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A Dictionary of Terms for the Dynamics and Handling of Single Track Vehicles (Motorcycles, Mopeds, and Bicycles)

***Foreword*—**This Document has not changed other than to put it into the new SAE Technical Standards Board Format. Preface was changed to Scope. References were added as Section 2. Definitions were numbered.

***1. Scope*—**This dictionary of terms was prepared for use by those with a need to describe and understand the dynamics and handling of two-wheeled, single track vehicles. It is intended to span the gap between vehicle dynamics specialists and those with a more general interest.

This report is pertinent to such areas as vehicle design and development, the description of two-wheeler properties, rider training and education, and the preparation of standards and regulations.

This report was prepared by the SAE Motorcycle Committee, which solicits suggestions for improvements and additions to be considered in future revisions. Comments should be directed to SAE Headquarters.

2. References

2.1 Applicable Publication—The following publication forms a part of the specification to the extent specified herein. Unless otherwise indicated the lastest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J670e—Vehicle Dynamics Terminology

3. Definitions

3.1 Acceleration—The time rate of change of velocity.

3.2 Aerodynamic Drag Force—A force opposite to the direction of travel due to aerodynamic resistance, measured in the nominal plane of symmetry of the vehicle. For some engineering purposes, it can be defined, alternatively, parallel to the relative wind vector.

3.3 Aligning Moment (on tire)—Torque from the roadway, acting on a tire, which tends to keep the wheel plane parallel to the vehicle velocity vector (at the tire contact point). See also SAE J670e.

3.4 Angular Velocity—Rotational velocity about an axis.

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3.5 Antilock Brake System—A braking system that automatically controls the slip ratio of one or more wheels of the vehicle during braking.

3.6 Antiskid Brake System—See antilock brake system.

3.7 Axis System—A coordinate system fixed in the vehicle, a component body, or the roadway, for purposes of defining positions and motions.

3.8 Axle—The shaft which comprises the spin axis of a wheel.

3.9 Bank Angle—See roll angle.

3.10 Bounce Motion—Translational motion of the vehicle in a direction parallel to its nominal plane of symmetry (i.e., relative to body fixed axes). Vertical translation if the vehicle is upright. See also SAE J670e.

3.11 Brake Fade—Reduction in the braking torque on a wheel for a given level of rider brake control force; caused by thermal or water factors, for example.

3.12 Braking—The process of decelerating the vehicle by applying the brakes.

3.13 Camber Angle—The roll or tilt angle of the plane of a wheel, measured relative to vertical. See also SAE J670e.

3.14 Camber Thrust—The side force generated by a tire due to camber angle.

3.15 Capsize—Tendency of the vehicle to roll from an upright position.

3.16 Capsize Mode—A usually low frequency dynamic characteristic of the vehicle which exists in the absence of rider control. If stable, the vehicle will gradually return to an upright position; and if unstable, the vehicle will gradually roll and turn from its original direction of travel.

3.17 Caster Angle—See rake angle.

3.18 Center of Gravity—If the vehicle is supported at this point, it will not rotate due to the force of gravity. See mass center.

3.19 Chopper—A motorcycle style and design, usually the result of aftermarket modification, which typically features lengthened forks, increased rake angle, modified suspension, small front tire and large rear tire, and a lowered rider seating position. The brakes and drive train may be modified also.

3.20 Compliance—Structural deflection, bending, or rotation.

3.21 Cornering Limit—The maximum vehicle lateral acceleration at a given speed; usually determined by road clearance of the vehicle structure (foot pegs, muffler, etc.) or by tire/roadway adhesion.

3.22 Cornering Stiffness—The amount of side force generated by a tire per unit slip angle. Quantified as a tire side force coefficient. See also SAE J670e.

3.23 Cornering Weave—A combined pitching and yawing motion which can occur in a steady-state turn, under certain adverse conditions. See also pitch-weave coupling.

3.24 Counter Steer—The process whereby the rider applies a steer torque in the direction opposite to that which the vehicle is turning, or is intended to turn.

