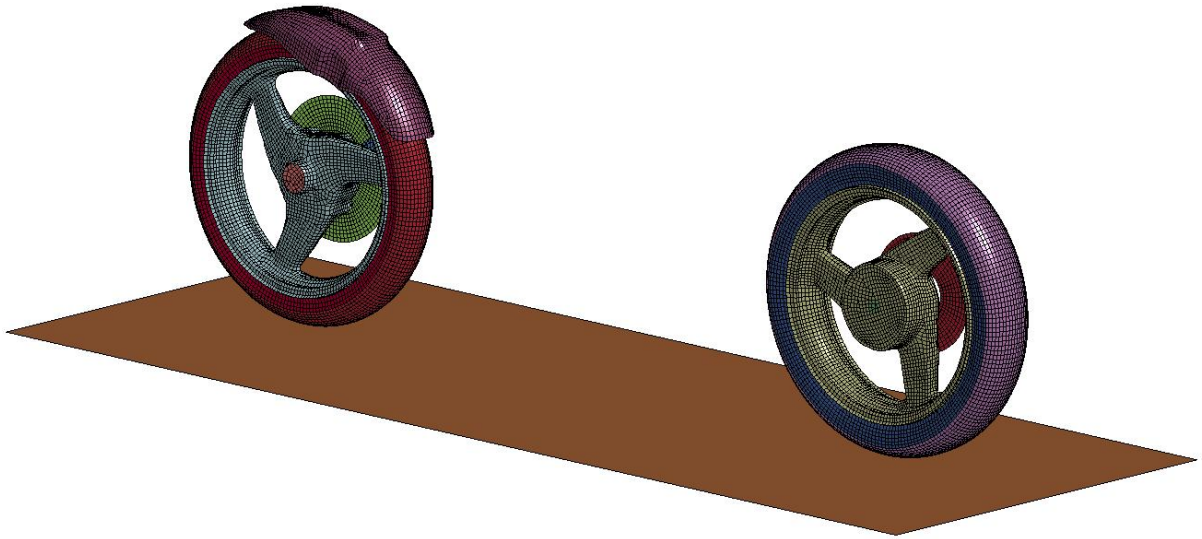

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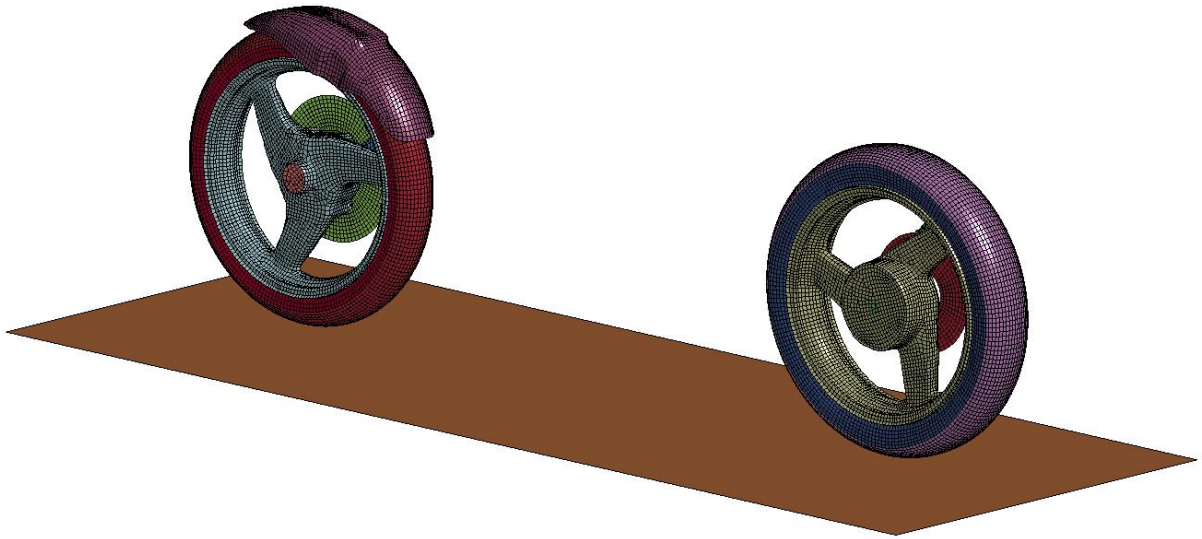

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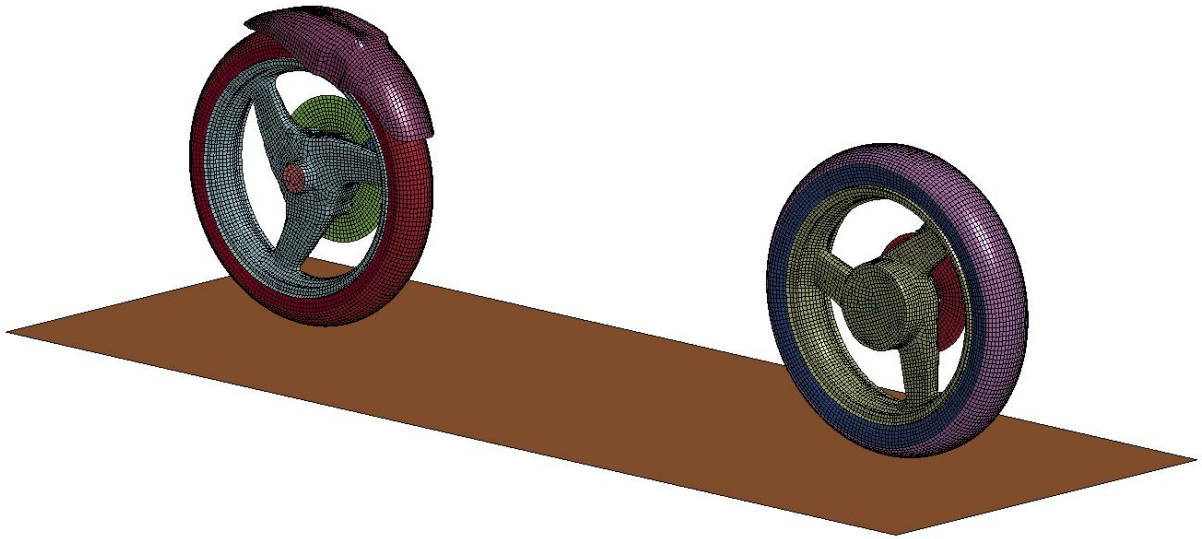

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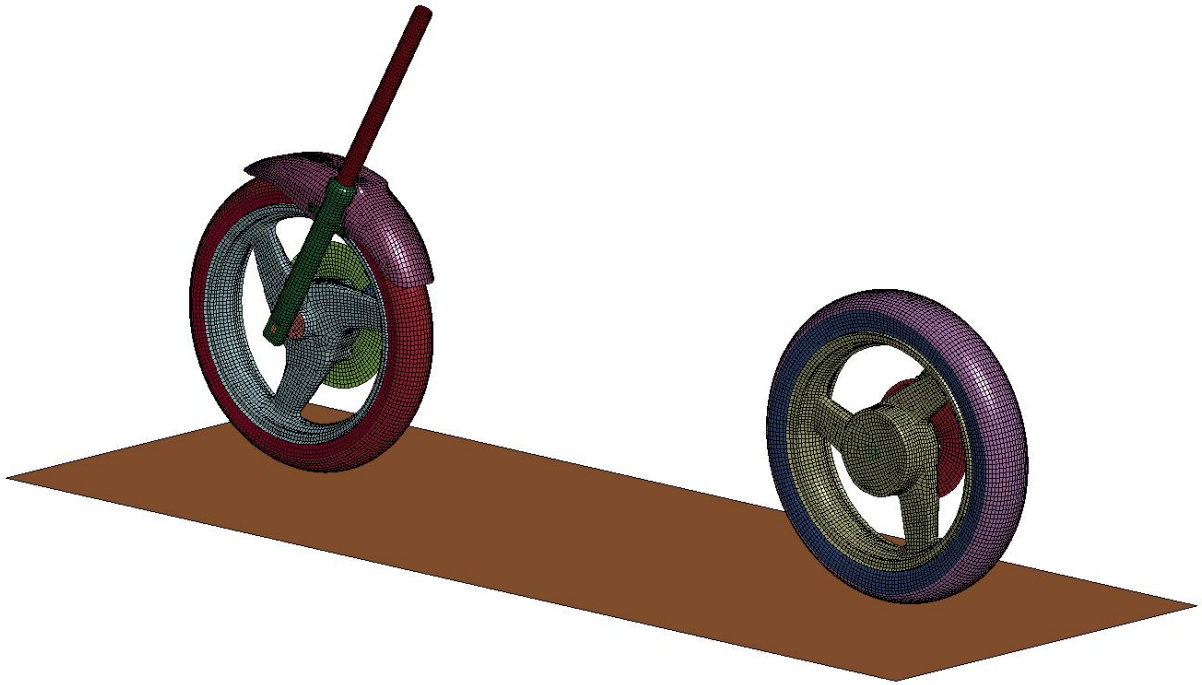

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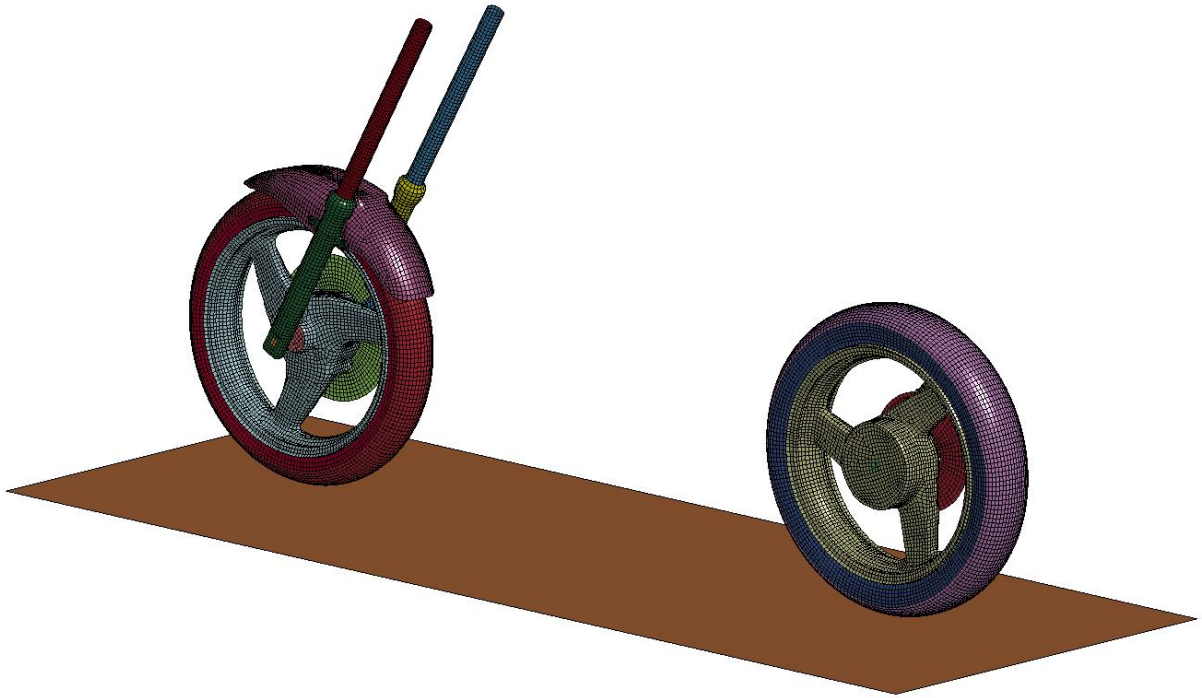

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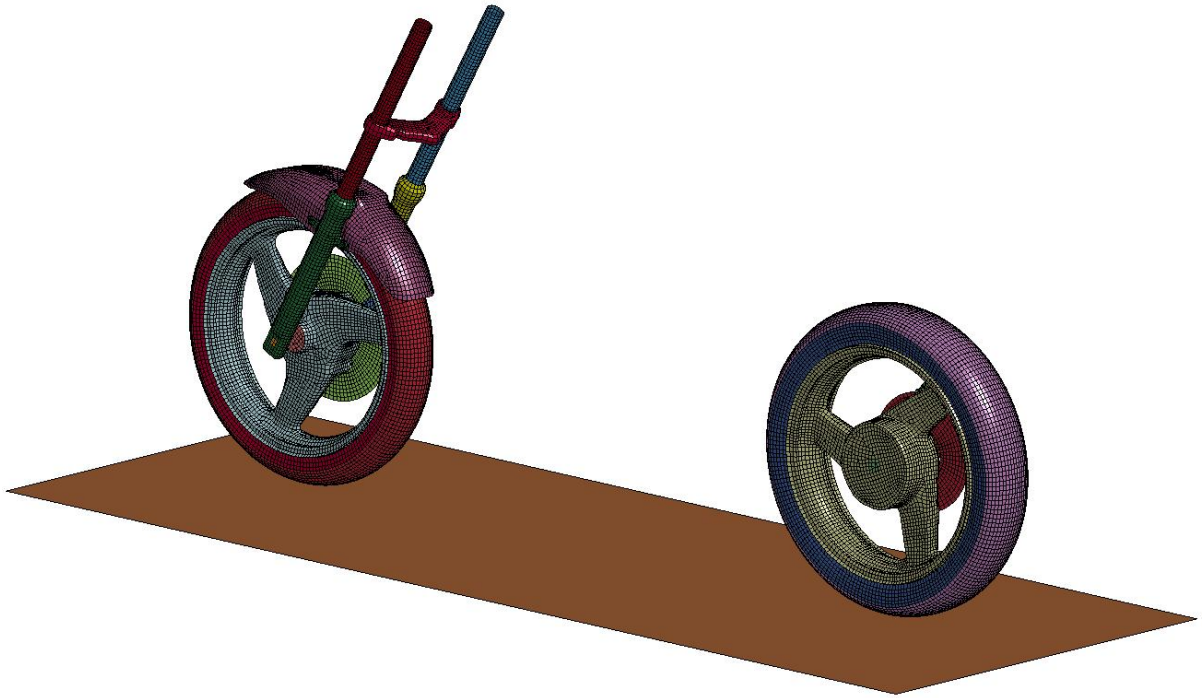

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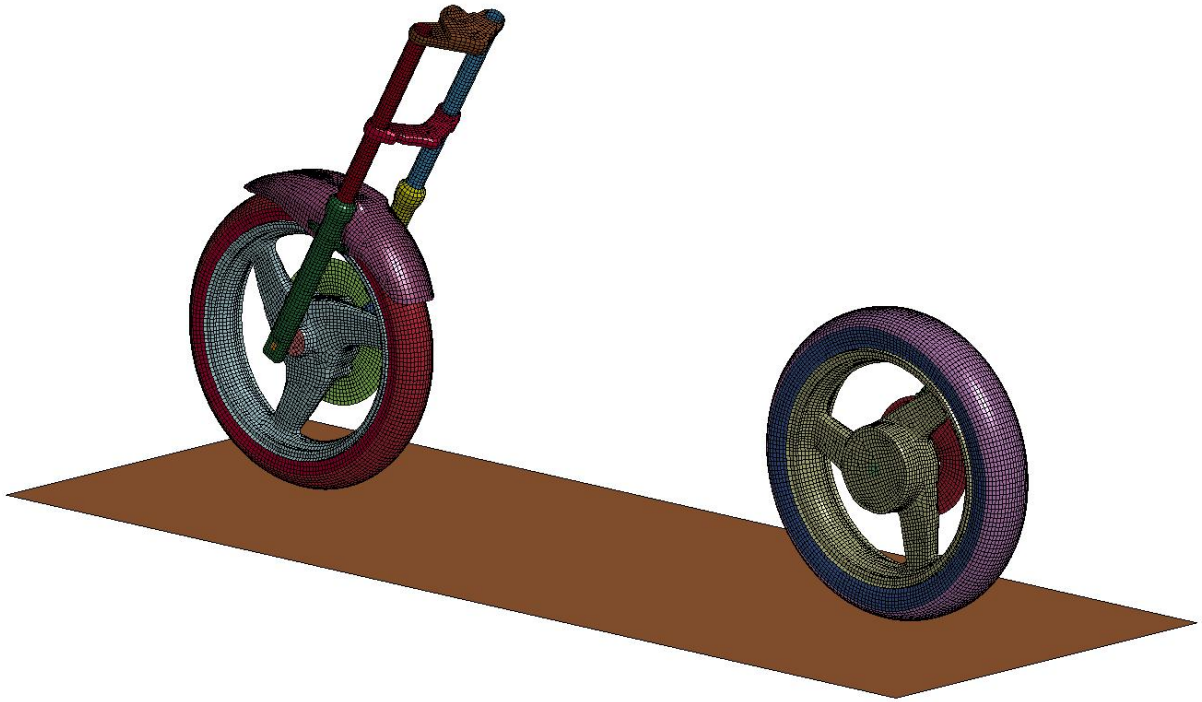

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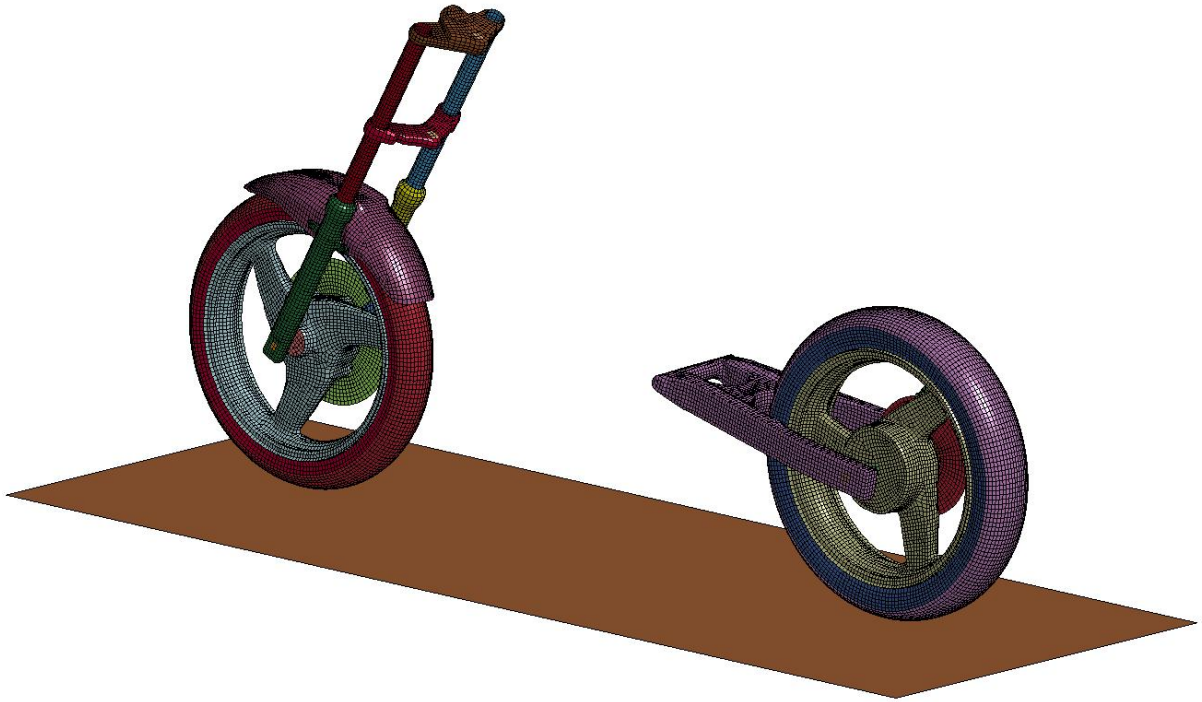

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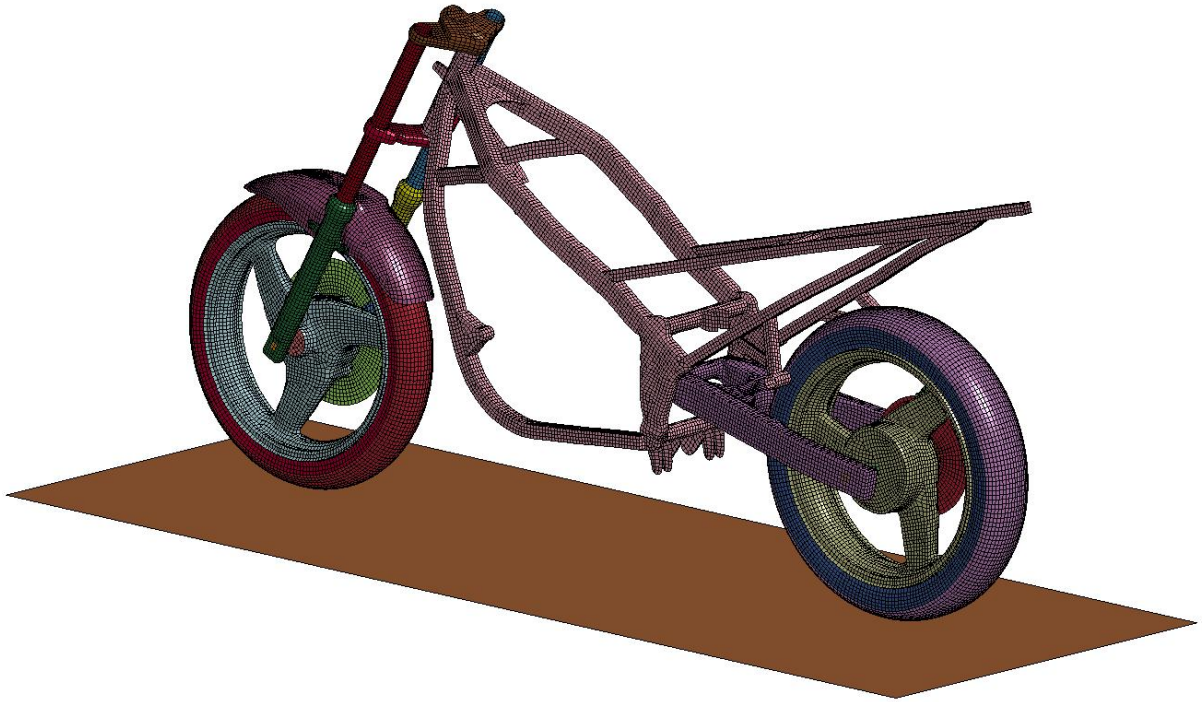

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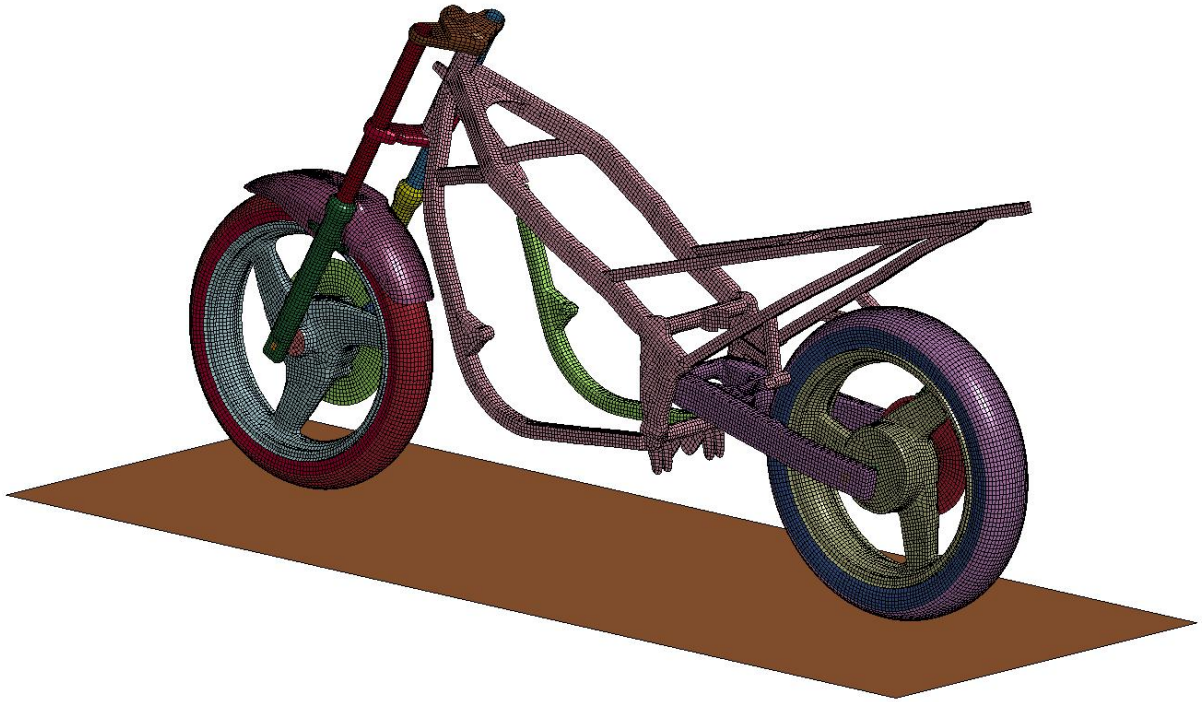

