SKID SIMULATOR FOR USE IN DRIVER TRAINING AND RESEARCH

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A large portion of accidents involve some type of skidding, yet most drivers lack knowledge of the procedures for avoiding skids or for bringing a skidding vehicle under control. The vehicle skid simulator being developed will provide a laboratory model of a skidding automobile in which the driver can experience the visual inputs and the yaw motions and learn how best to use the brake pedal, accelerator, and steering wheel to control his vehicle. The simulator rotates about a pivot point at the center of gravity of the skidding vehicle. The driver is placed in a potential skidding situation and told to keep the vehicle centered in a simulated lane. Manipulations of the controls are converted into voltages by transducers and fed into an analog computer programmed to represent the yaw responses of an actual automobile on various types of surfaces. The computed heading is compared to the actual heading, and the error signal is fed into a drive system that rotates the mock vehicle in the appropriate direction. Where friction demands are excessive for the simulated surface, speed, and tire conditions, a skid will be initiated. The simulator will be used for research to define the characteristics of control and skidding and to determine the potential for skid training. It will also be useful for studying some human-factors aspects of motion and acceleration effects on perception.

•IT IS quite obvious, even to the beginning driver, that some pavements are slipperier than others. The same pavement also varies from time to time with the presence of other materials, and recently the intense advertising and discussion of the virtues of snow tires, studded tires, belted tires, and radial-ply tires has made the general public aware that there are differences among tires. Although it is quite difficult to obtain reliable skidding accident data, there is a strong indication that the skidding accident rate is on the increase and that something beyond what is presently being done is required. For example, Miles and Shelton (1) report that skidding was a primary cause of accidents in at least 35 percent of all wet-pavement accidents in Virginia. A British study (2) reported that skidding was involved in approximately one-third of all wet-road accidents in Great Britain. Because of the variations in regional climate, pavement maintenance, and pavement composition, and because of differences in methods of obtaining the estimates of various causes in the United States, skidding accidents reported have ranged from 0 to 34 percent of the total at different times in different states (3).

Baker (4), in discussing single-vehicle accidents, concludes that most accidents appear to have numerous contributing factors, but "The factor which most commonly combines with others is a wet or slippery roadway. It is combined with almost every other listed factor, especially with lack of skill. . . ."

There also are seasonal variations in skidding accidents. Most wet skidding accidents happen in the summer and fall, obviously related to rainfall and to heat, which

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affects both the pavement surface and the characteristics of the rubber tires. As more reliable and faster methods for assessing the slipperiness of pavements are developed, it may be possible to modify or treat surfaces that become slippery at specific times of the year.

There are obvious differences in the requirements of friction at different situations in driving. On curves and intersections, especially where stop signs artificially increase the frequency of high friction requirements, a greater coefficient of friction is required and the greater wear results in faster smoothing of the pavement. Thus, any treatment of the existing surface is likely to be temporary because the wearing is a continuous process.

SOURCES OF DATA

Although it may be possible to discover useful information about skidding by investigating, in detail, a large number of skidding accidents, there are more direct studies of driver behavior that could provide information as a function of highway type, highway appearance, vehicle type, traffic, weather, average speeds, acceleration and acceleration patterns, tracking error and consistency, and similar variables. The driver, in addition to gathering information visually about the road surface, has other means for obtaining information about the surface and incipient skidding. For example, peripheral streaming patterns as cues to tracking performance and speed estimation have been investigated in a few studies (e.g., 5, 6), but much remains to be discovered on the uses and capabilities of cues from peripheral vision.

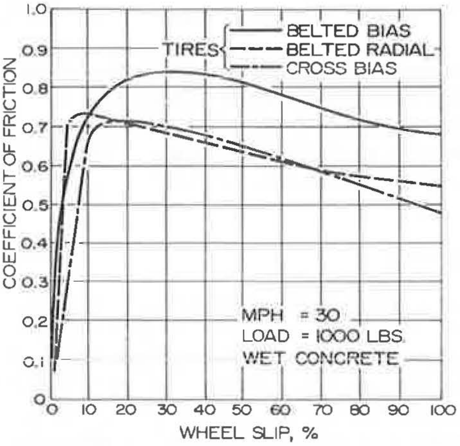
One of the potentially most useful sources of knowledge of roadway condition and available friction is the feedback from the road to the driver by means of the steering wheel. For example, the State Highway Patrol of California purchased over 1,500 vehicles with police specifications for use in the 1969 model year, choosing a moderately heavy vehicle, often a large Dodge model, specifying manual steering in all vehicles (personal communication, 1968). Discussion with the officer in charge of equipment disclosed that this was not a matter of cost or maintenance but strictly for the reliability, feel, and handling differences, which were felt to be important in high-speed driving under all road conditions. Undoubtedly, the highway patrolman is physically able to handle the occasional heavy torque demands of manual steering where a considerable portion, perhaps 20 percent, of the driving population would have difficulty. However, the strong preference for manual steering, even in a heavy car, indicates that some professional drivers feel that there are advantages.