3.25 Coupled Motions—Coupling occurs when different motions (i.e., about different axes) have similar frequencies, and their oscillatory behavior has a definite phase relation.

3.26 Course Angle—See path angle.

3.27 Damper—A device which produces a reactive force or torque as a function of translational or rotational velocity, respectively. See shock absorber. See also friction damper.

3.28 Damper Rate—The amount of force or torque produced by a damper as a function of velocity.

3.29 Damping—The process of diminishing amplitude progressively.

3.30 Damping Ratio—A measure of the amount of damping for oscillatory systems. See also SAE J670e.

3.31 Degree-of-Freedom—A characteristic motion of the vehicle, or a relative motion between component bodies. Measured about or along an axis. One or more degrees-of-freedom are associated with each mode of motion. See also SAE J670e.

3.32 Destabilize—To reduce the stability or damping, e.g., of a characteristic motion or dynamic mode.

3.33 Divergence—A motion with progressively increasing amplitude, an instability.

3.34 Down Tubes—The lower frame members; typically extending from the head, down and under the motor and back to the swing arm pivot.

3.35 Drive Train—The mechanism between the motor and a driven wheel.

3.36 Driving—The process of accelerating the vehicle or maintaining forward velocity.

3.37 Dynamics—The branch of mechanics which treats the motion of bodies (kinematics) and the action of forces which produce or change the motion (kinetics).

3.38 Eigenvalue—A numerical value, derived from mathematical modeling and equations of motion, which describes the frequency, amplitude, and damping properties of a mode of motion.

3.39 End-Over—An extreme forward pitching motion; typically resulting in the rider and the rear frame assembly going over the front wheel in the direction of travel. Also called an endo or a reverse wheelie.

3.40 Enduro—A motorcycle sporting event or race run off-road and cross country from one point to another, usually lasting hours or days, and emphasizing timing, speed, and reliability. Also a motorcycle intended to compete in such an event.

3.41 Equations of Motion—A set of mathematical relationships which describe and quantify the dynamics of the vehicle.

3.42 Equilibrium—A state of balance among the forces acting on the vehicle, wherein the resulting motions have achieved steady-state values.

3.43 Fade—See brake fade.

3.44 Fairing—A windscreen device on the front of the vehicle attached to either the fork assembly or rear frame assembly.

3.45 Feedback Control—The process of comparing output motions with desired (input) motions in order to regulate against disturbances and follow a prescribed path. The rider accomplishes this by making control actions in response to perceived cues, thereby establishing feedback loops. See also rider control.

3.46 Fork—The mechanism between the steering head and the front wheel axle; including the triple clamps, fork slider tubes, and shock absorbers. The fairing, lights, fender, front wheel, handlebars, etc., are excluded.

3.47 Fork Assembly—The connected set of components which rotates as a single body about the steer axis. It includes the fork, fairing, lights, fender, front wheel and tire, front brake, handlebars, etc. The fork assembly plus the rear frame assembly constitute the vehicle.

3.48 Fork Clamp—See triple clamp.

3.49 Fork Hinge Line—See steer axis.

3.50 Fork Offset—The perpendicular distance from the steer axis to the front axle.

3.51 Fork Rake Angle—See rake angle.

3.52 Fork Steer Angle—See steer angle.

3.53 Fork Tube—The upper fork component that connects to the triple clamp above, and the slider tube below.

3.54 Frame—The structural part of the rear frame assembly. Attached to it, typically, are the fork assembly, the motor and transmission, the rear swing arm and suspension, the rider's seat, and numerous other mechanical components.

3.55 Frame Assembly—See rear frame assembly.

3.56 Frame Flexibility—Structural deflection and bending of the frame.

3.57 Frame Head—See steering head.

3.58 Frame Rake Angle—See rake angle.

3.59 Free Control—The situation where the rider provides no control input to the vehicle; typically, by removing his/her hands from the handlebar and making no body motions.