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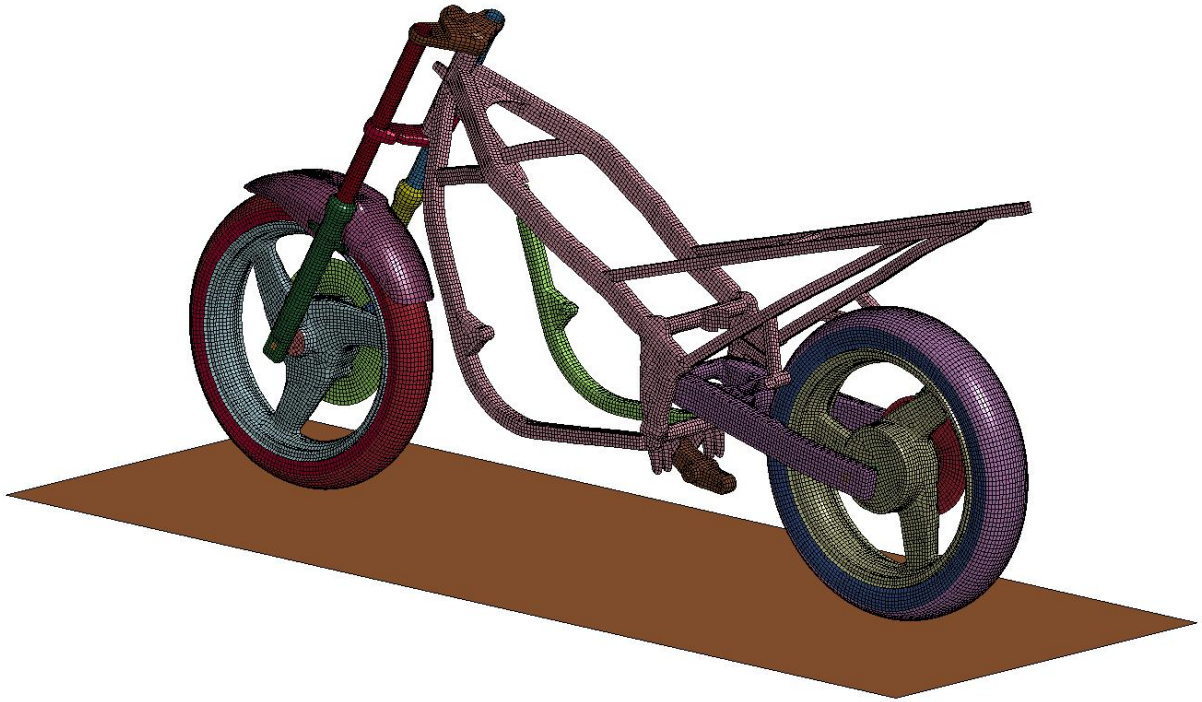

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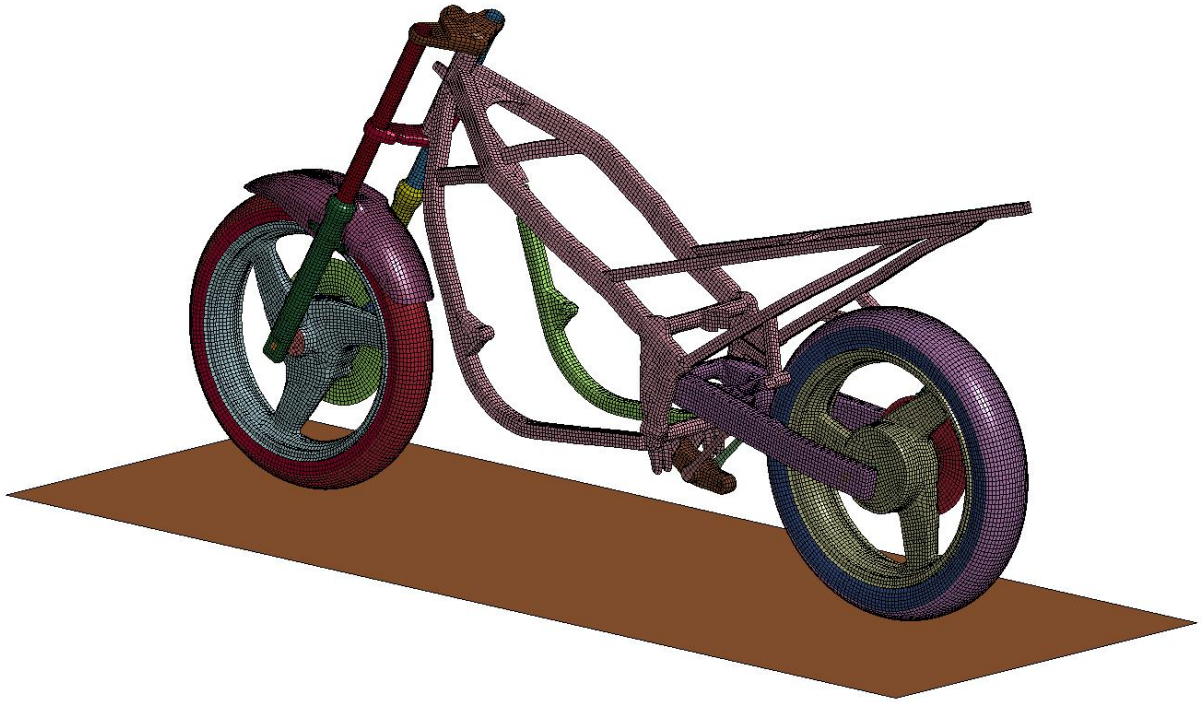

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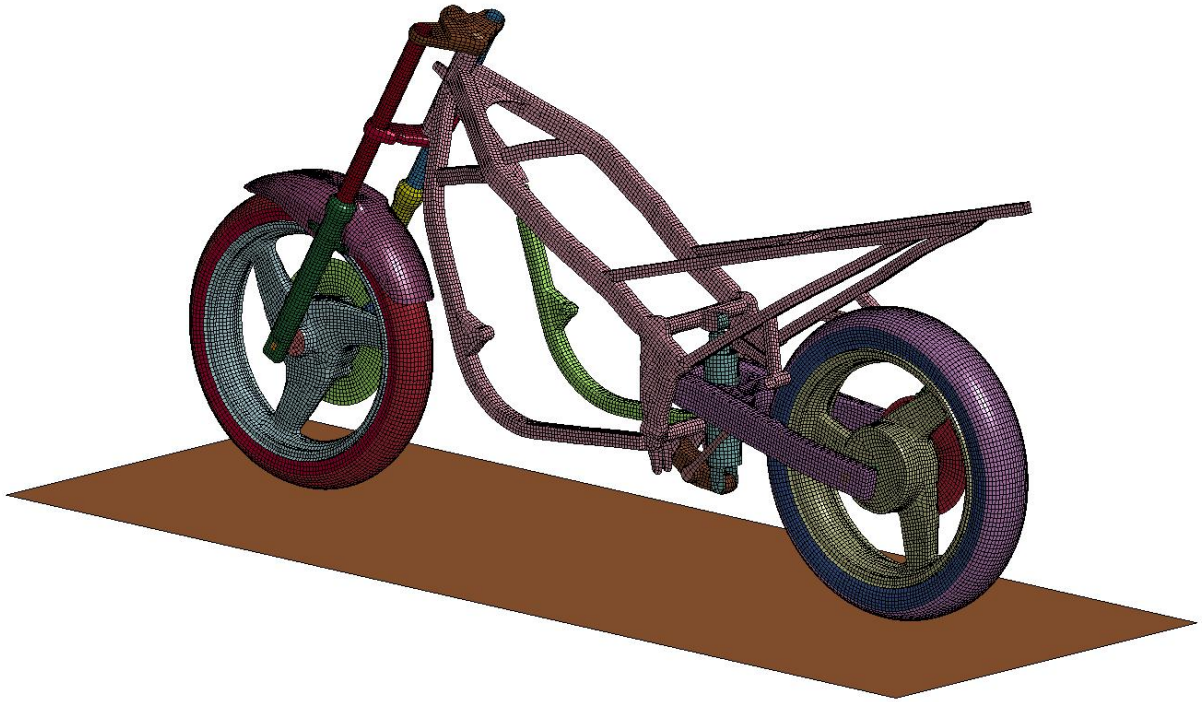

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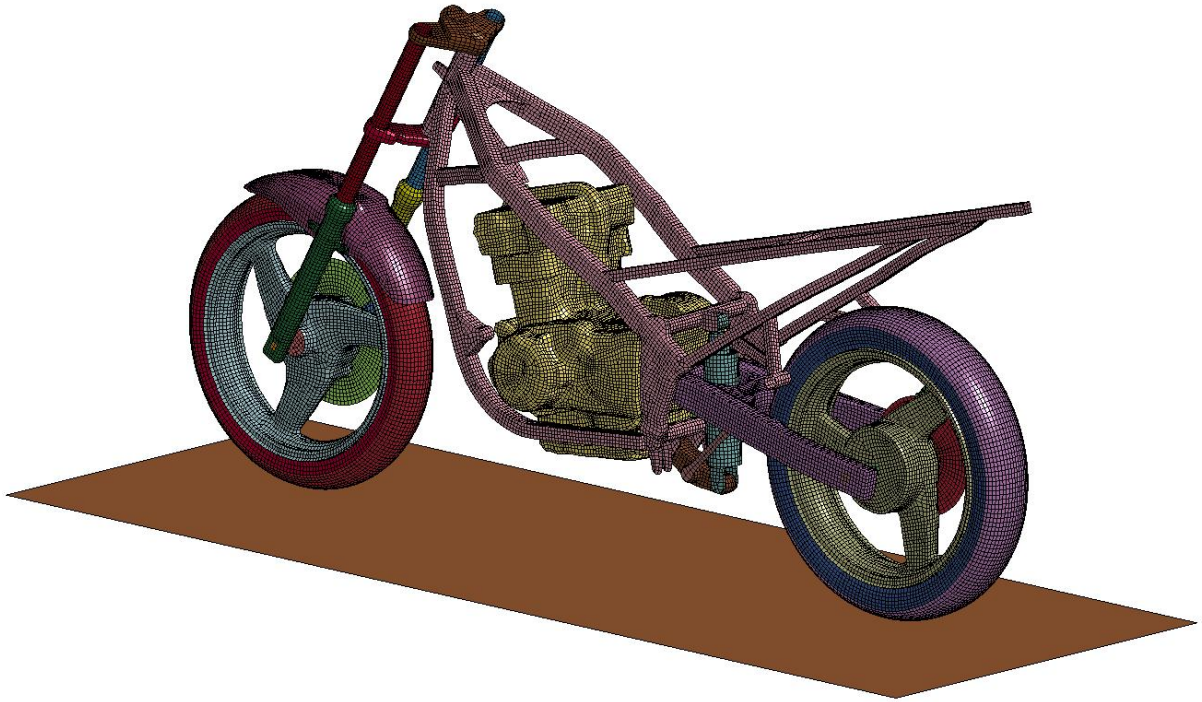

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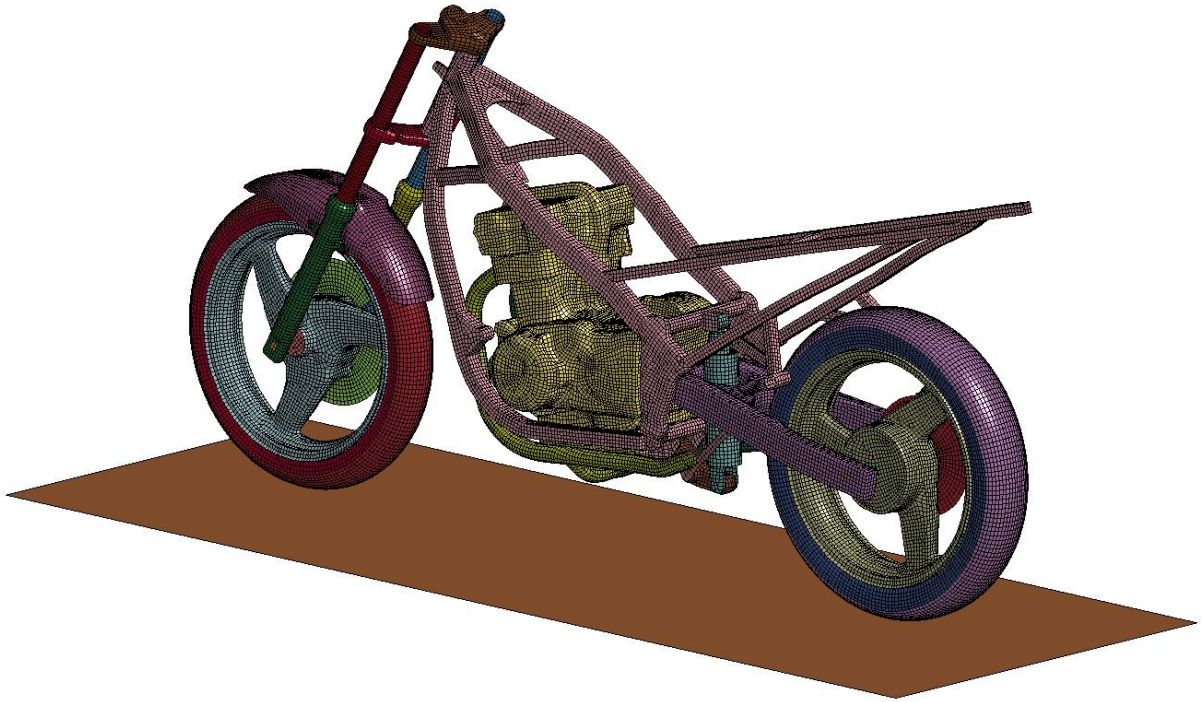

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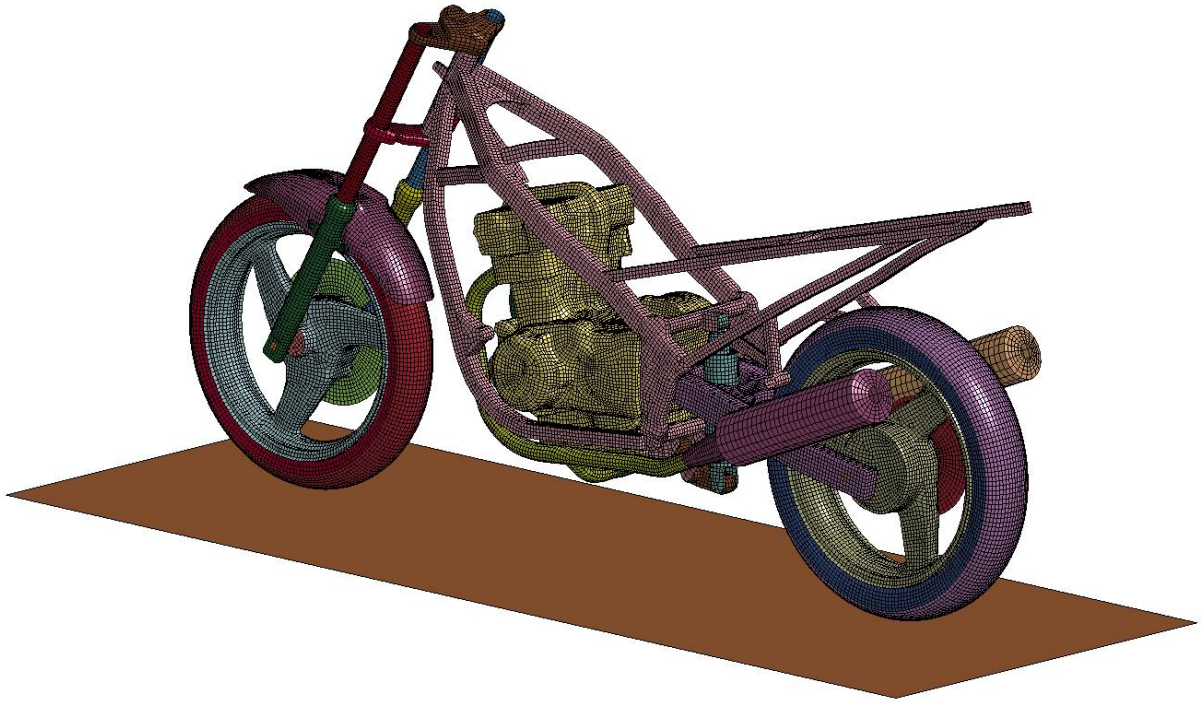

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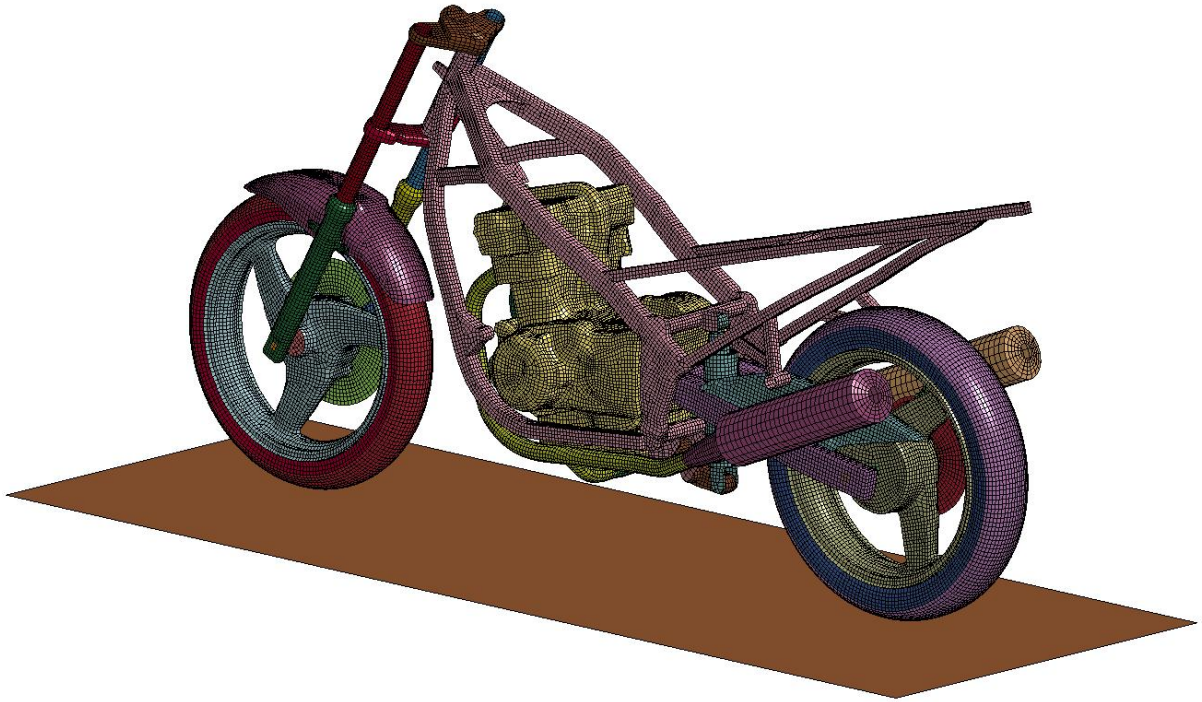

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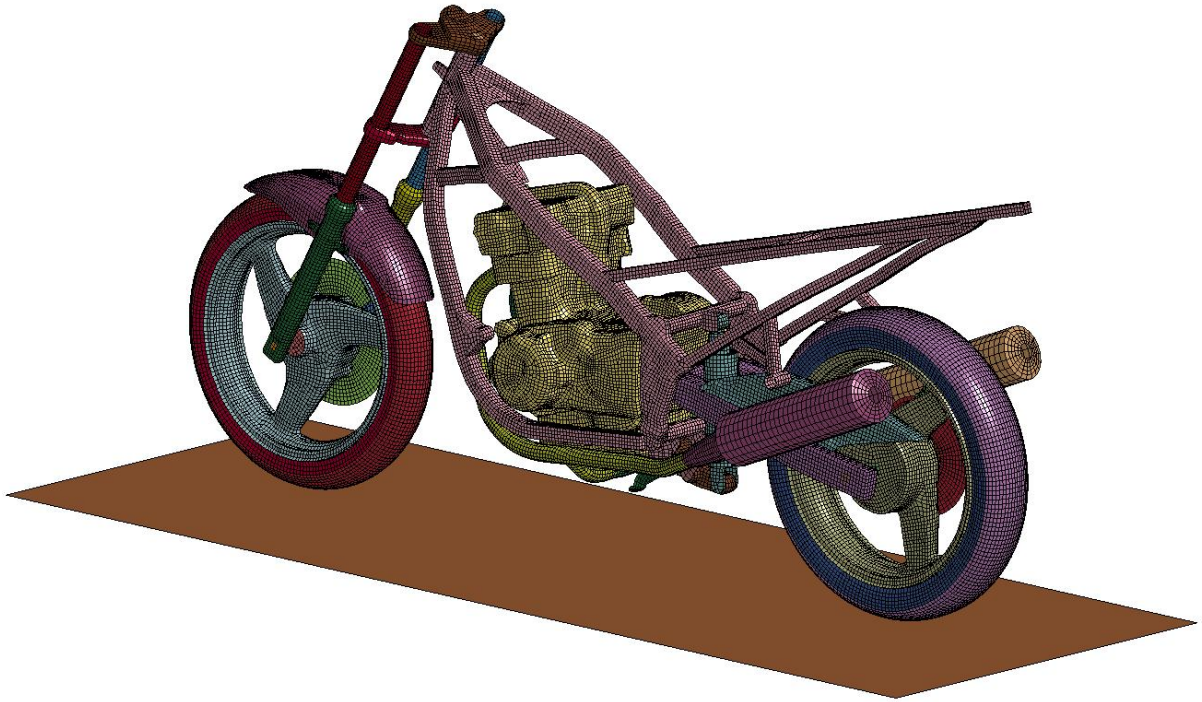