3.60 Frequency—For periodic or oscillatory motion, a measure of the cycles completed per unit time. See also SAE J670e.

3.61 Friction Damper—A device wherein the reacting force or torque is roughly constant with velocity, and results from Coulomb friction.

3.62 Front Assembly—See fork assembly.

3.63 Front Fork—See fork.

3.64 Gain—The numerical ratio between the amplitude of the output and input of a component under specified conditions.

3.65 Grooving—See pavement grooving.

3.66 Gross Axle Weight Rating (GAWR)—The value specified by the manufacturer as the load carrying capacity of a single axle system, as measured at the tire-roadway interface.

3.67 Gross Vehicle Weight Rating (GVWR)—The value specified by the manufacturer as the loaded weight.

3.68 Gyroscopic Moment—The reactive torque on the spin axis of a momentum wheel, resulting from precession.

3.69 Handling—The response properties of a vehicle as perceived and experienced by the rider acting as a controller.

3.70 Head—See steering head.

3.71 Heading Angle—The horizontal angle between a reference axis fixed in the vehicle and a reference axis fixed in the roadway, giving a measure of vehicle yaw rotation or directional orientation relative to the roadway. See also SAE J670e.

3.72 High-Side—A vehicle upset involving an extreme rolling and capsizing motion, where the upper part of the vehicle rolls towards the direction of travel.

3.73 High Speed Weave—See weave mode.

3.74 Hinge Line—See steer axis.

3.75 Inclination Angle—See camber angle.

3.76 Inertia—The resistance offered by a body to a change in its state of motion. See mass and moment of inertia.

3.77 Instability—The condition of being unstable, a tendency for the amplitude of motion to increase progressively without bound. See divergence.

3.78 Kinematics—The translational and rotational motions of the vehicle and its component bodies.

3.79 Lash—See snatch.

3.80 Lateral—To the side. See lateral-directional.

3.81 Lateral Acceleration—The side acceleration of the vehicle, in a horizontal plane and perpendicular to a longitudinal axis in the plane of symmetry. See also SAE J670e.

3.82 Lateral-Directional—Having to do with overall vehicle motions and forces to the side of the vehicle. Such motions include roll, yaw or heading, and side-to-side translation. They include the response to rider steer and side-to-side body movement inputs. Note: The remaining overall vehicle motions are mainly longitudinal.

3.83 Lateral Force—See side force.

3.84 Lean—See rider lean or (vehicle) roll angle.

3.85 Lift Force—An upward force, due to aerodynamic flow, lying in the vehicle's nominal plane of symmetry. A vertical force component if the vehicle is upright.

3.86 Linear Behavior—Motions when the vehicle response has the following (linear) properties: Superposition holds, the proportionality between input and output is independent of the input amplitude, the output cannot contain components at frequencies not present in the input, and the question of stability is unaffected by the nature of the input function and the initial conditions.

3.87 Link Ratio—The ratio of: (1) the force at the reference point in the suspension to (2) the normal force applied at the tire contact point when the wheel is perpendicular to the roadway.

3.88 Load Transfer—Refers to a redistribution in the normal load between the front and rear tires, usually due to braking or driveline torques. Aerodynamic forces, and rider and passenger position changes can be factors, as well. See also SAE J670e.

3.89 Longitudinal — Fore and Aft—In general, having to do with overall vehicle motions and forces in the nominal plane of symmetry. These motions include pitch, bounce, and forward translation. They include the response to rider throttle, brake, and fore and aft body movement inputs. Note: The remaining overall vehicle motions are mainly lateral-directional.

3.90 Longitudinal Acceleration—The fore and aft acceleration of the vehicle, in a horizontal plane and along a longitudinal axis in the plane of symmetry. See also SAE J670e.

3.91 Longitudinal Slip Velocity—The difference between the rotational velocity of a driven or braked wheel, and the rotational velocity of a free rolling wheel. See slip ratio.

3.92 Low-Side—A vehicle upset involving an extreme rolling and capsizing motion, where the upper part of the vehicle rolls away from the direction of travel, e.g., a lay down.