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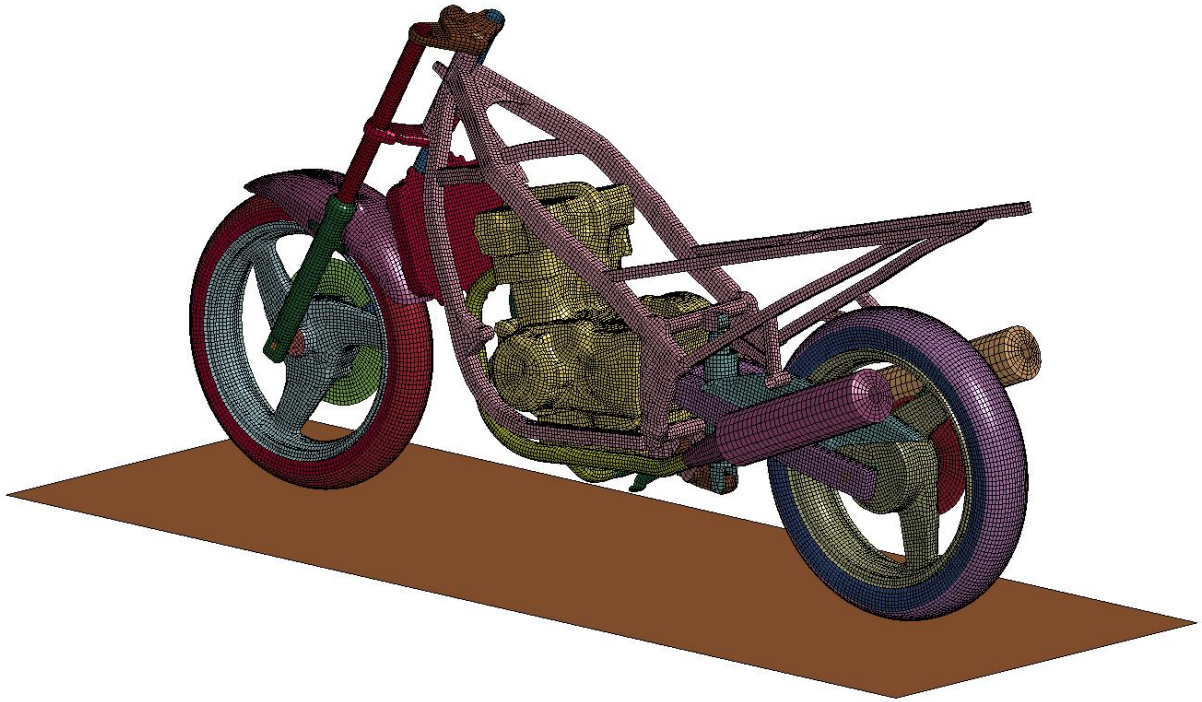

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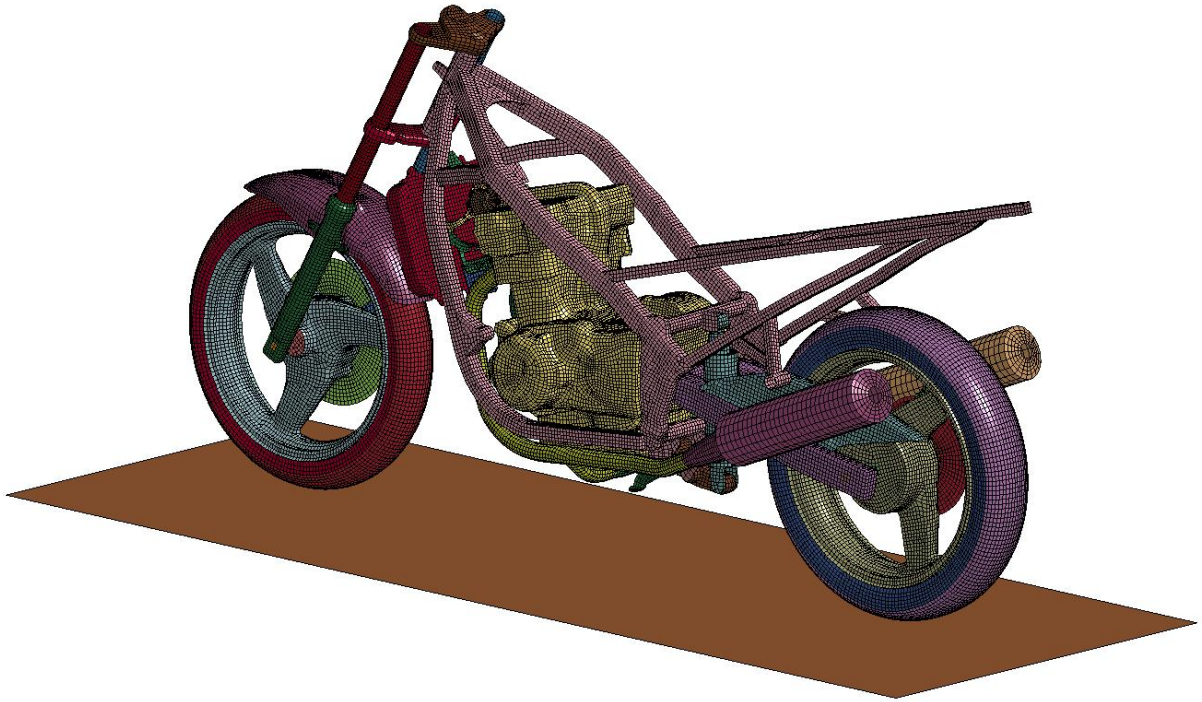

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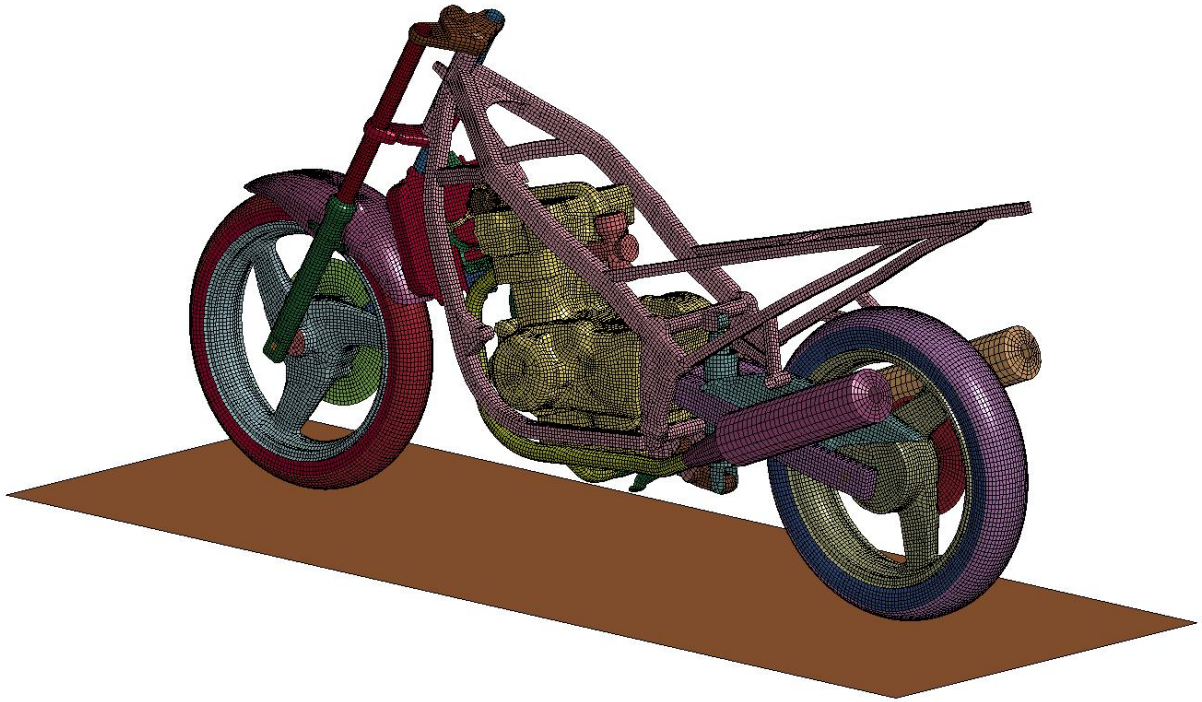

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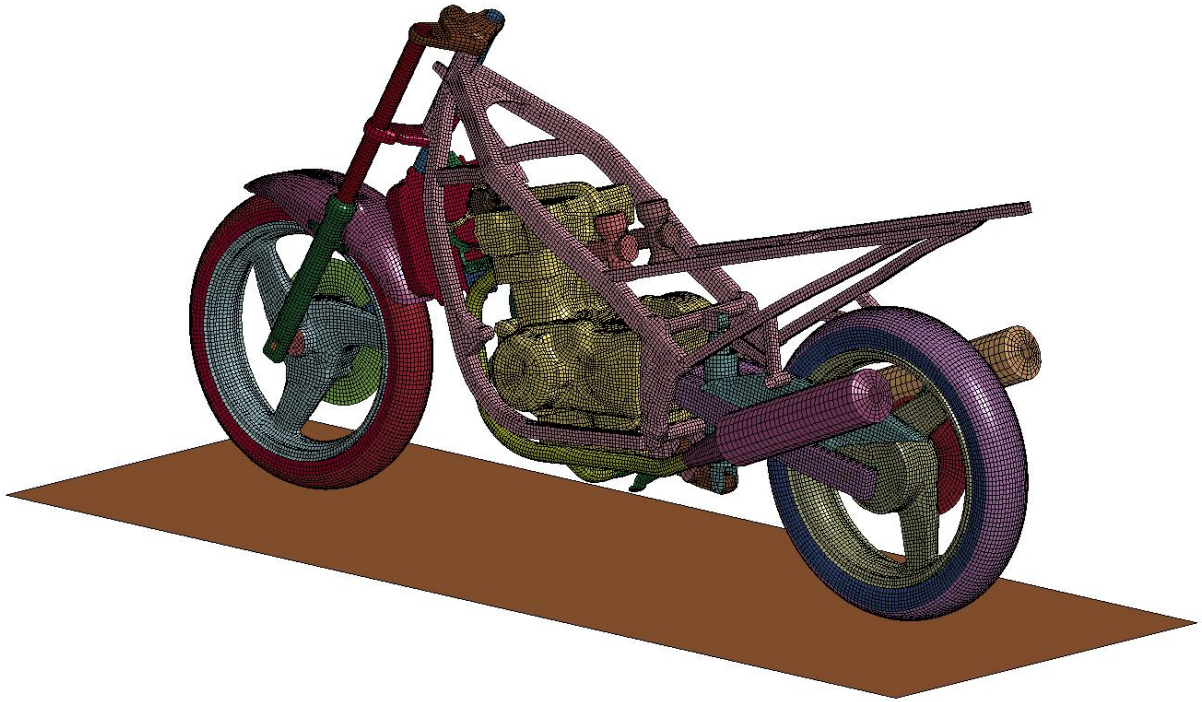

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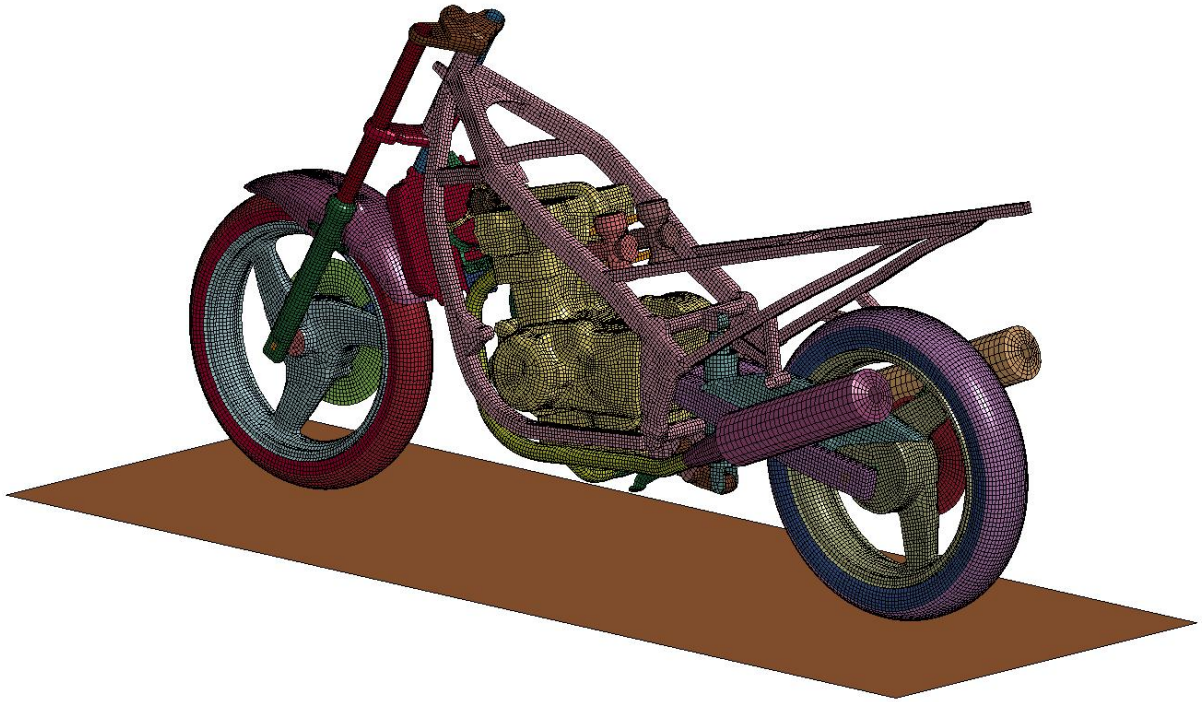

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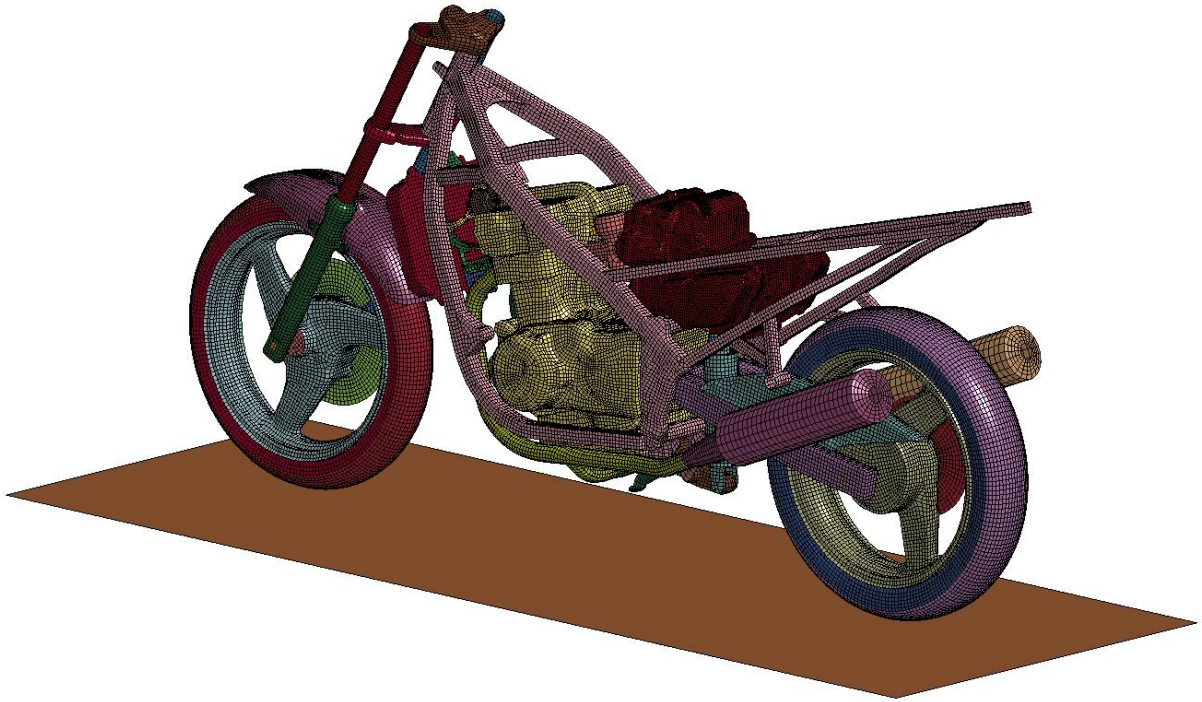

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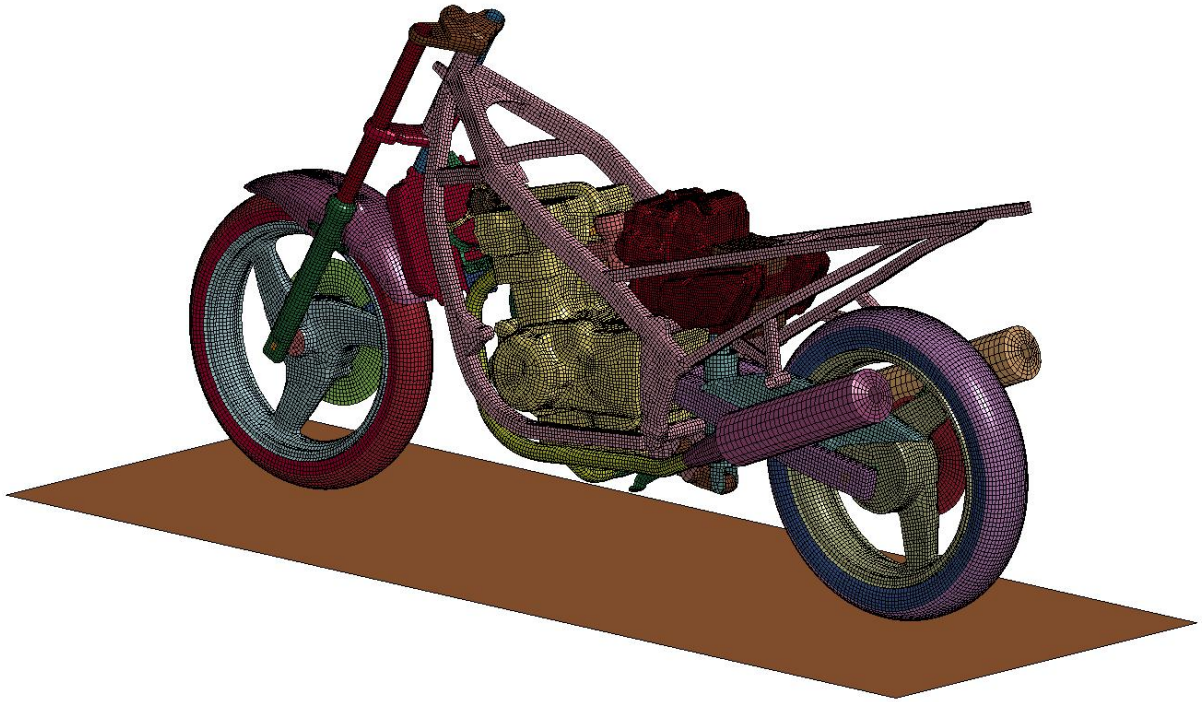

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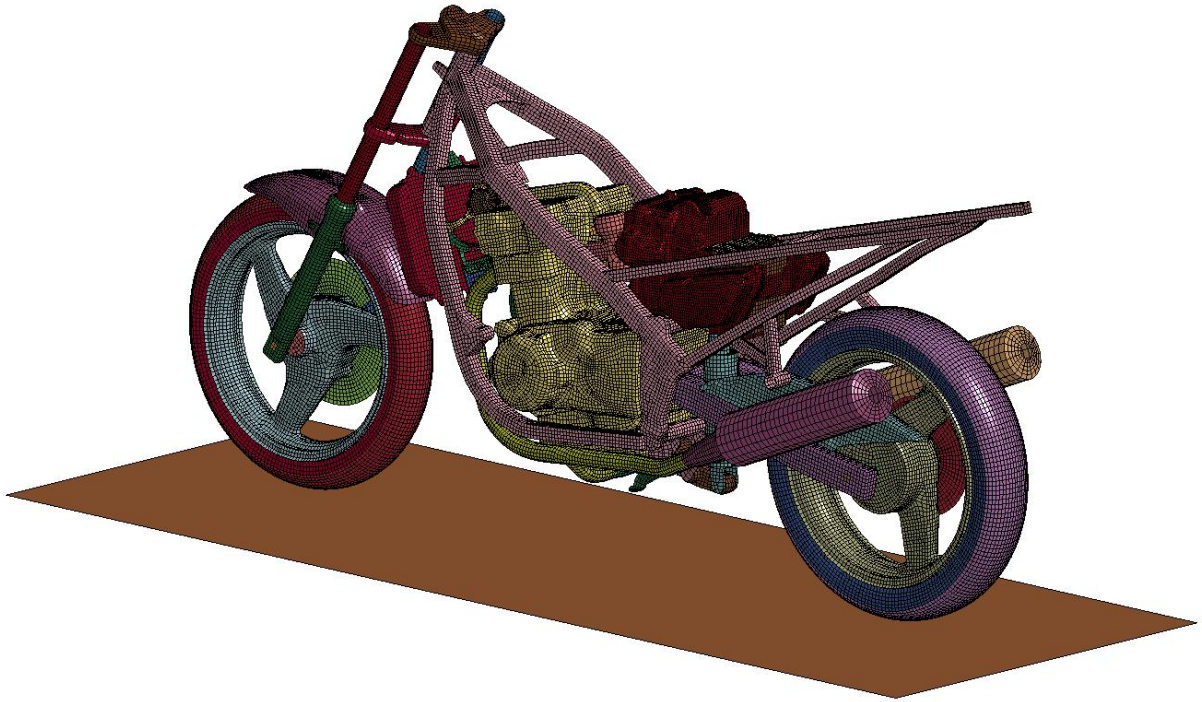

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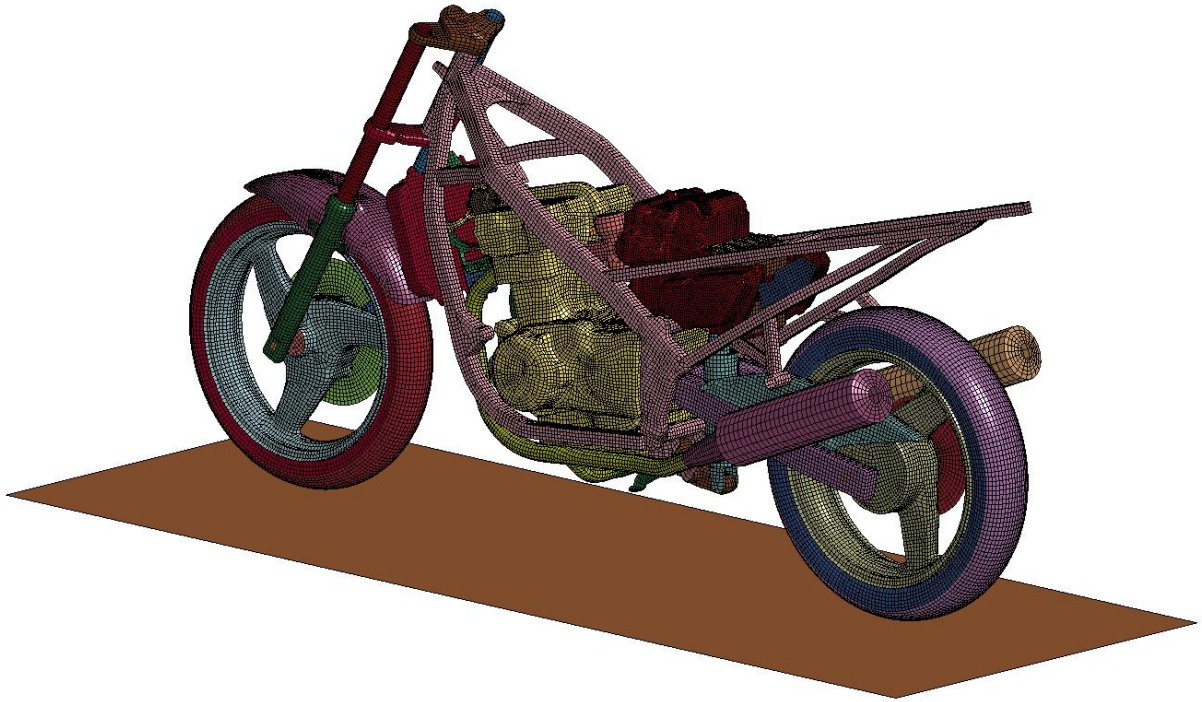