3.93 Mass—A quantity of matter. In the earth's gravitational field, 1 kg of mass weighs about 9.8 N (in the metric, SI system), and 1 slug of mass weighs about 32 lb (in the traditional U.S. system).

3.94 Mass Center—The point in a free rigid body where, if a force is applied, only translational acceleration results. Conversely, if a force is applied to a free body at any point other than the mass center, a rotational acceleration will occur, also, due to the resulting moment about the mass center.

3.95 Mechanical Trail—The perpendicular distance from the steer axis to the front tire contact point. It is sometimes measured horizontally, also, from the point where the steer axis intersects the roadway to the tire contact point.

3.96 Mode of Motion—For a vehicle composed of several interconnected rigid bodies, the total dynamic response consists of a summation of different motions; each associated with one or more lateral, longitudinal, or other degrees-of-freedom. Each of these several different kinds of motion can be termed a mode. These motions are characteristic of the vehicle; they are physically observable, and their quantification is independent of the choice of axis system.

3.97 Moment of Inertia—A measure of resistance of the mass of a body to rotation. It reflects the amount of mass as well as its distribution within the body. Torque applied to a moment of inertia results in a rotational acceleration, analogous to the way that force applied to a mass results in a translational acceleration.

3.98 Motocross—A motorcycle sporting event or race, run over a closed course on rough unprepared terrain, usually lasting less than an hour.

3.99 Natural Frequency—The frequency at which a periodic or oscillatory motion tends to occur when the body is not acted upon by a disturbing external force or torque. See also SAE J670e.

3.100 Nonlinear Behavior—Motions when the vehicle response has the following (nonlinear) properties: The relation between input and output is dependent on the input amplitude, the output can contain components at frequencies not present in the input, and question of stability can be influenced by the nature of the input function and the initial conditions.

3.101 Normal Load—The force on the tire at the tire contact point in a direction perpendicular to the roadway.

3.102 Off-Road—Not on a paved surface.

3.103 Overturning Moment—Torque from the roadway or other external source which tends to roll the vehicle or component body away from an upright position. Note: Usually refers to the torque on a tire and wheel caused by the tire side force. See also SAE J670e.

3.104 Passenger—A person on the vehicle who is not exercising control over the motions of the vehicle.

3.105 Path Angle—The horizontal angle between the vehicle velocity vector and a reference axis fixed in the roadway. The sum of the heading angle and sideslip angle.

3.106 Pavement Grooving—Channels cut into a paved surface for purposes of drainage. Usually in curves and in the direction of travel.

3.107 Performance—The behavior of a vehicle as related to some reference or criterion. Often applies to path and forward speed motions.

3.108 Perturbation Motion—A small amplitude motion, typically used to remain within the response region where the system behavior is linear. For example, to excite one mode of motion without significantly exciting the others.

3.109 Pitch Angle—The angle in a generally upward direction between a reference axis fixed in the roadway and a reference axis fixed in the vehicle, and measured in the nominal plane of symmetry of the vehicle. A vertical angle if the vehicle is upright. See also SAE J670e.

3.110 Pitch Moment—Torques about the same body-fixed axis which is used to define pitch velocity.

3.111 Pitch Rate—See pitch velocity.

3.112 Pitch Velocity—The rotational velocity of the vehicle about an axis fixed in the vehicle and perpendicular to the nominal plane of symmetry, i.e., a transverse of side-to-side axis. See also SAE J670e.

3.113 Pitch-Weave Coupling—An interaction that can occur between the pitching and weaving motions when the natural frequencies of these modes of motion are approximately the same. The result is a combined rolling, yawing, and pitching motion, in general.

3.114 Plane of Symmetry—For an upright vehicle, a vertical plane which splits the vehicle fore and aft, and which reflects the fact that two-wheelers are nominally symmetric left and right.

3.115 Pneumatic Trail—A way of defining the tire aligning moment relative to the tire side force. It is the horizontal distance between the point of action of the tire side force due to slip angle, or the camber thrust, and the tire contact point.