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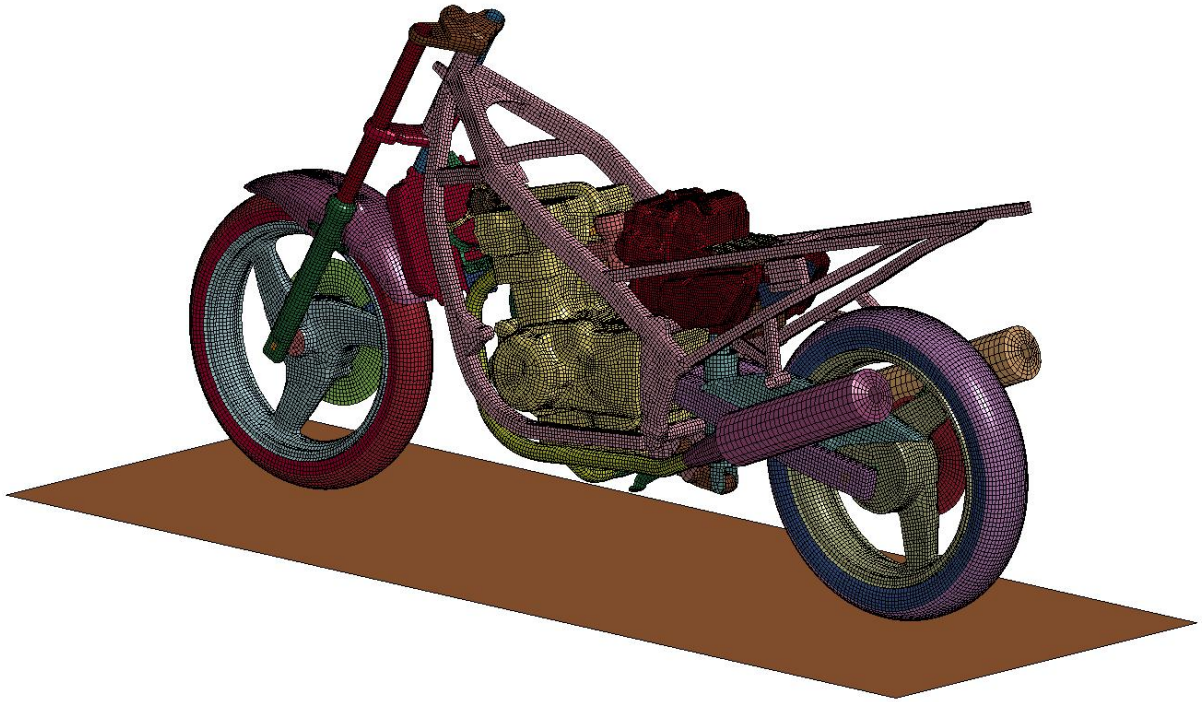

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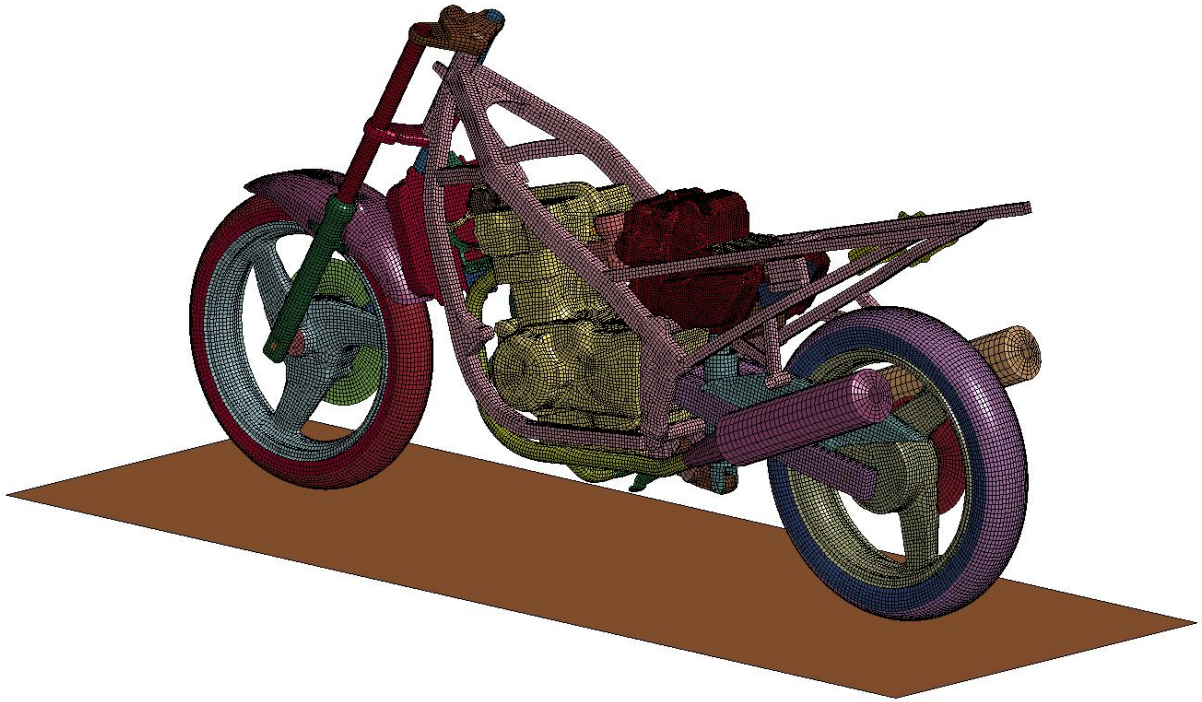

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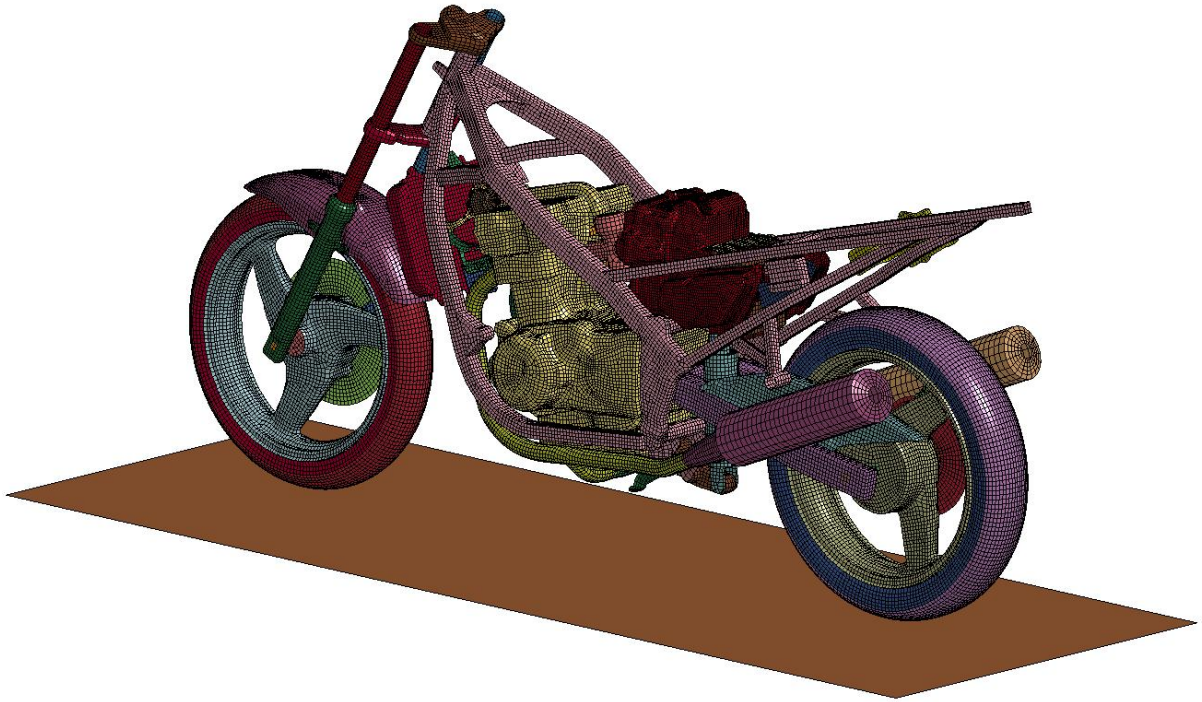

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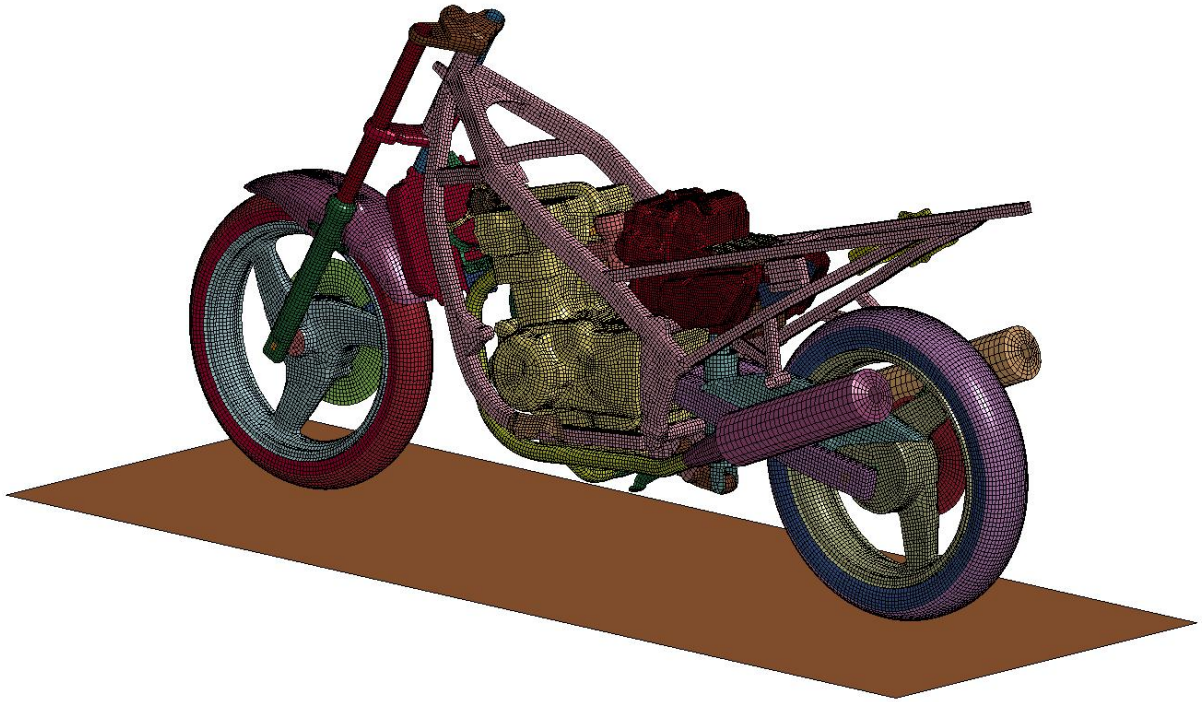

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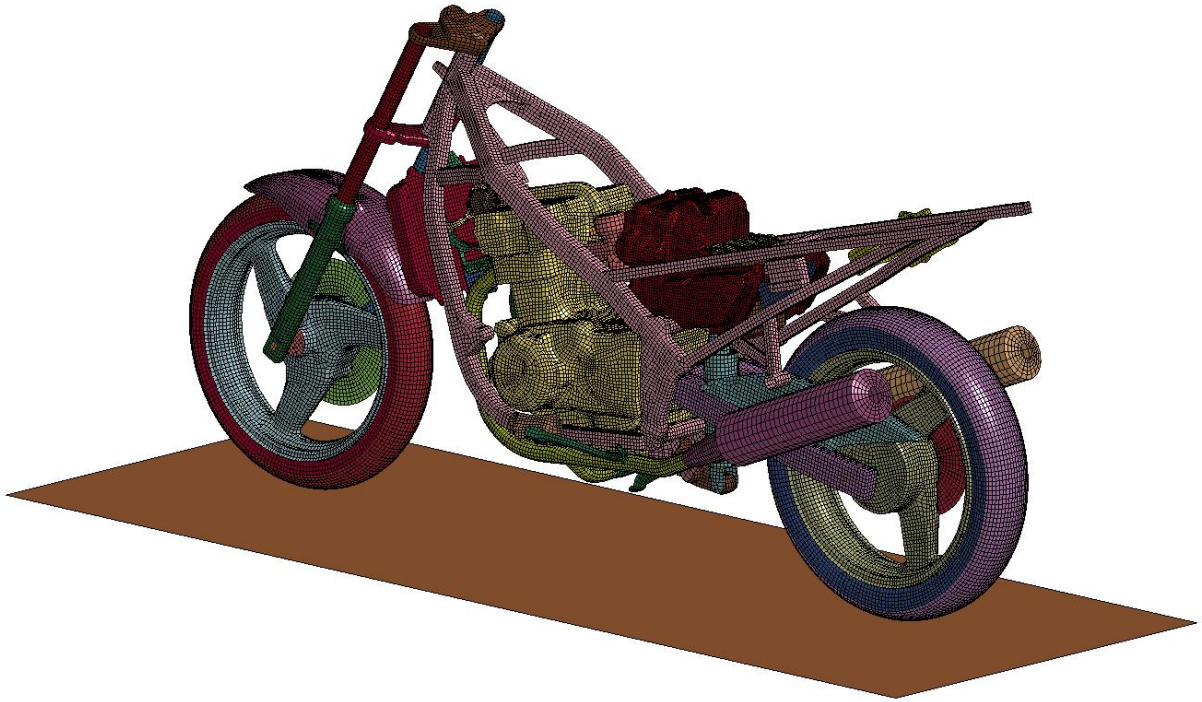

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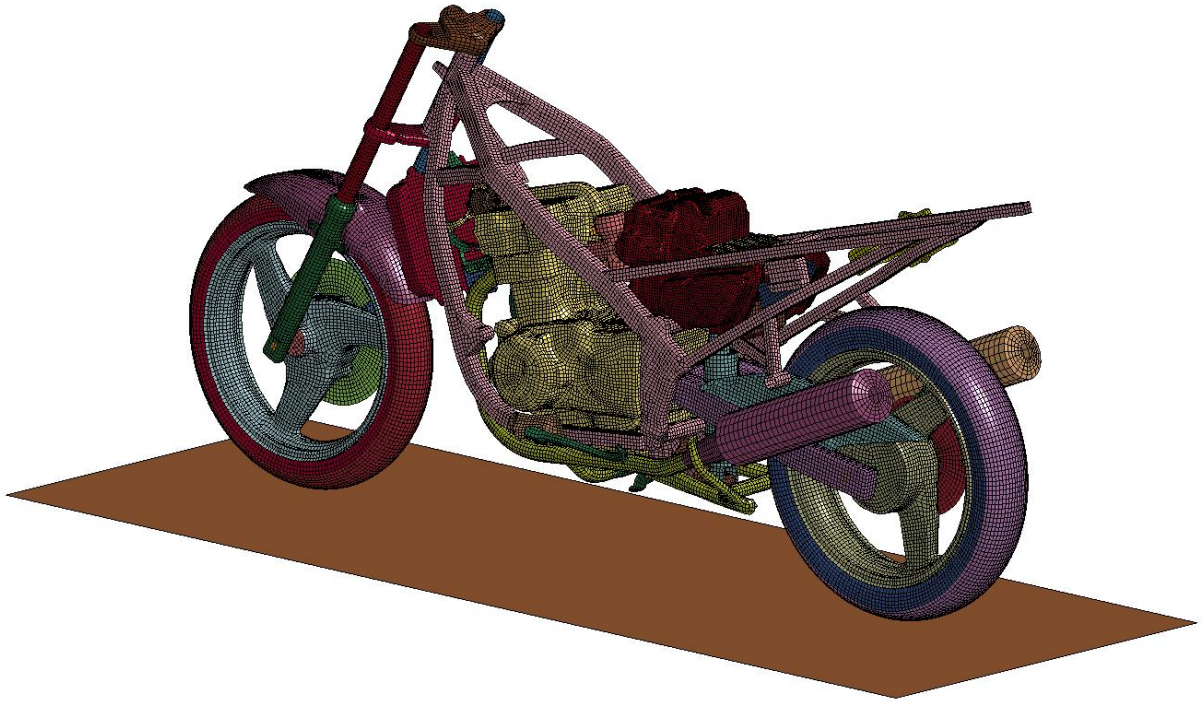

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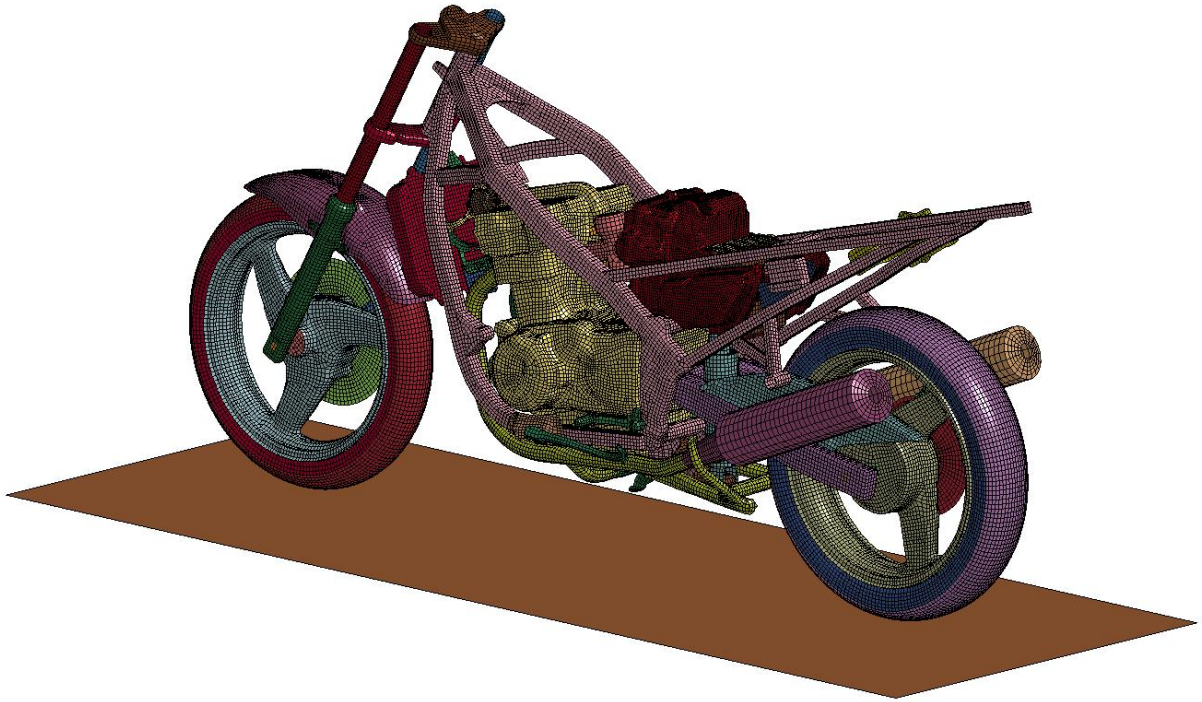

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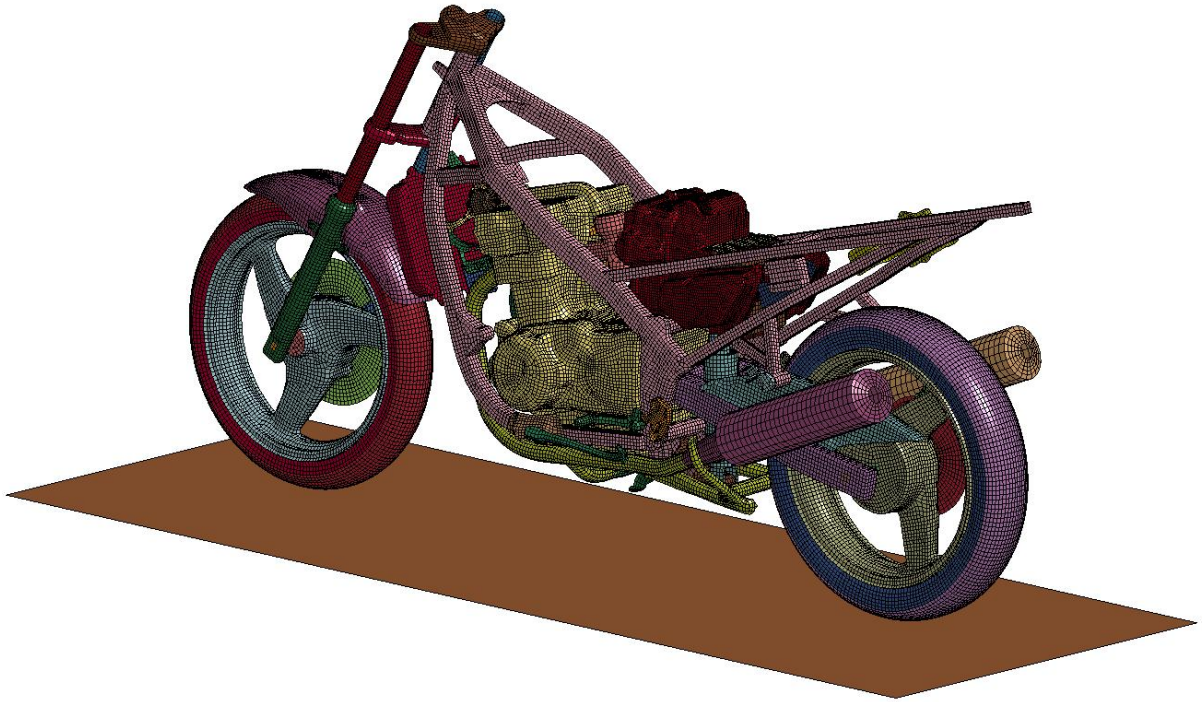

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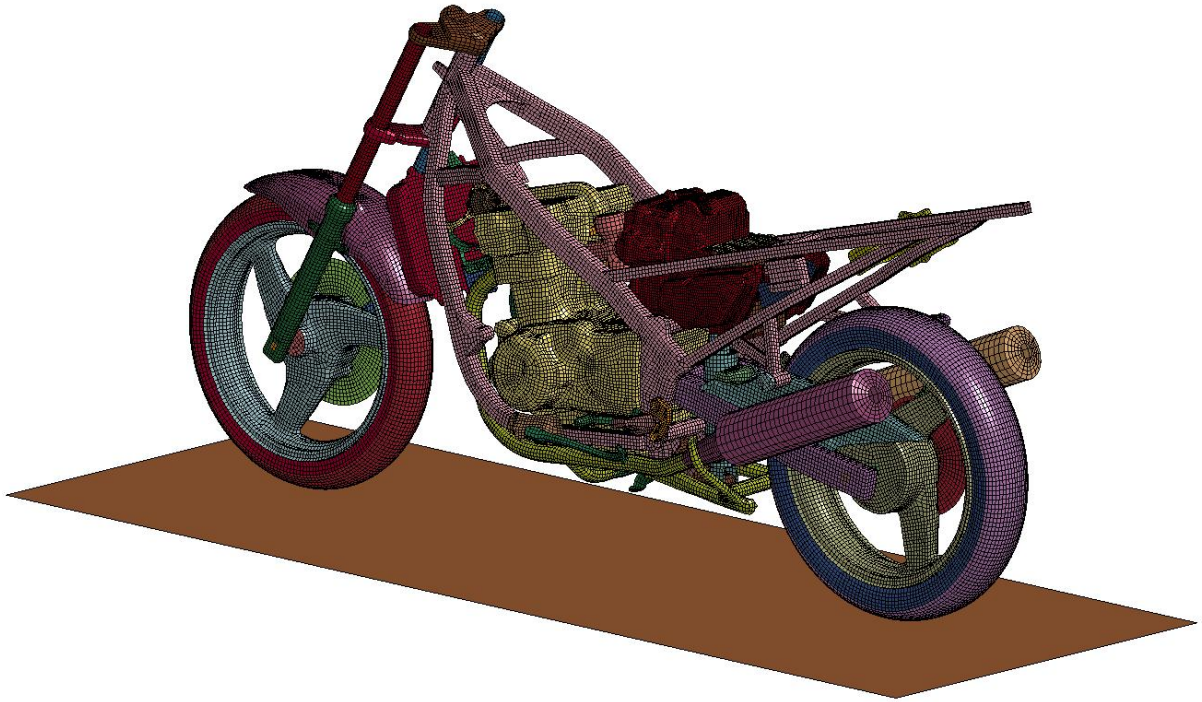