3.116 Pole—Mathematically an eigenvalue, which analytically describes a component of the motion of the vehicle.

3.117 Rake Angle—Generally, the angle between the steer axis and vertical when the vehicle is upright; more precisely called the frame rake angle. Note: There can also be a fork rake angle which is an angle between the steer axis and the slider tube axis (or whatever axis defines the instantaneous direction of front axle translation due to suspension motion). The fork rake angle is usually zero, in which case the rake angle is defined by the angle between the fork assembly axis and a vertical axis in the rear frame assembly, when the vehicle is upright.

3.118 Rear Fork—See swing arm.

3.119 Rear Frame Assembly—The connected set of components which comprises the vehicle, except the fork assembly. It includes the frame, motor, transmission and drive train, rear swing arm and suspension, rear wheel and tire, and other components attached to the frame. For mathematical modeling and analysis, the rider's lower body is often included, also, as if it were rigidly attached to the frame. The rear frame assembly plus the fork assembly constitute the vehicle.

3.120 Rider—The person who is exercising control over the motions of the vehicle. Also called the operator.

3.121 Rider Control—The processes the rider uses to maintain stability, provide damping, regulate against disturbances, and follow a prescribed path at a desired speed. See also feedback control.

3.122 Rider Lean—Motions of the rider's body relative to the vehicle for purposes of exercising control. See rider control.

3.123 Roadway—The surface or plane which is supporting the vehicle, and on which it is moving.

3.124 Roll Angle—The angle about an axis which is fixed in the vehicle, points forward, and is nominally horizontal when the vehicle is in an upright, straight ahead condition. Usually fixed in the nominal plane of symmetry. The roll angle is measured relative to a reference axis fixed in the roadway. See also SAE J670e.

3.125 Roll Moment—Torques about the same body fixed axis which is used to define roll velocity.

3.126 Roll Rate—See roll velocity.

3.127 Roll Velocity—The rotational velocity of the vehicle about an axis fixed in the vehicle, lying in the plane of symmetry, and nominally horizontal and pointing forward; i.e., a longitudinal axis. See also SAE J670e.

3.128 Rolling Resistance—A force opposite to the direction of travel resulting from deformation of a rolling tire. See also SAE J670e.

3.129 Root—Mathematically, the negative of a pole, see eigenvalue.

3.130 Rotational Velocity—Velocity about an axis, which does not include any translational component. See angular velocity.

3.131 Self-Aligning Torque (on tire)—See aligning moment.

3.132 Shimmy—Directional oscillation of a rotating wheel about a pivot axis perpendicular to the axle of the wheel; especially about the steer axis for a front wheel. Usually the wobble mode for a two-wheeler. See also SAE J670e.

3.133 Shock—See shock absorber.

3.134 Shock Absorber—A device to control suspension motions by producing reactive forces that are functions of velocity and position.

3.135 Side Force—Force that acts perpendicular to the nominal plane of symmetry of the vehicle. See also SAE J670e.

3.136 Sideslip Angle—The horizontal angle between a reference axis fixed in the vehicle and the vehicle velocity vector. See also tire slip angle. See also SAE J670e.

3.137 Single-Track Vehicle—One whose tires run along the same path in a nominal straight ahead condition. A two-wheeler.

3.138 Skid—The situation where the entire tire contact path is sliding relative to the pavement surface.

3.139 Slide-Out—See low-side.

3.140 Slider Tube—The lower fork component, which slides relative to the fork tube and carries the axle. Together, the fork and slider tubes contain the front suspension and provide for a translational degree-of-freedom in compression and extension.

3.141 Slip Angle—See tire slip angle.

3.142 Slip Ratio—The ratio of the longitudinal slip velocity to the rotational velocity of a free rolling wheel, expressed as a percentage. Also called longitudinal slip or percent slip. See also SAE J670e.