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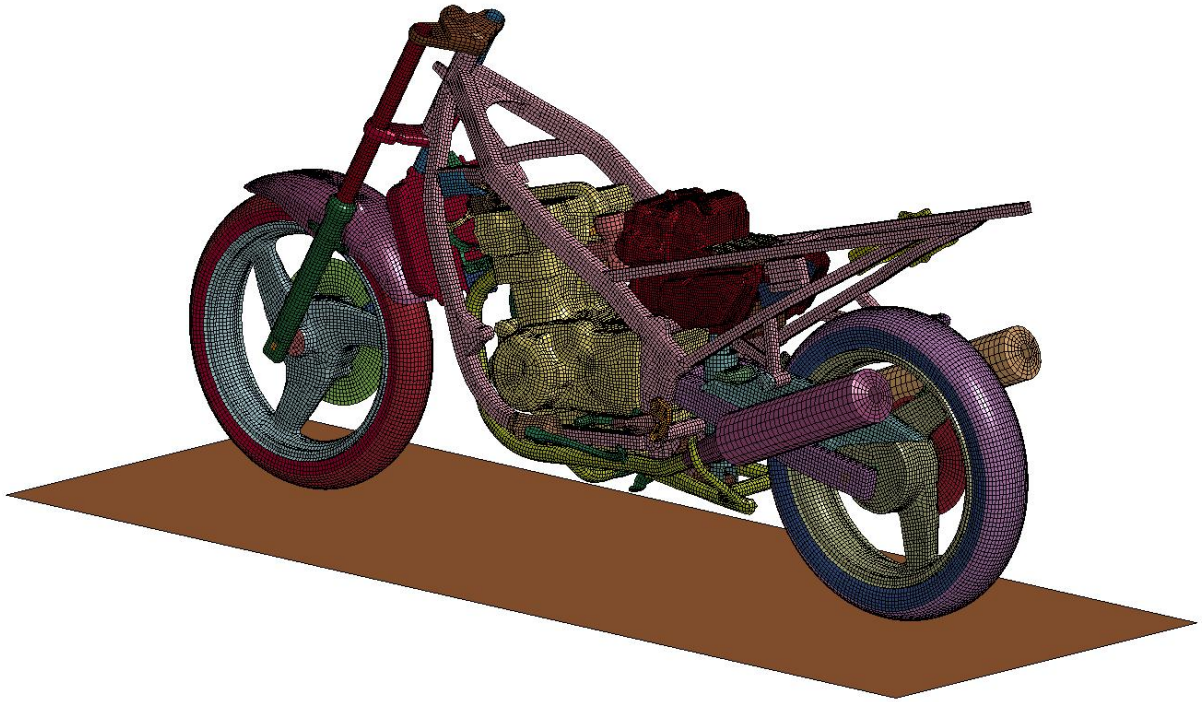

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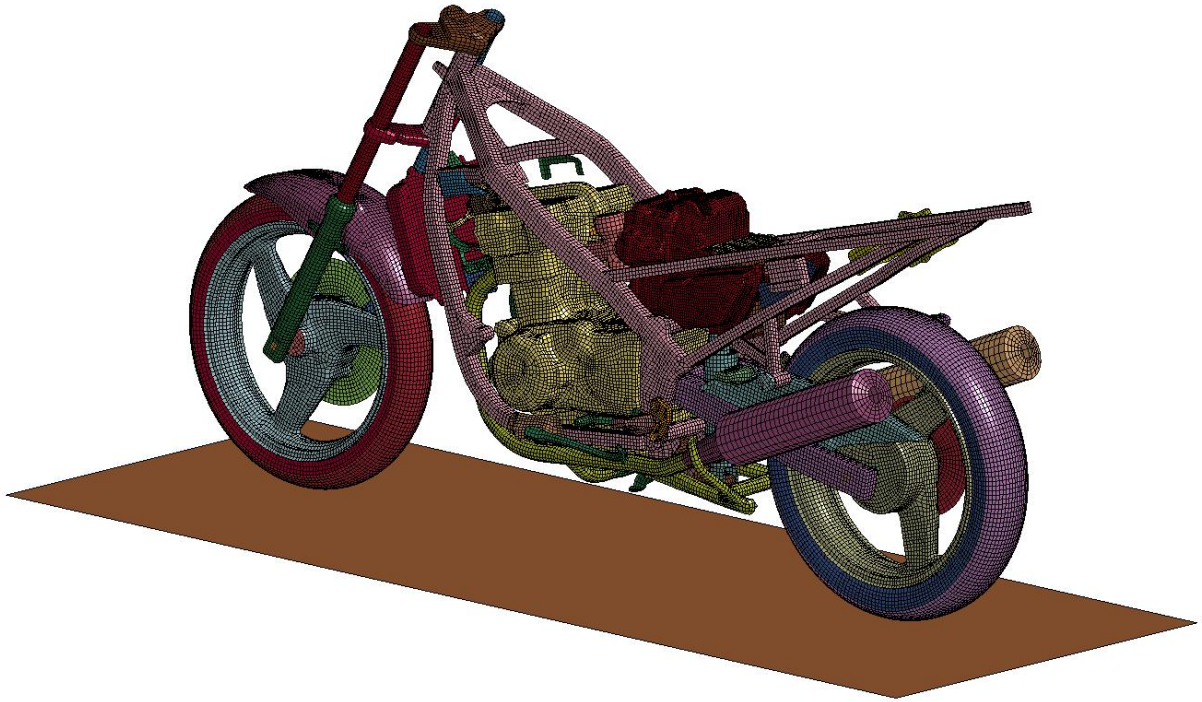

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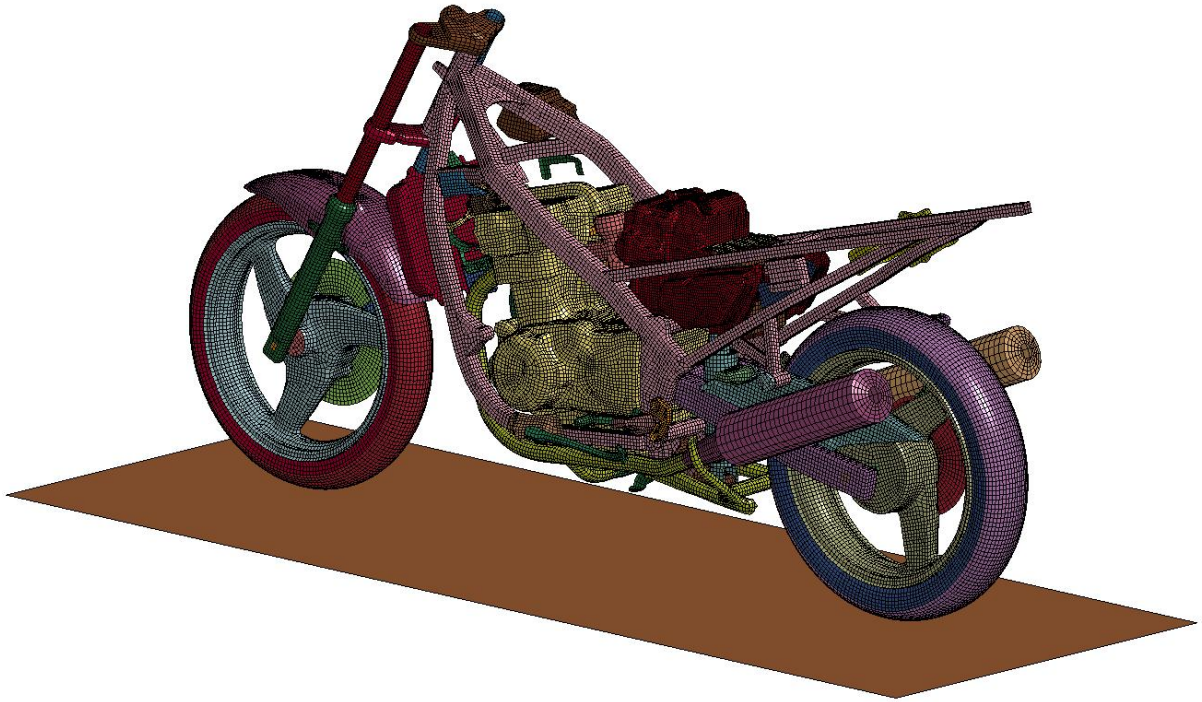

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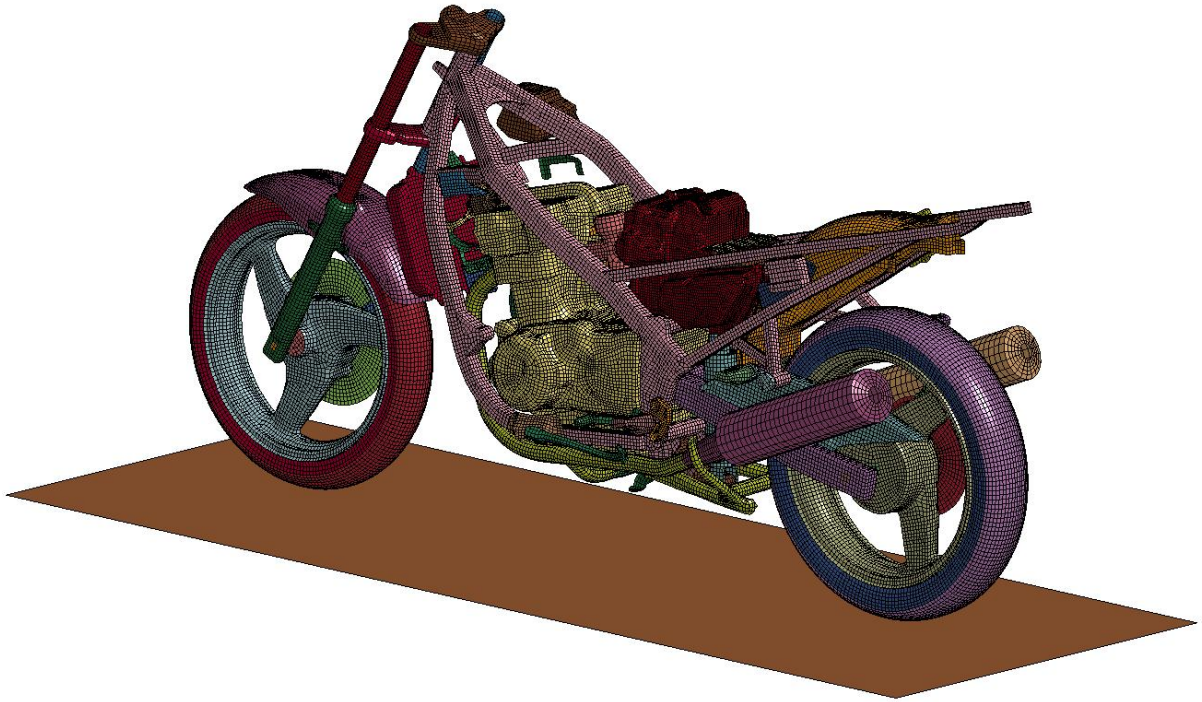

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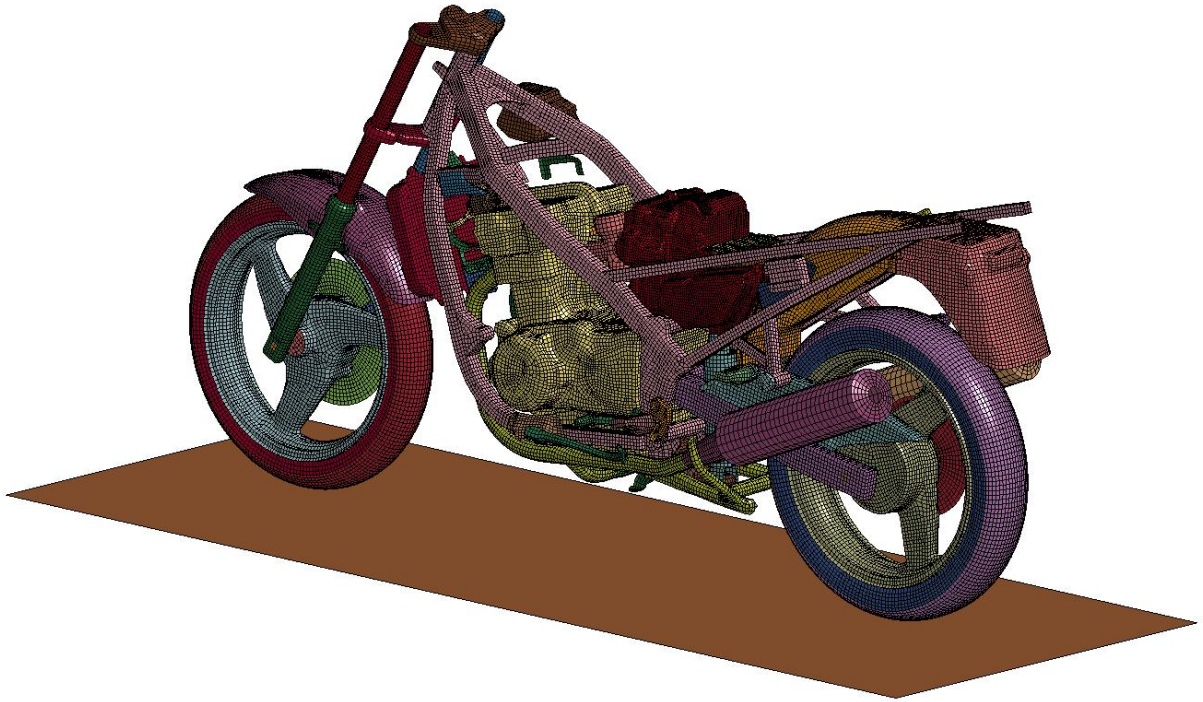

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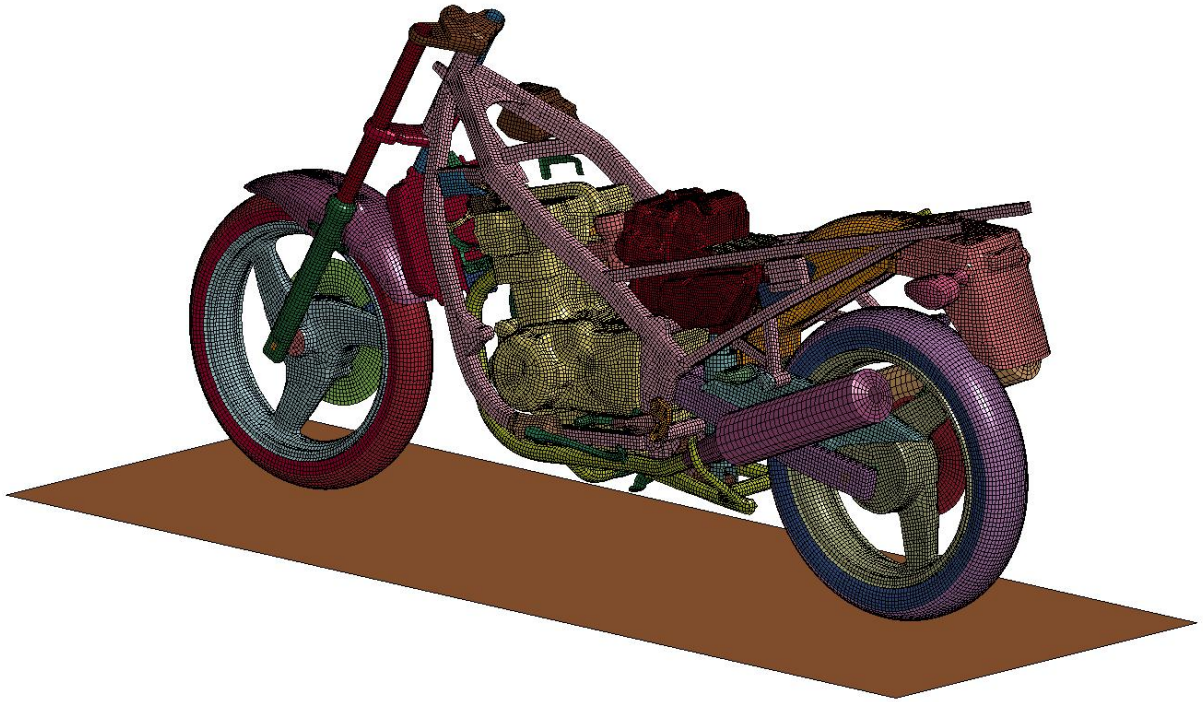

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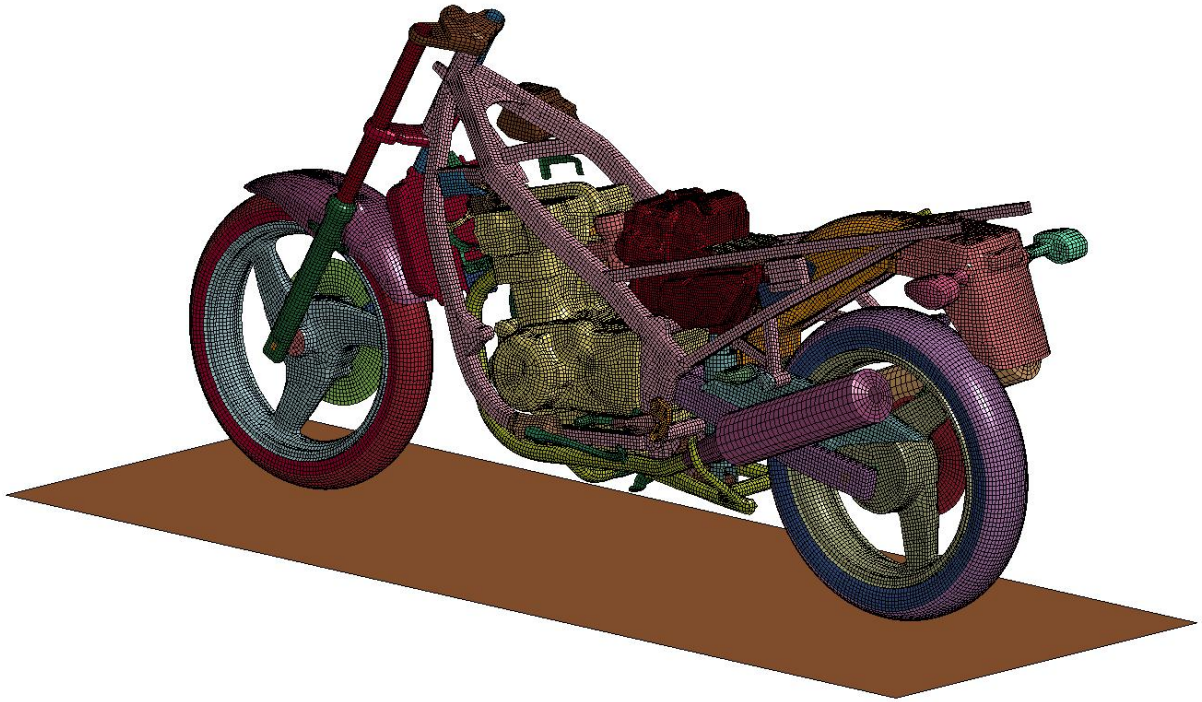

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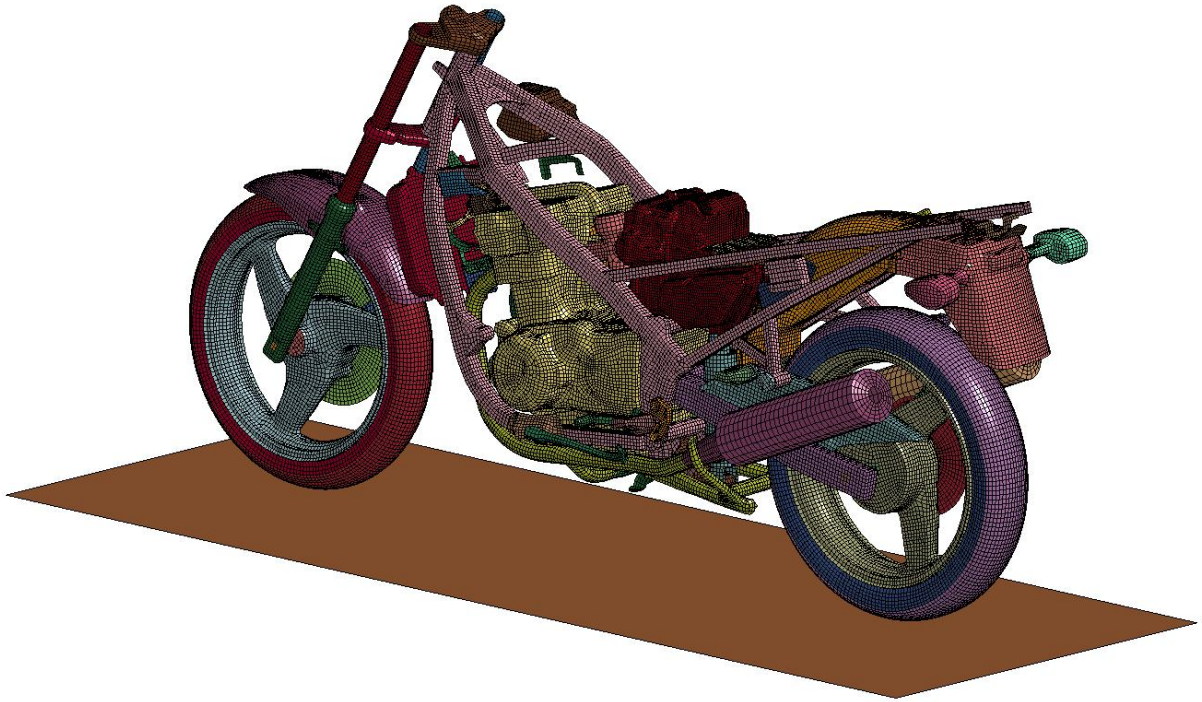

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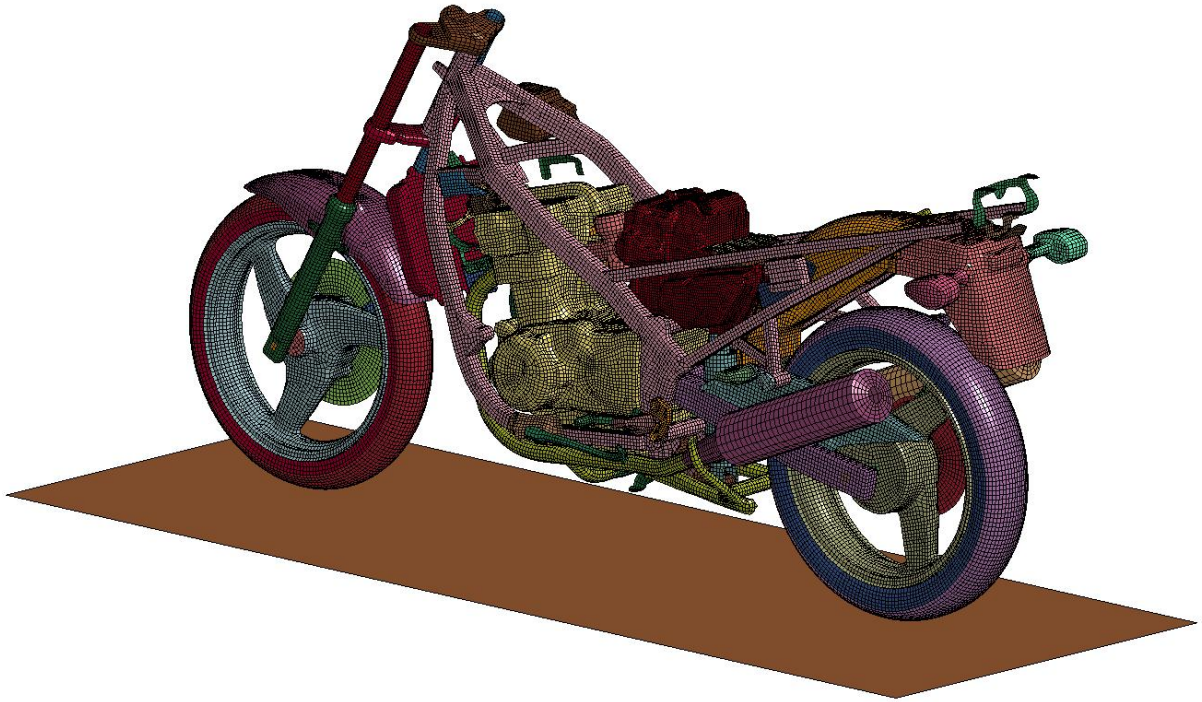

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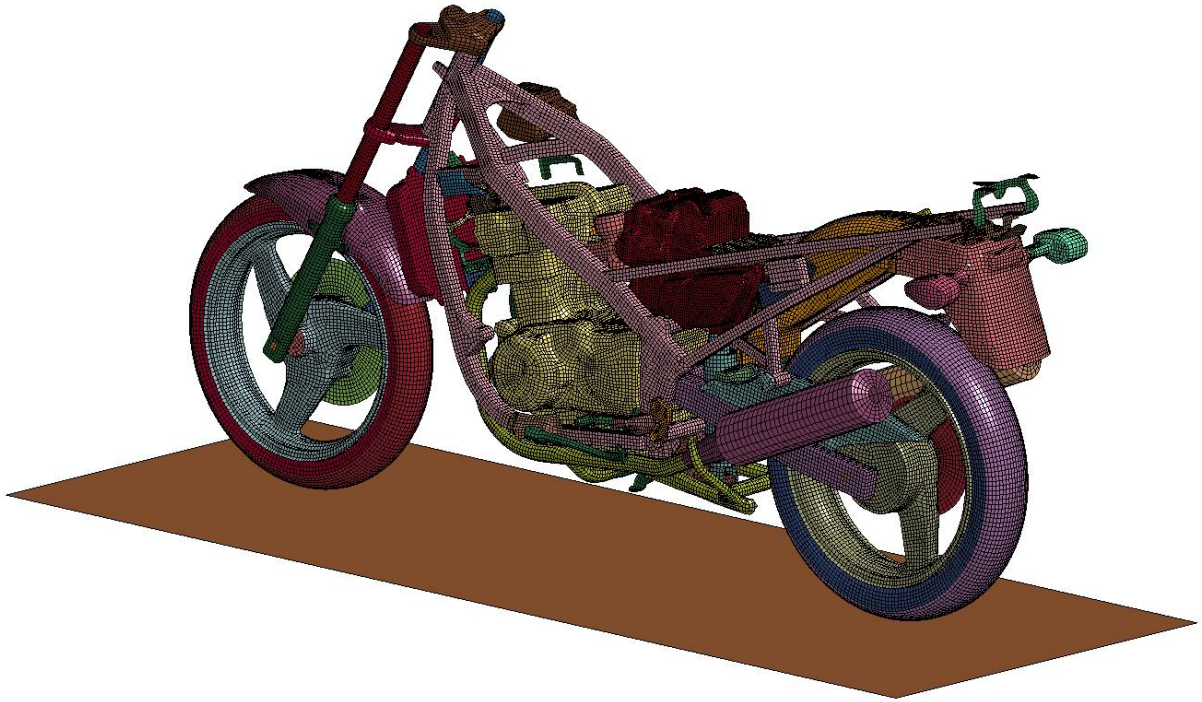

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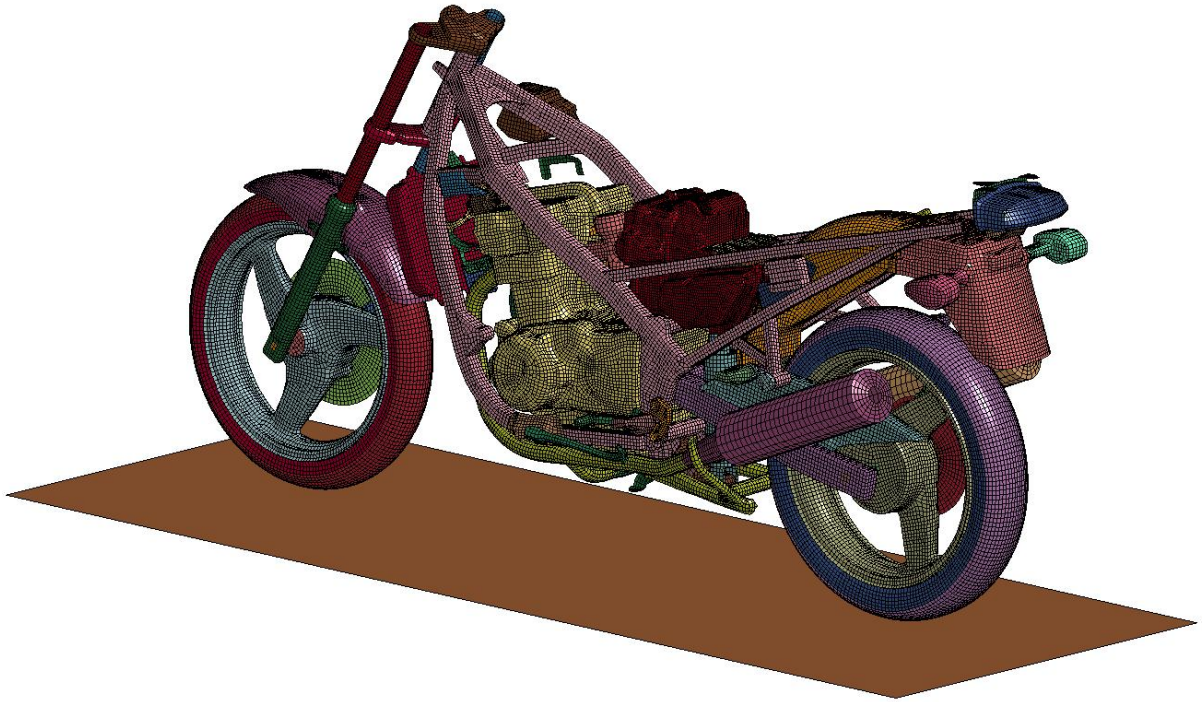

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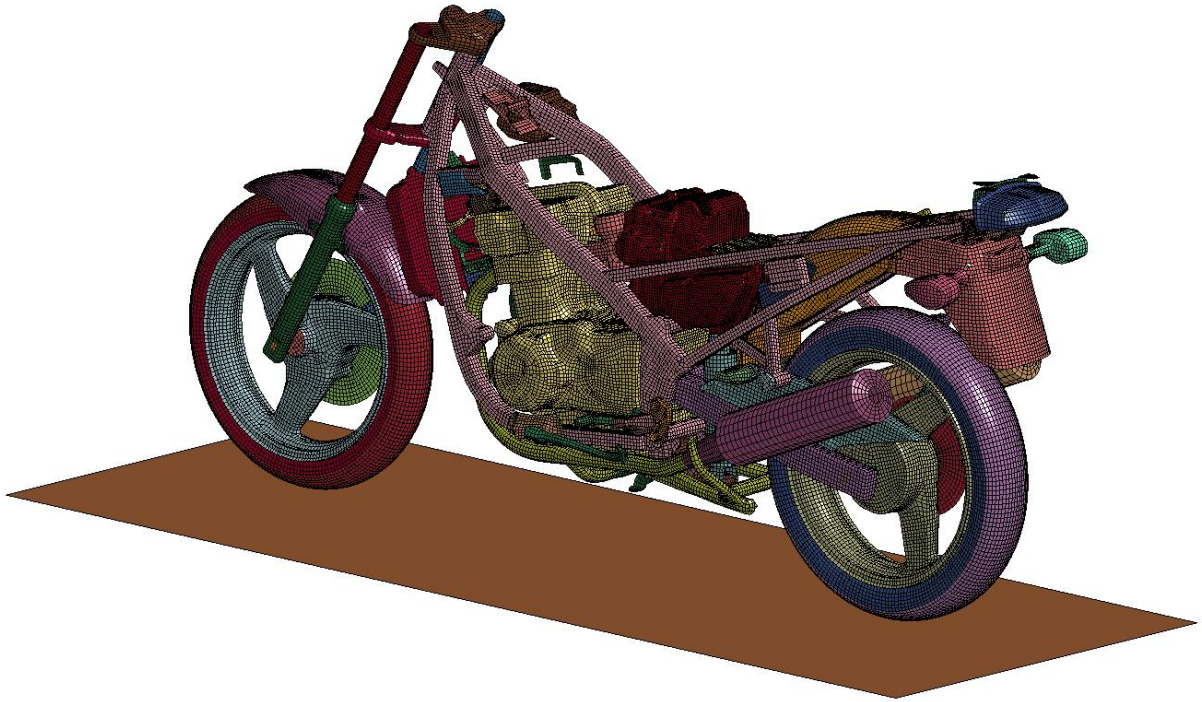

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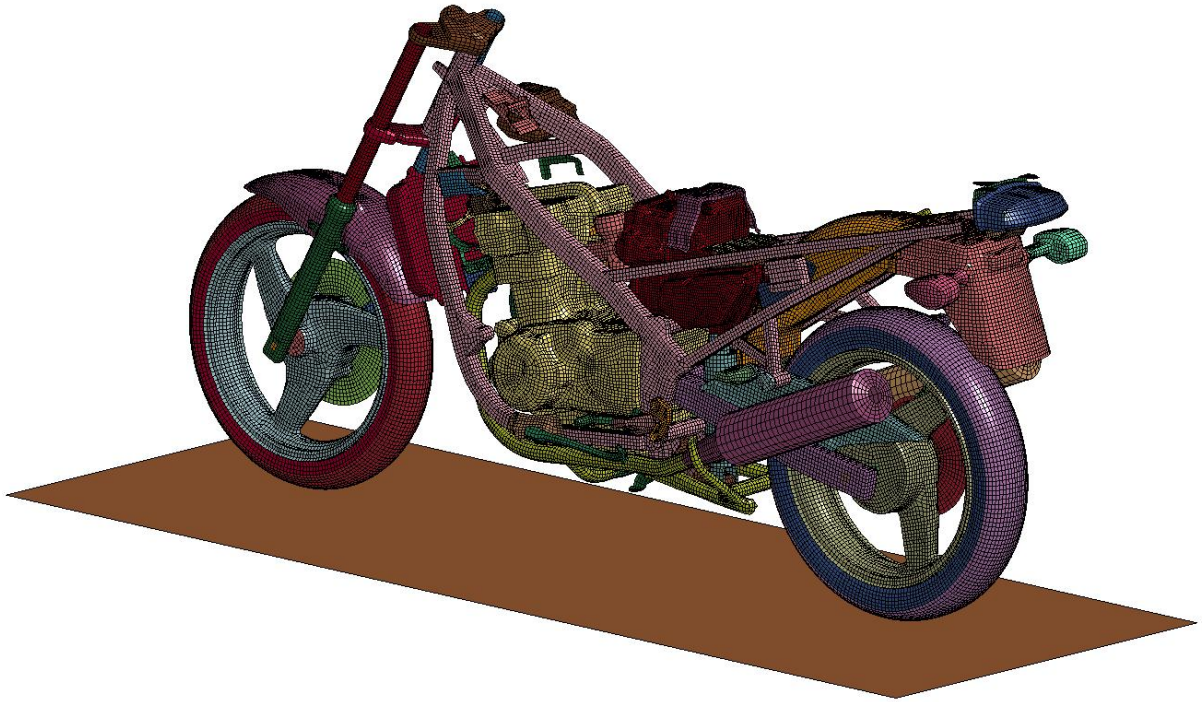

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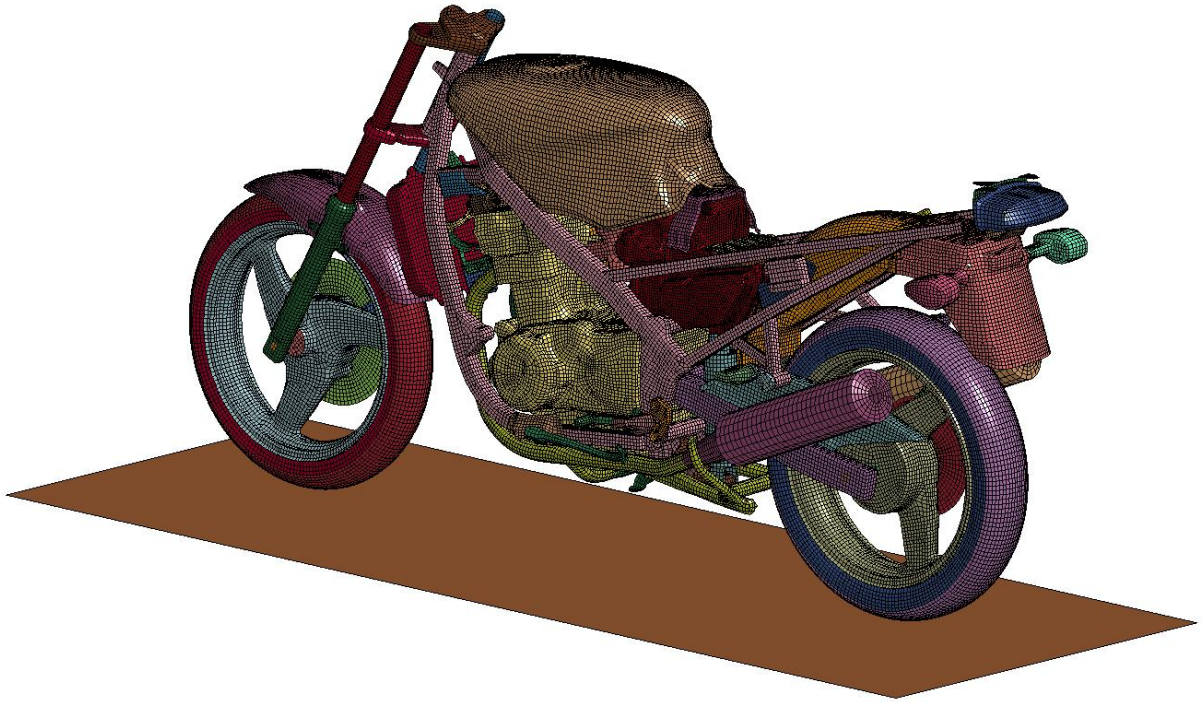

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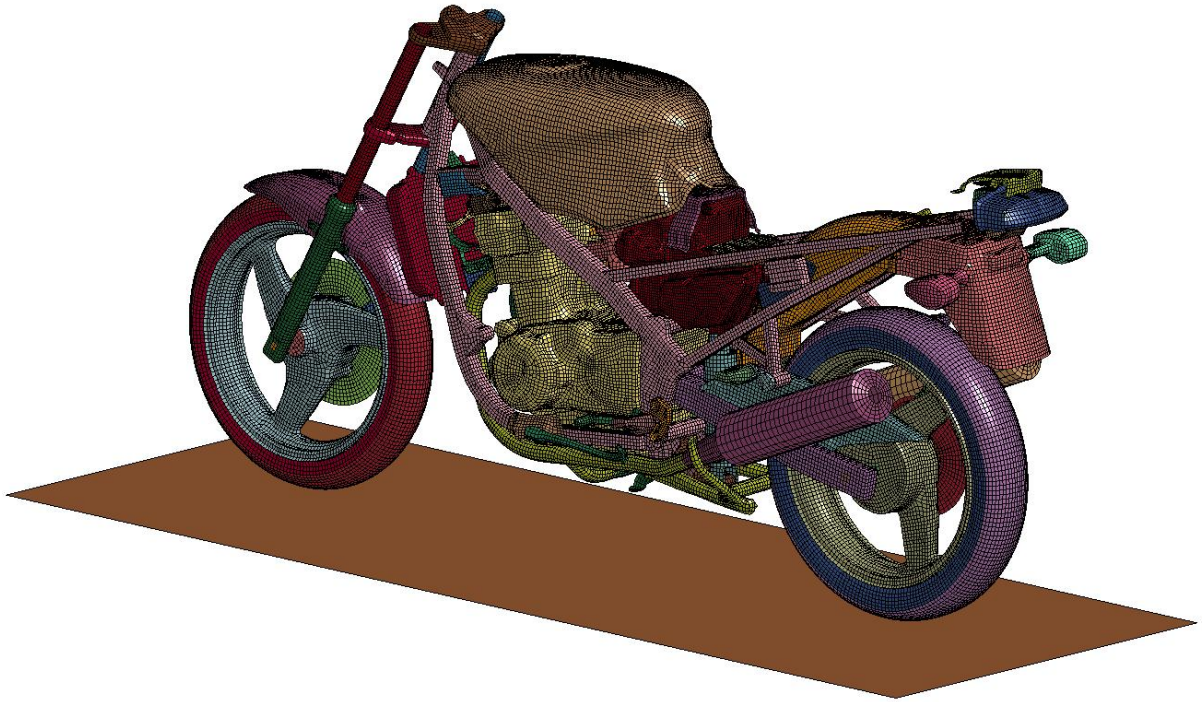

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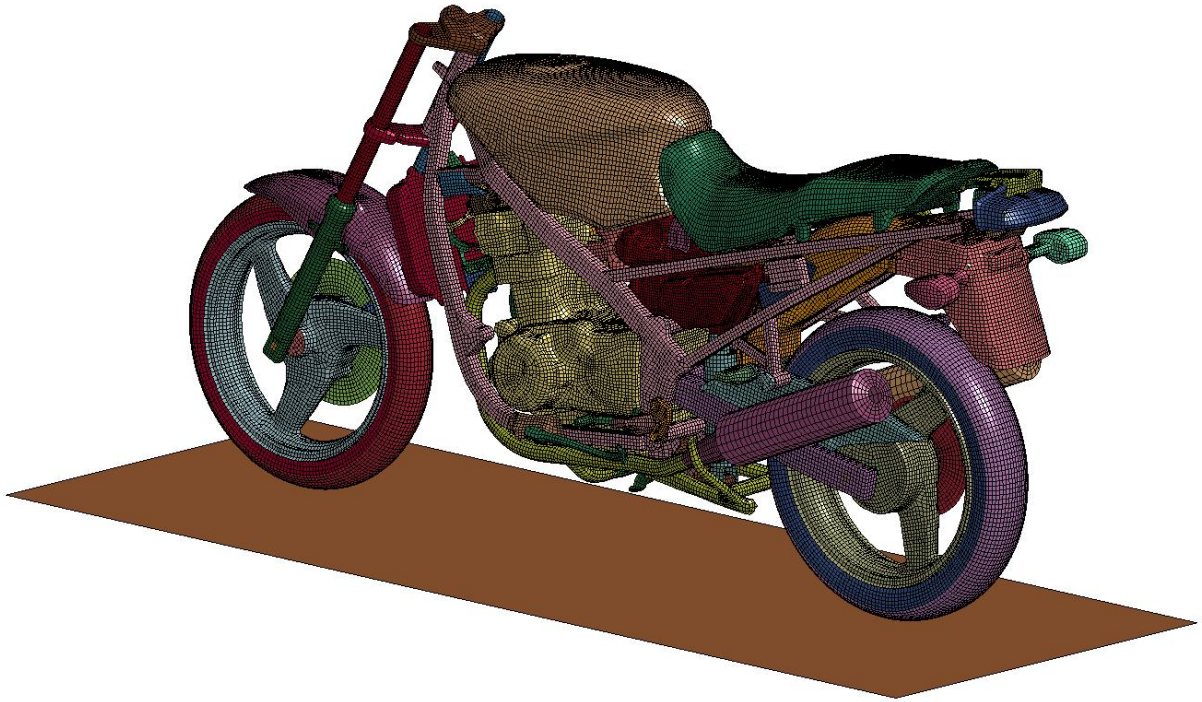

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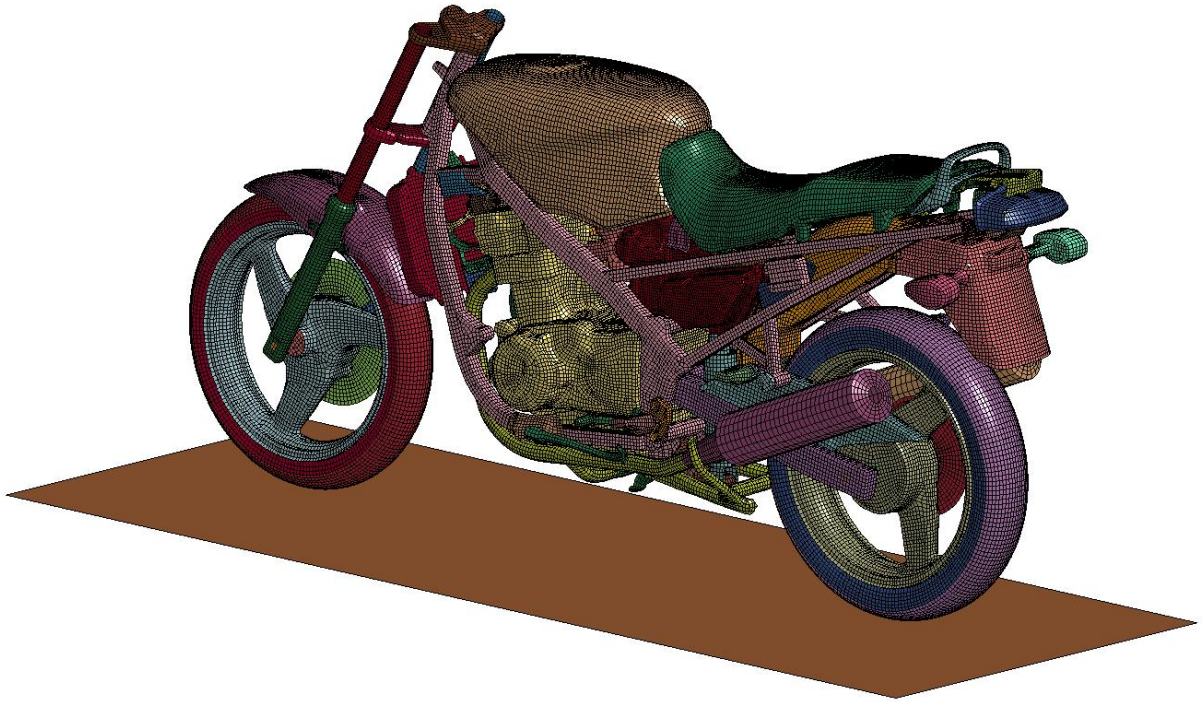