3.143 Snatch—Intermittent transmission of drive torque, usually due to lash or free play.

3.144 Solid Wheel—A one piece wheel structure, i.e., using a construction principle other than spokes.

3.145 Speed Wobble—An instability of the wobble mode occurring at very high speeds. Archaic.

3.146 Spin Axis—The axis of rotation, perpendicular to the plane of rotation of a body.

3.147 Spoked Wheel—A wheel constructed with tensioned spokes between the hub and the rim.

3.148 Spring Rate—The amount of force or torque produced by a spring as a function of deflection or position relative to a reference.

3.149 Sprung—Refers to vehicle components which are supported by the suspension.

3.150 Stability—The property of a system which causes it to return to a condition of equilibrium or steady motion when disturbed. The tendency for the amplitude of motion to decrease progressively; i.e., convergence.

3.151 Stability Margin—A measure of the amount of stability.

3.152 Steady-State Motion—That which continues unchanged over successive intervals of time. A stationary process or equilibrium condition. It can involve constant motion or cyclic motion in a repetitive pattern (e.g., oscillatory). See also SAE J670e.

3.153 Steer Angle—The angle of motion of the fork assembly about the steer axis, usually measured relative to straight ahead (the plane of symmetry of the rear frame assembly).

3.154 Steer Axis—The axis about which the rear frame assembly and the fork assembly rotate relative to one another. See also rake angle.

3.155 Steer Torque—Torque about the steer axis applied by the rider.

3.156 Steering Assembly—See fork assembly.

3.157 Steering Control—The rider's process of maintaining directional control of the vehicle by applying steer torque and steer angle inputs to the handlebars, in response to perceptual inputs. See rider control.

3.158 Steering Damper—A damping device which produces a torque about the steer axis.

3.159 Steering Gain—The steady-state relation between a vehicle motion (such as roll angle) and rider steer torque input.

3.160 **Steering Head—**Part of the rear frame assembly which contains the mount, bearings, and steering stem for the fork assembly.

3.161 **Steering Head Angle—**See rake angle.

3.162 **Steering Head Axis—**See steer axis.

3.163 **Steering Sensitivity—**See steering gain.

3.164 **Steering Stem—**The shaft of the fork assembly which is carried in the steering head. Note: The axis of this shaft is the steer axis.

3.165 **Steering Stops—**Mechanical obstructions which limit the maximum fork rotation.

3.166 **Stem—**See steering stem.

3.167 **Straight Line Stability—**The properties of the vehicle which cause it to proceed upright and without turning, in the absence of rider control. See capsize mode and stability.

3.168 **Street Motorcycle—**One designed principally for operation on paved roadways, under normal traffic and regulatory conditions.

3.169 **Surge—**Variations in applied drive torque for a fixed rider throttle control input.

3.170 **Suspension—**The assembly of mechanical devices which connects the axle of the rotating wheel to the main vehicle. It can include linkages, slider tracks, pivots, springs, and dampers.

3.171 **Suspension Stroke—**See suspension travel.

3.172 **Suspension Travel—**The displacement of a reference point on the suspension (such as the wheel axle) from when the suspension is fully extended (no force applied) to when it is fully compressed.

3.173 **Swing Arm—**The linkage which connects the rear wheel axle to the rear frame assembly. Sometimes called the rear fork.

3.174 **Swing Arm Angle—**The angle of motion of the swing arm about the swing arm pivot axis. This term also refers to the static (or trim) value of this angle.

3.175 **Swing Arm Pivot Axis—**The axis about which the swing arm rotates. It is usually perpendicular to the nominal plane of symmetry of the rear frame assembly

3.176 **Tank Slapper—**An extreme oscillation of the fork assembly relative to the rear frame assembly about the steer axis, which drives the steer angle from stop to stop. In general, it reflects unstable and divergent behavior of either the weave or wobble mode.

3.177 **Time Constant—**A measure of the response delay or lag, and damping, of a non-oscillatory dynamic system.

3.178 **Tire Contact Point—**The point on the ground lying at the intersection of the plane of symmetry of the wheel and the vertical plane which contains the spin axis of the wheel. See also SAE J670e. Note: When the wheel is cambered, the geometric center of the tire contact area can differ from the tire contact point, due to tire distortion and wheel flexibility.