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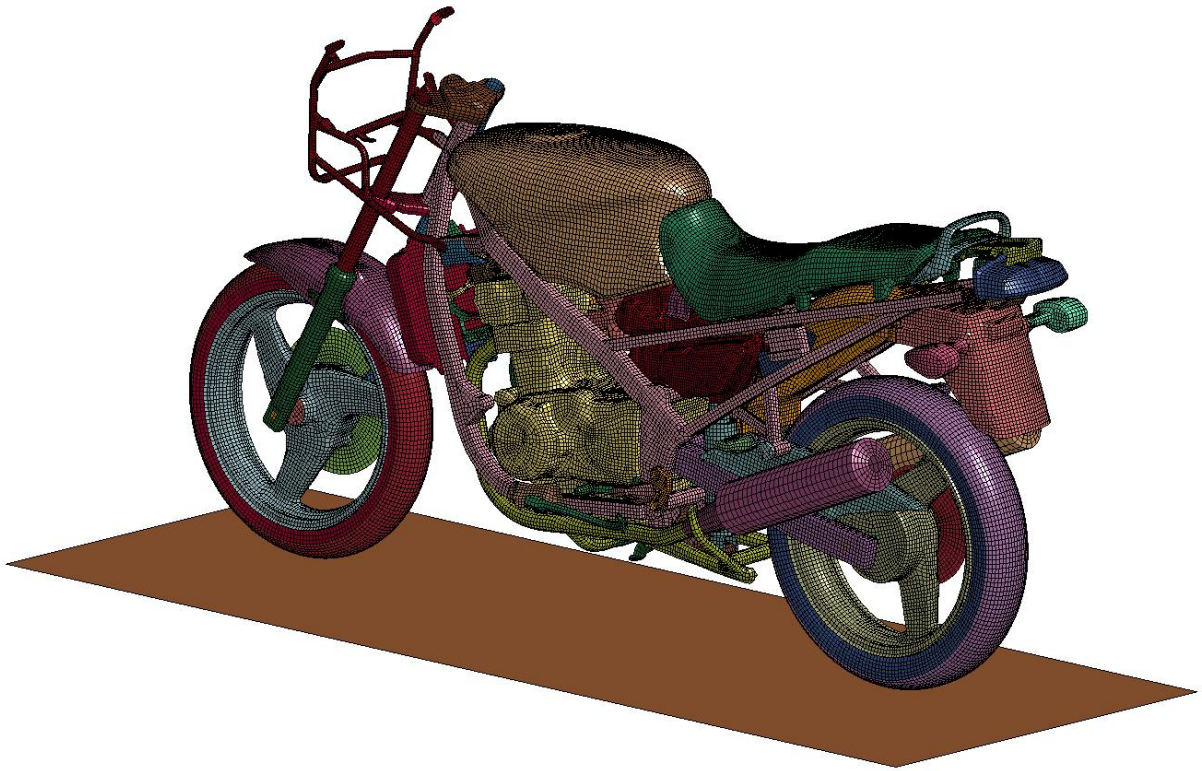

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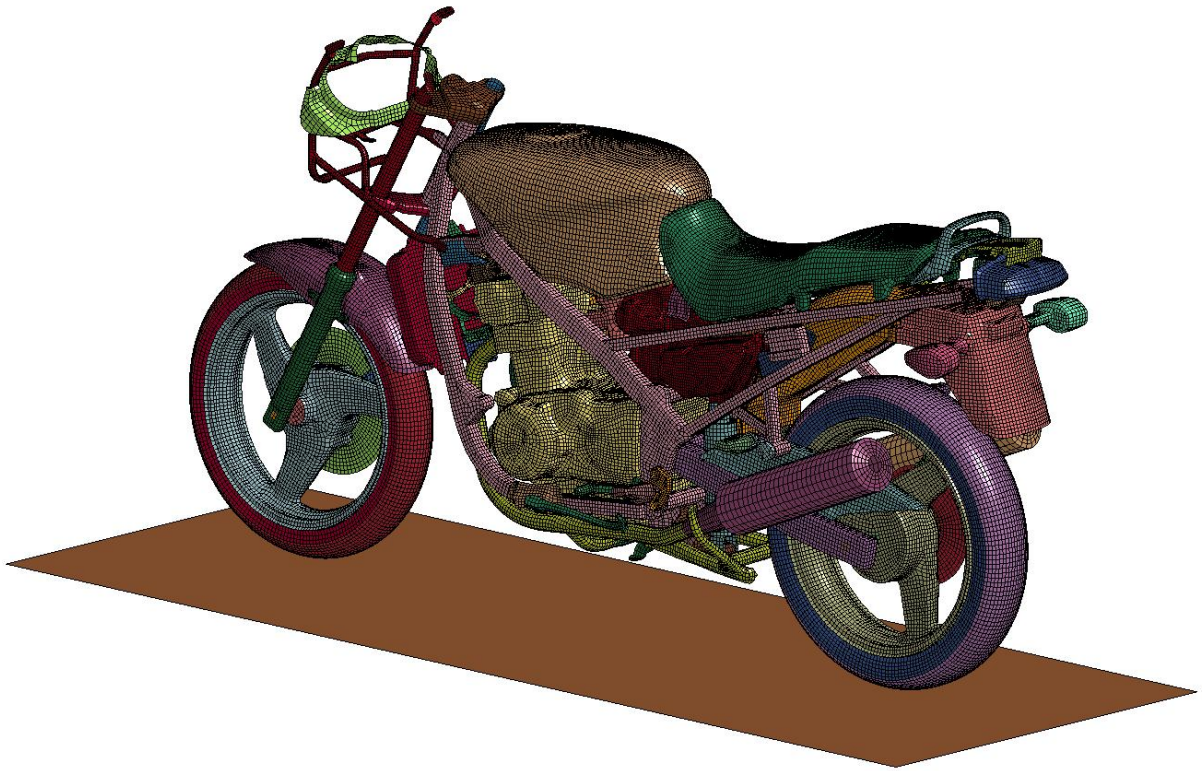

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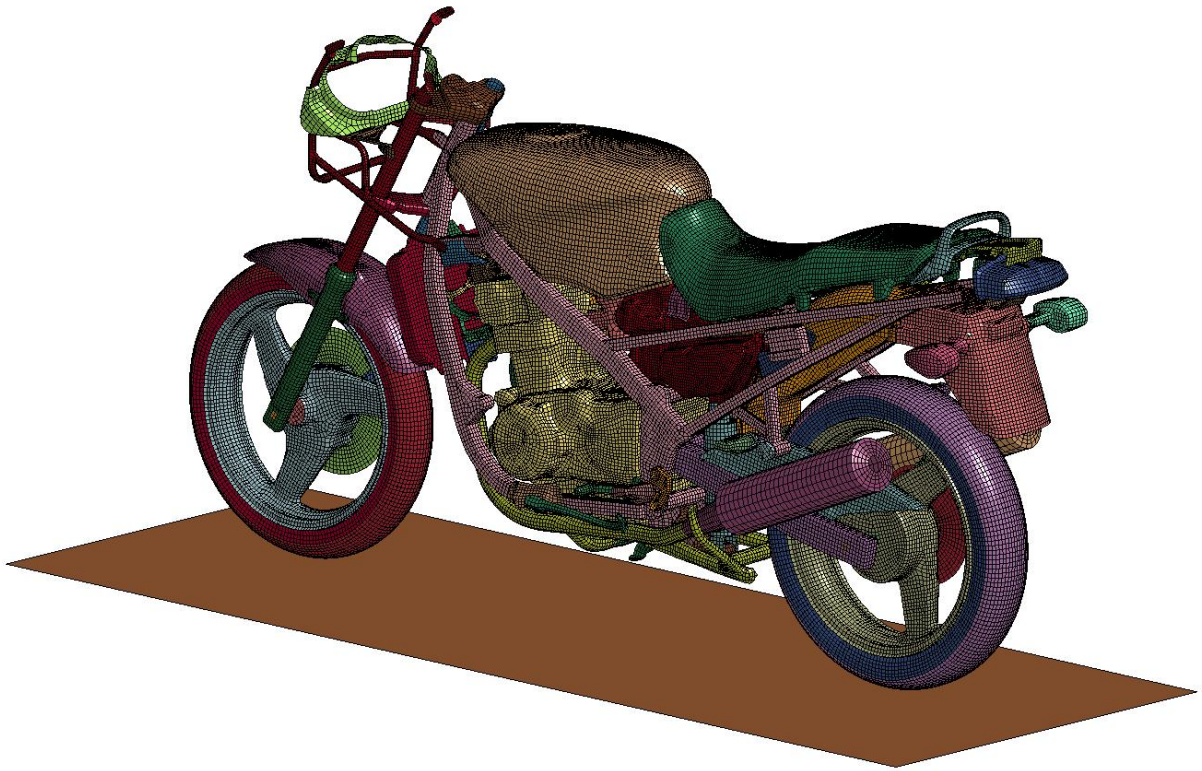

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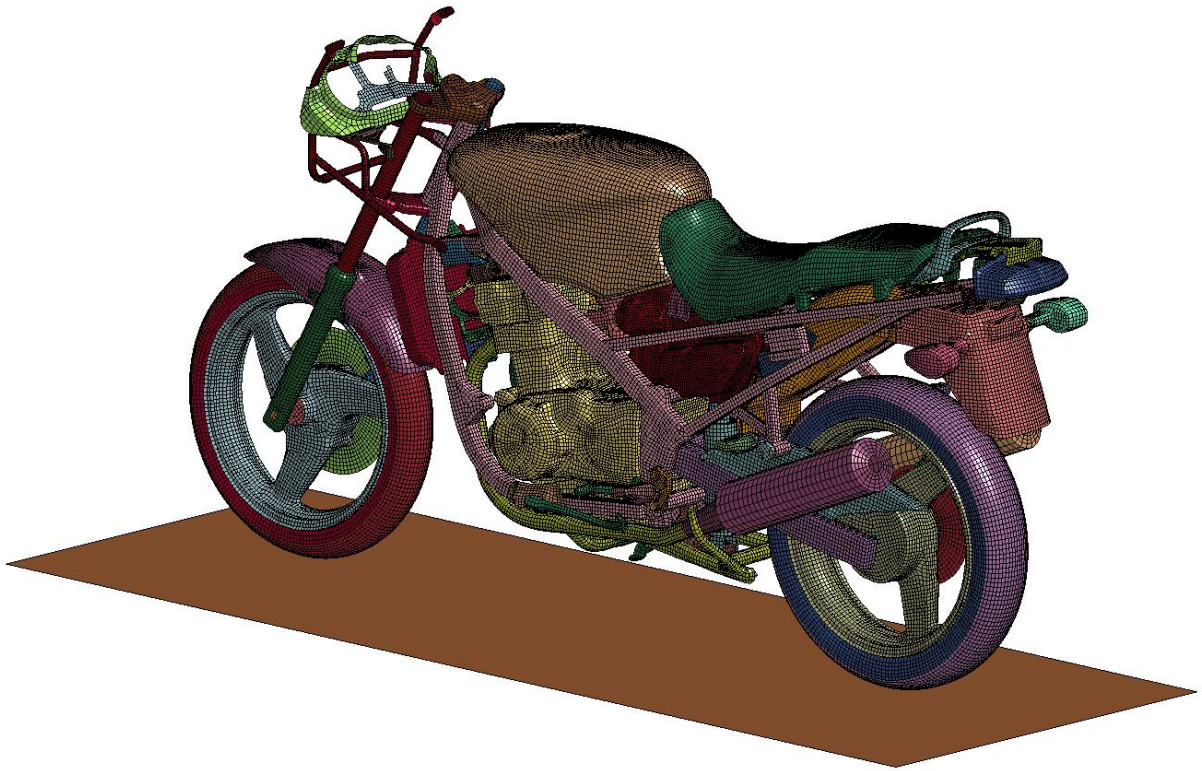

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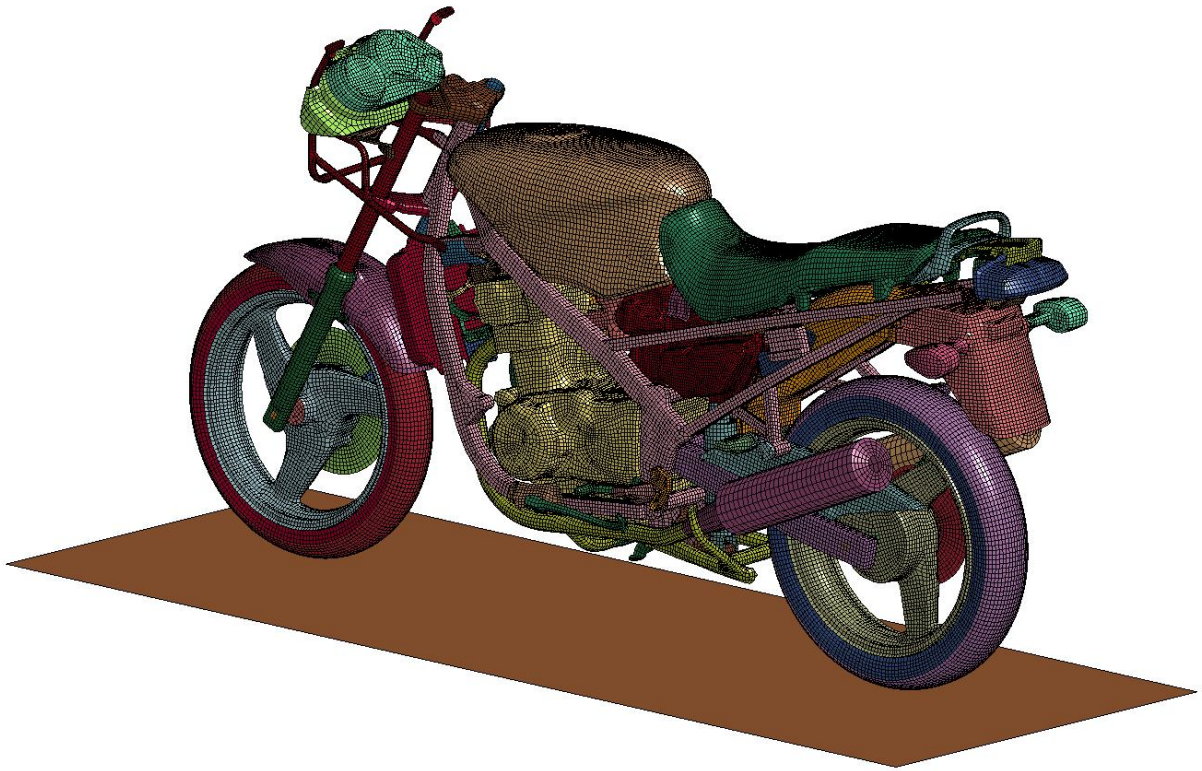

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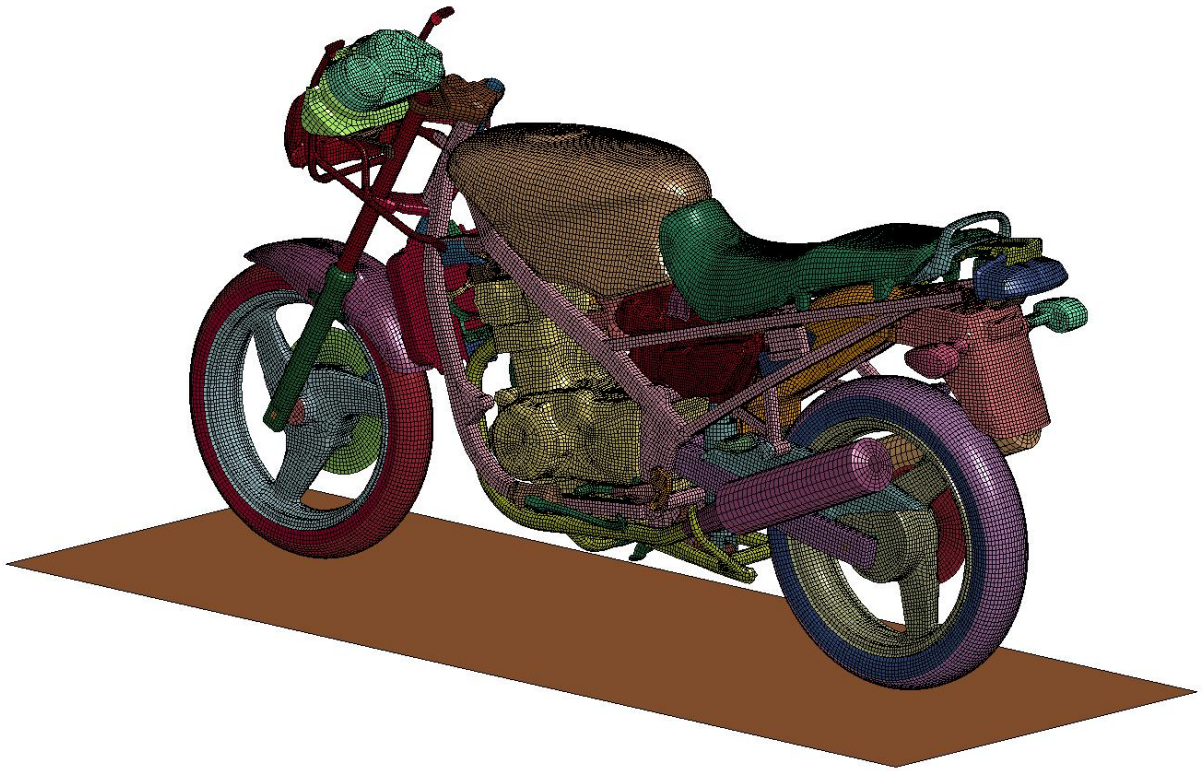

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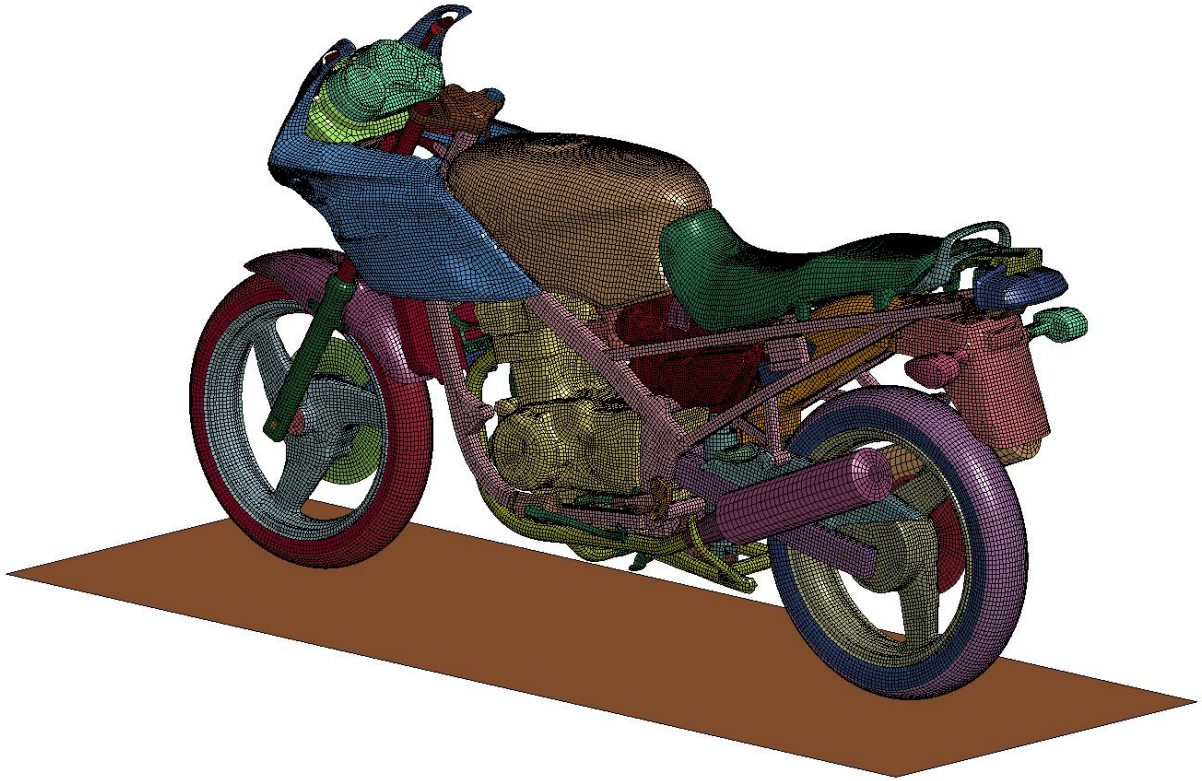

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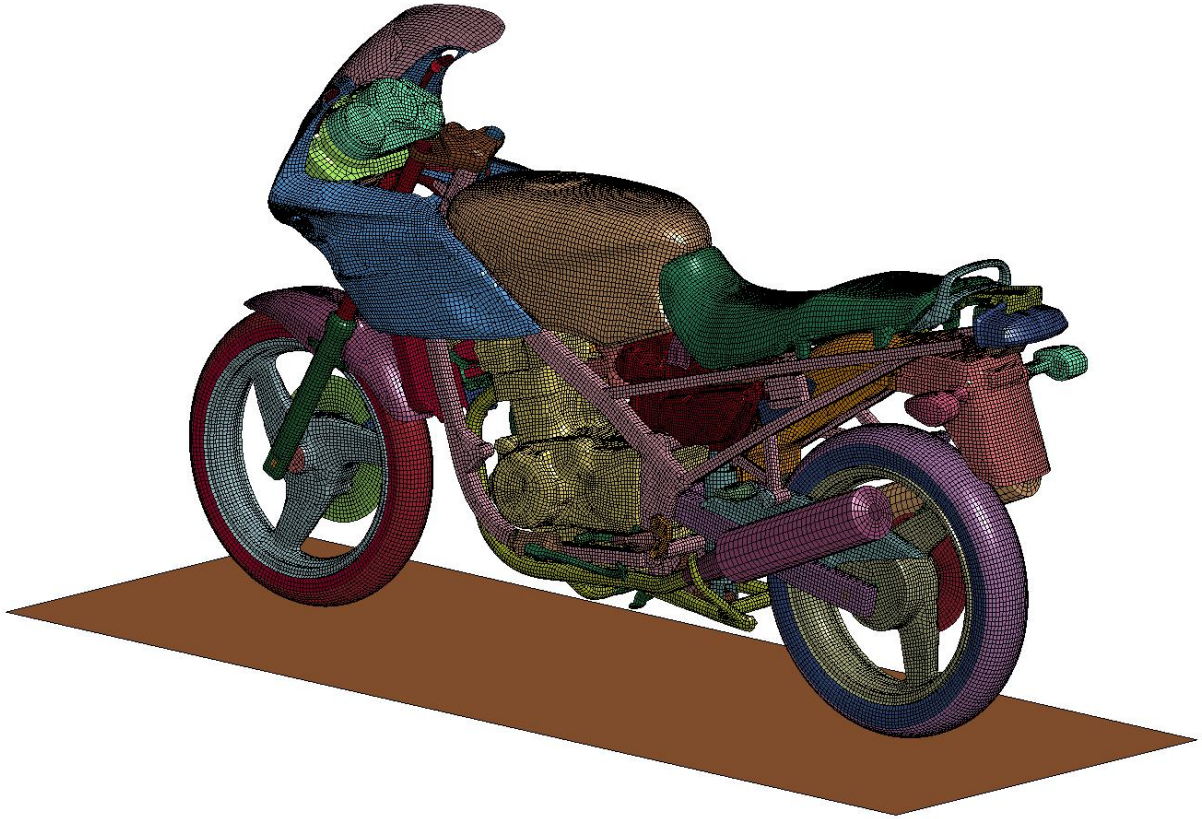

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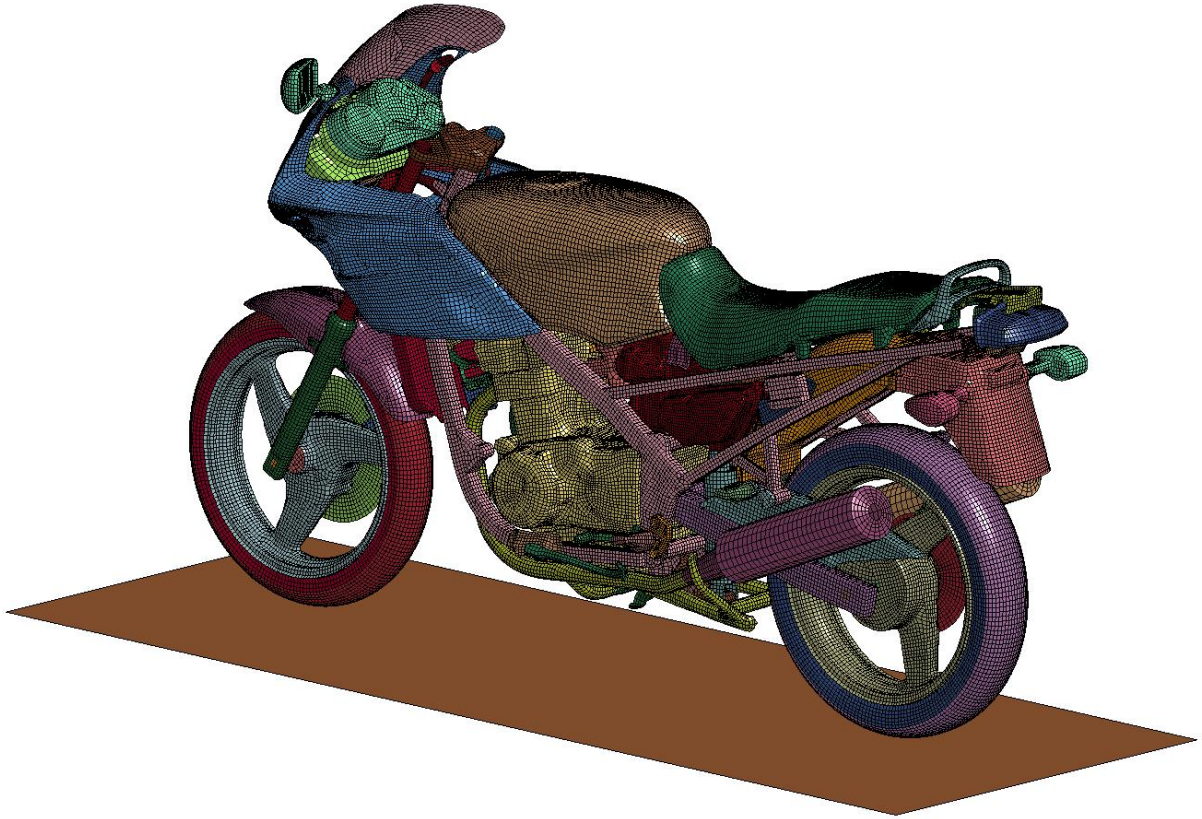

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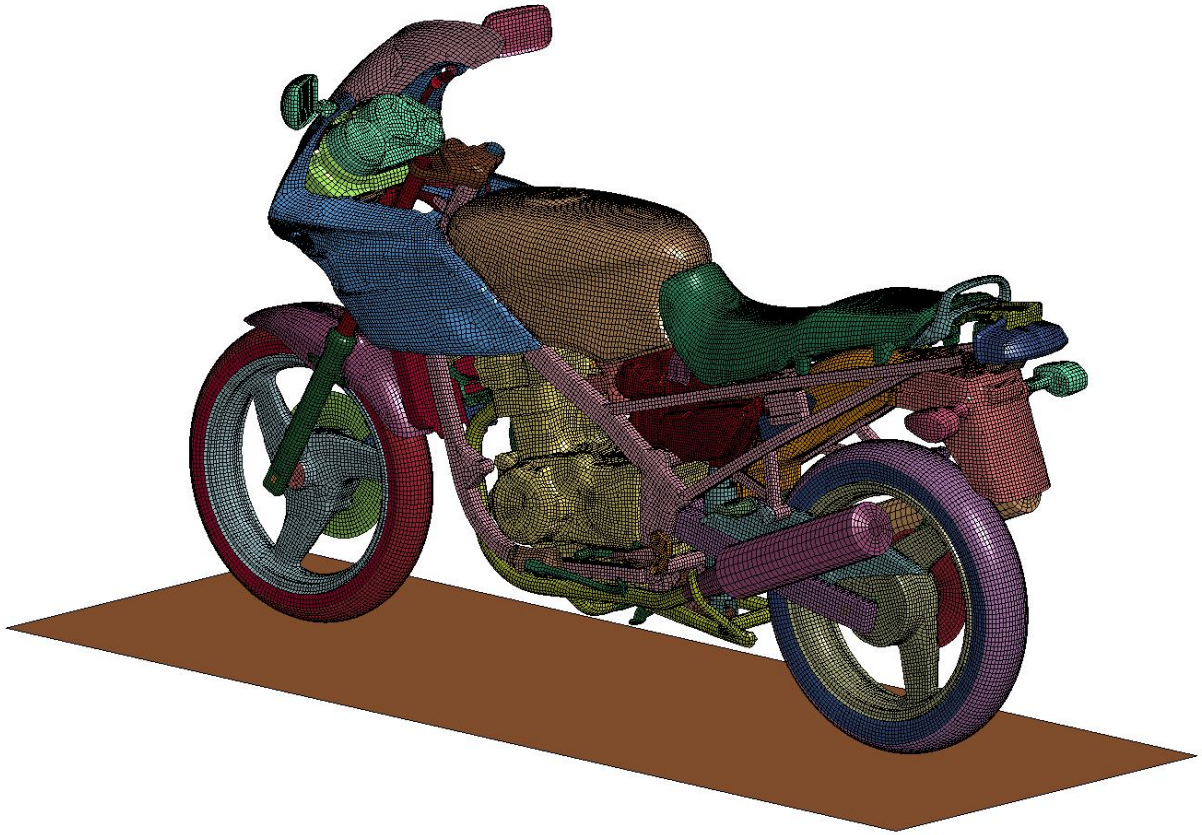

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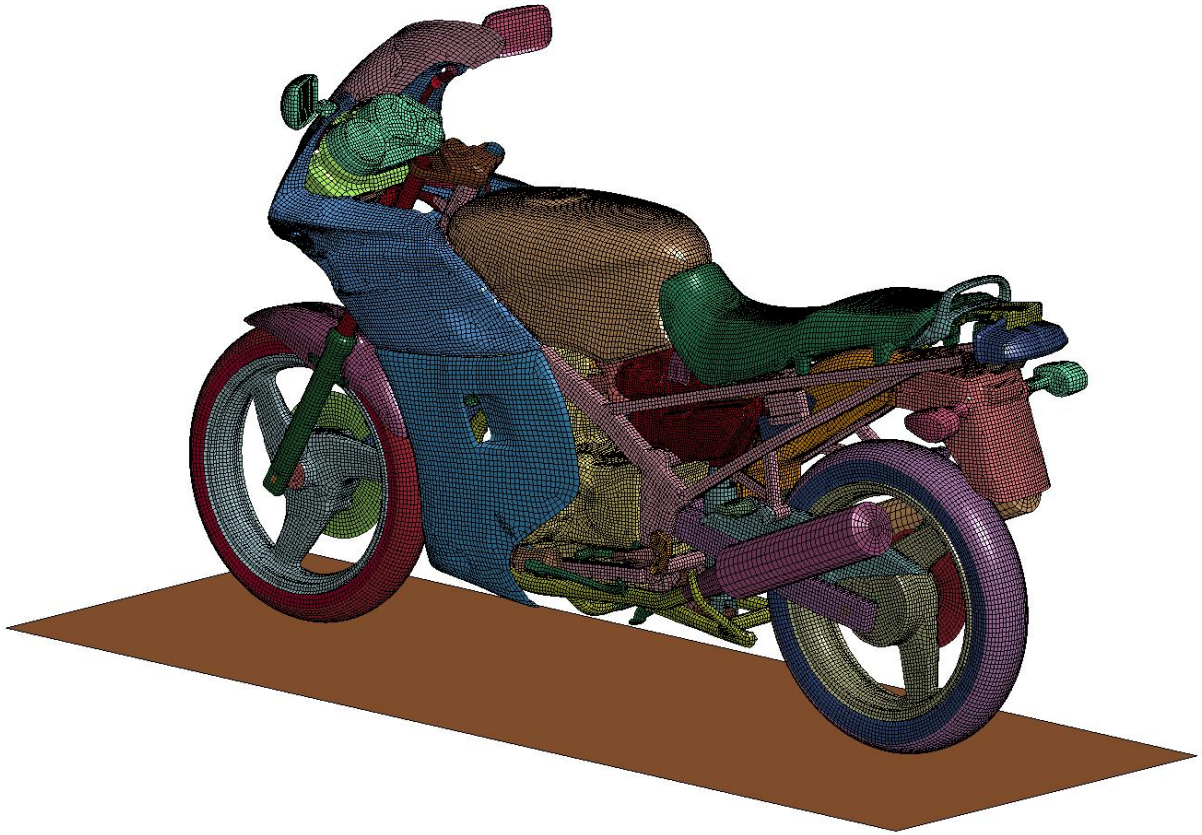

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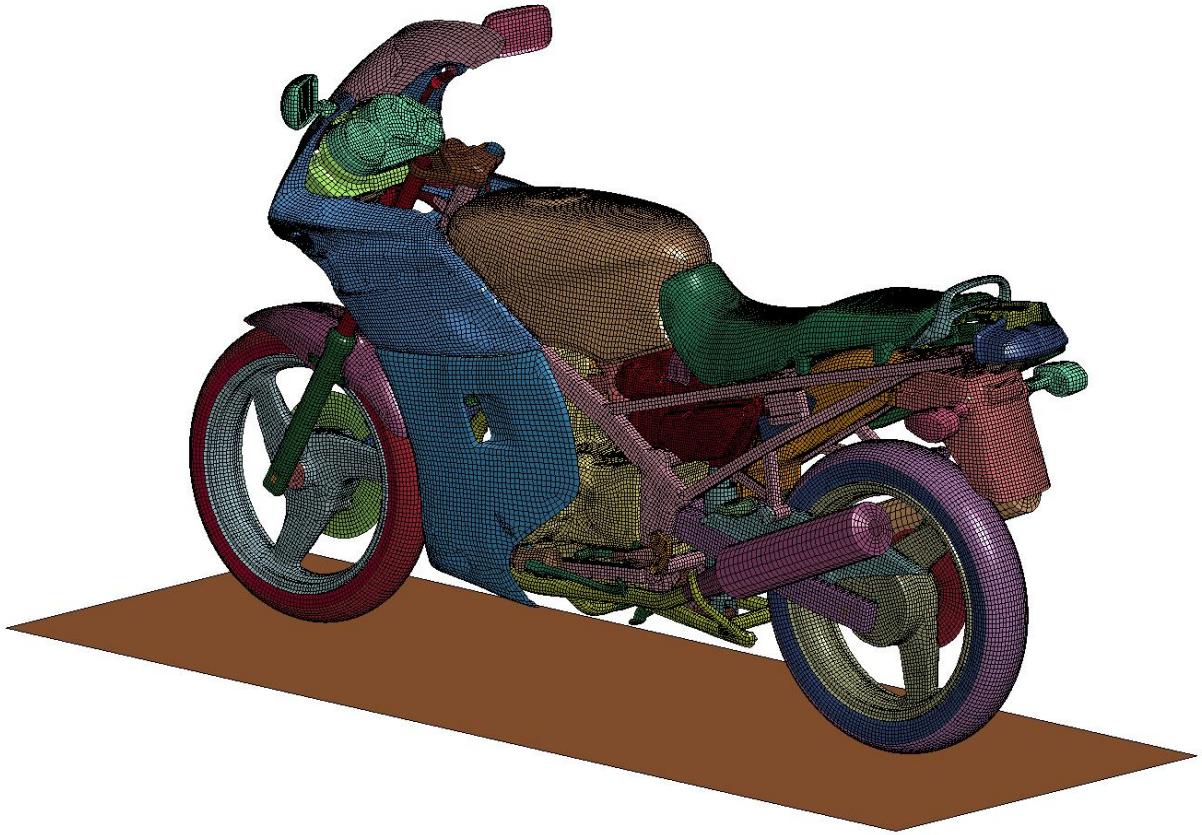

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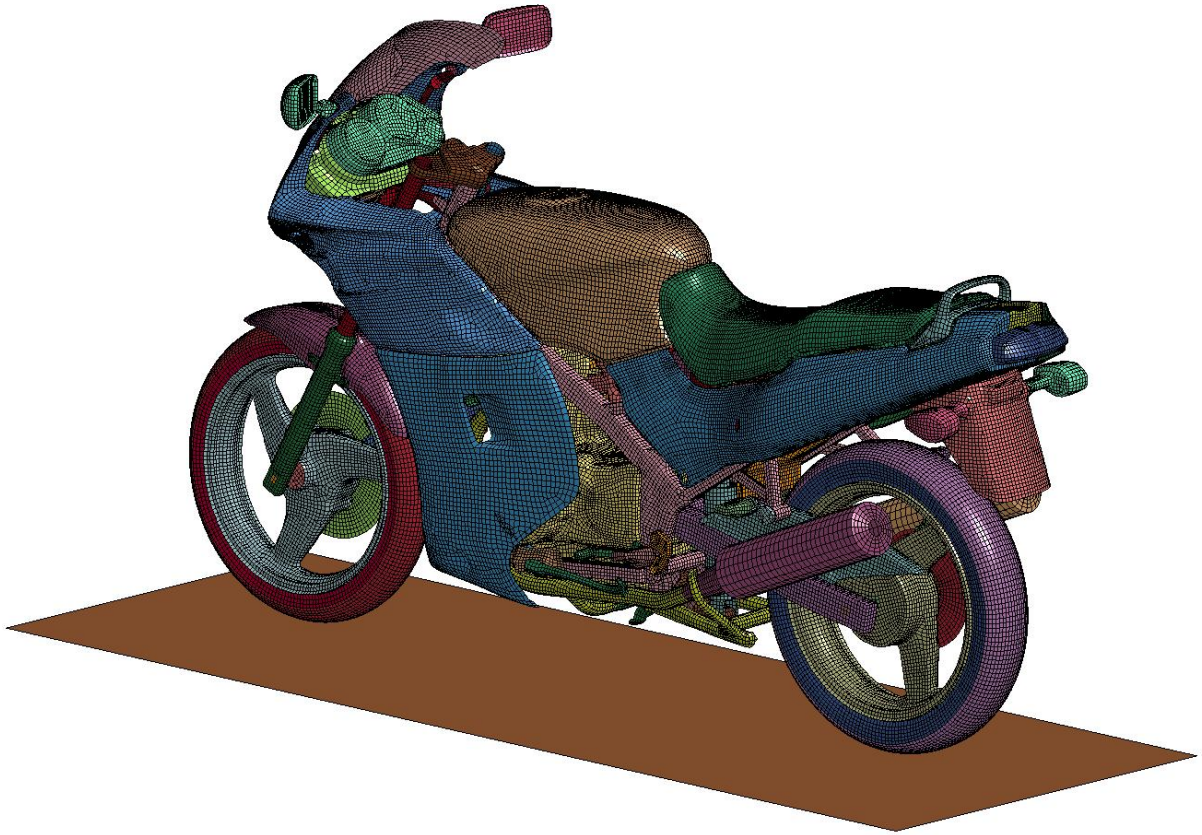

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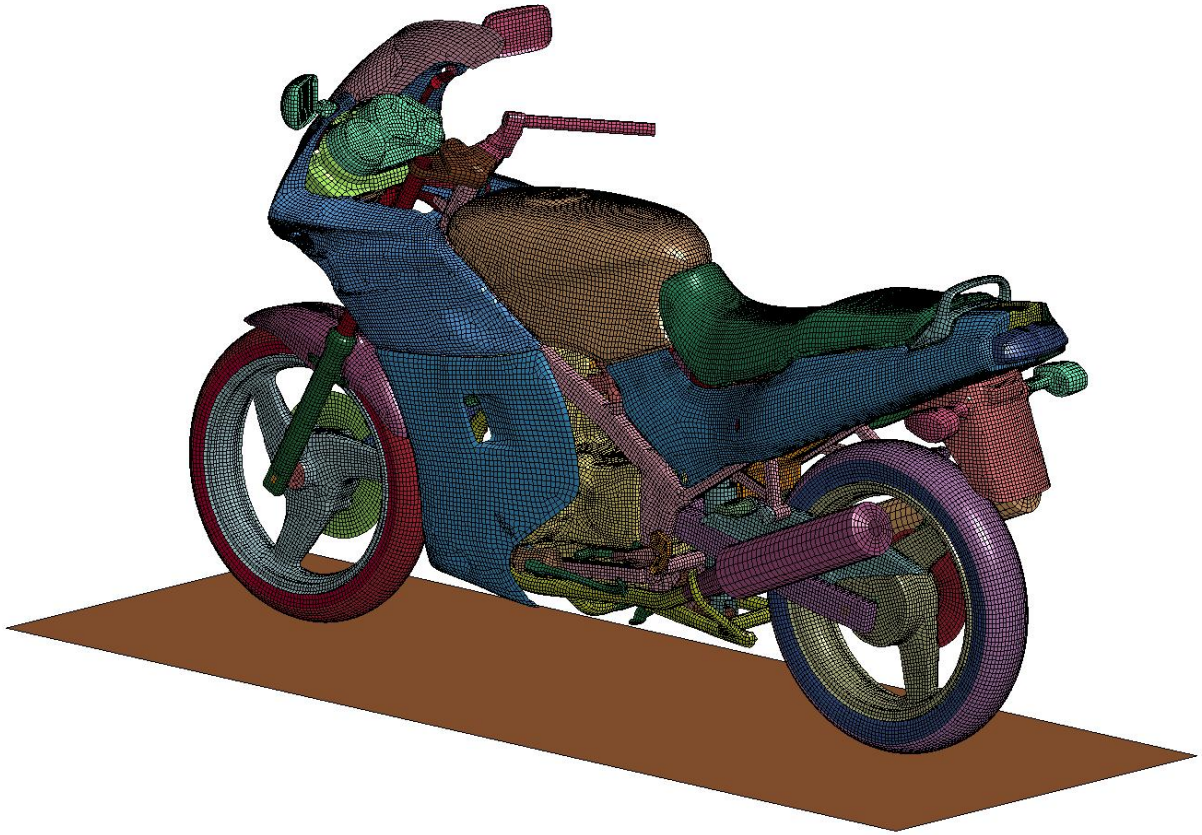

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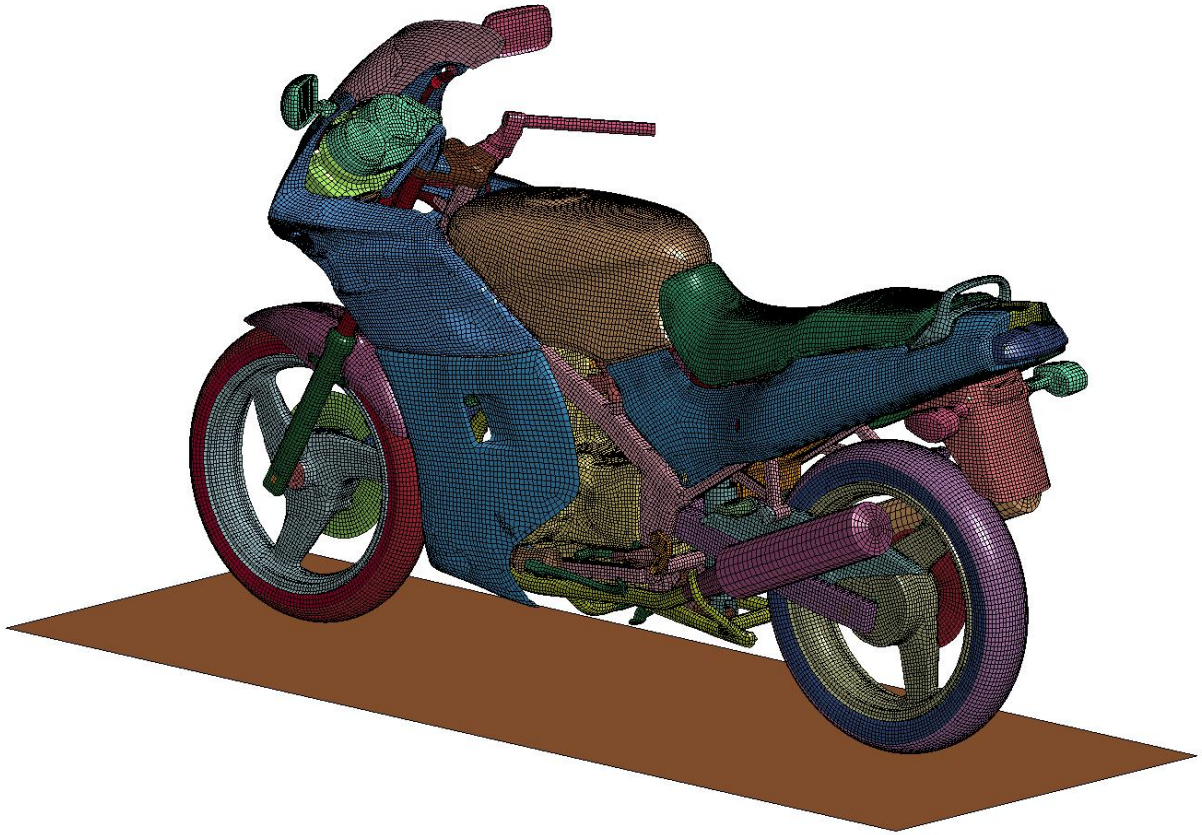

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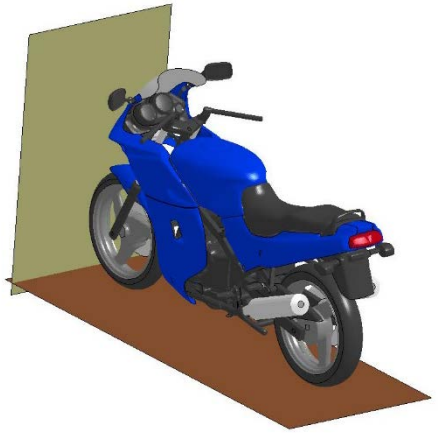
FE Motorcycle Comparison

- The total mass for the FE model was 172 kg, while the mass of the physical motorcycle was 176 kg

	Physical Motorcycle (mm)	FE Motorcycle (mm)	Percent Difference (%)
Width	701.0	722.6	3.08
Height	1195.0	1194.0	0.08
Length	2096.0	2094.5	0.07
Wheelbase	1435.0	1448.5	0.94
Wheel Radius	292.1	289.9	0.75
Seat Height	787.4	786.1	0.17
Ground Clearance	150.0	155.0	3.33

Motorcycle Simulation Impact with Rigid Wall

- Impact speed of 48.3 km/h (30 mph)
  - Based on ISO 13232-7 standards
- Simulation run time of 0.04 seconds
  - Time when motorcycle began to rebound from wall



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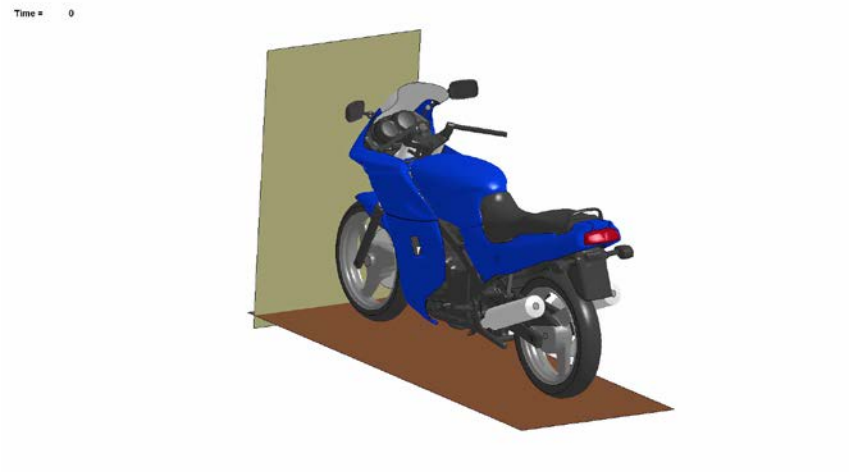
Motorcycle Simulation Impact with Rigid Wall



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Motorcycle and Rider ATD

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Full-Scale Testing - Motorcycle Guide System

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Future Work

- Validate motorcycle model components
- Validate motorcycle against full-scale crash test
- Include ATD to determine motorcycle crash scenarios with severe injury probability

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Acknowledgements

- Robert Wunderlich (Director, Center for Transportation Safety, TTI)
- Dr. Dean Alberson (Bulwark Design Innovations)
- Dr. Mike Manser (Human Factors Program Manager, TTI)

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Questions?

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