Obviously, there are driver preferences as well as driver abilities that must be considered in developing a steering mechanism. Some sports cars have a reputation for their handling or feel. Racing drivers have developed preferences for individual types of steering, and there are many possible variations in the steering mechanisms, both power-assisted and manual. Driver preference for steering ratio or quickness has been considered, but there is no body of data relating steering ratio to accident rates or the effectiveness of evasive maneuvers.

Although there is a common feeling among many of the more mechanically inclined, especially young male drivers, that certain models are "good" and other models are "bad" in the way they handle, there is little known about the types or amounts of information that could be fed through the steering wheel to the driver. The dither signals generated by a driver during ordinary tracking can have very noticeable variations in the amount of torque feedback provided by different surface conditions and various speeds. Very likely there are cues that are used by drivers, even though they may deny knowledge of these cues.

Driver alertness and expectancy are serious problems in skidding emergencies. There are relatively few accidents on icy roads where the conditions are constant over a wide area, partly because drivers elect to stay off the road and partly because they adapt sufficiently to obvious conditions. It is unlikely that a driver will fall asleep when the conditions are obviously hazardous, but it is likely that the occasional patch of refrozen snow-bank melt will not be expected or observed by the driver who has been completely unchallenged for a long period of driving on dry, clear roads. The sudden change

Figure 1. Effect of tire construction on slip curve (from 8 as cited in 7).



of conditions is likely to produce a skid and unlikely to alert the driver in time.

Another area where driver expectancy could lead to loss of control is the range of effects of tire construction on handling qualities. Except for a slight increase in harshness of ride in some vehicles, the radial tire seems to have gained a reputation as the tire for all purposes. There are some indications that this reputation is not fully deserved. For example, many emergency maneuvers will result in some wheel slip. The maximum braking force occurs with a moderate rate of wheel slip. Generally, without automatic skid controls, a locked-wheel stop will result in a shorter stopping distance than is possible for most drivers attempting to use controlled-slip rates. In any event, once a skid has begun, a high coefficient of friction is still desirable. Figure 1 shows the effect of tire construction on the coefficient of friction with tire slip (7, from 8); the belted bias tire appears to be superior to the belted radial tire by a factor of 20 percent or more when slip has developed. Since the driver has need of this friction advantage in emergencies, the conservative choice for safety seems to be the belted bias tire. In any case, the more gradual change of coefficient with slip for the belted bias tire should give the driver a better degree of control than the abrupt peaking characteristic of the radial or regular bias tire. Its more consistent and predictable friction force for all degrees of slip is easier to handle.

The data on skidding and friction properties are complex and often display large variances. Most important, the theoretical conclusions from skid resistances and slip curves are not necessarily generalizable to driver behavior and vehicle reaction on the road. Whatever the characteristics, there should be methods for making the driver aware of the qualities of the various vehicles, tires, road surfaces, and road conditions that he may encounter or choose to avoid. In addition to setting performance standards for tires, the methods can involve improved or augmented feedback to the driver or widespread skid training and experience. The most effective technique would probably involve both improved feedback and skid training, although many basic questions have yet to be answered.

Recognition of the part training can play in controlling skidding is not new; there have been "skid schools" in Britain for many years. Although it may not be possible to operate skid schools at a profit in this country, it certainly would profit highway users as a group if everyone who drives had some knowledge of skidding control and prevention. In 1964, Liberty Mutual Insurance Company established their Skid Control School (Hopkinton, Mass.) to show how emergency training could be brought into advanced driver education programs. Other groups, including major auto manufacturers, also sponsor skid and winter driving courses. Research programs can be established in any area by the Department of Transportation, but it is a strong selling point for the utility of a program when it is established by a commercial firm such as an insurance company that stands to profit directly from an effective program. Liberty Mutual has sent their specially equipped cars and a driver trainer to several communities to illustrate the type of training involved and to help local jurisdictions set up skid schools. They recently have expanded their efforts along these lines by providing information on training and by demonstrating these skid-school concepts to groups involved in driver performance. Their program consists of sealing existing surfaces available to local groups to provide a low-friction surface and training local instructors in the skid techniques. These programs alone, however, cannot reach any large part of the driving public.

THE SKID SIMULATOR

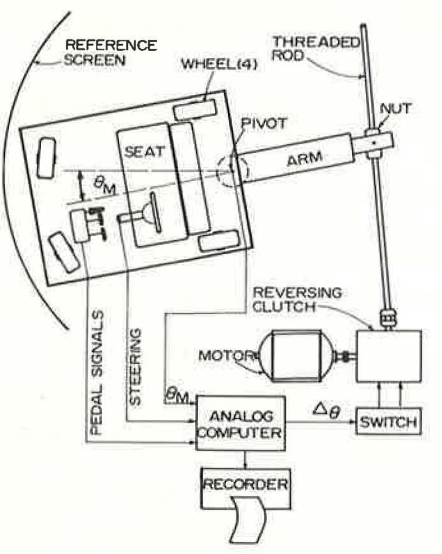
At Penn State, the skidding control and prevention program has several aspects: studies of road friction and surface wear, tire-pavement interactions, a vehicle skid simulator, and facilities for experiencing actual skids in a driver education training center driving range. Skid prevention obviously depends on road and surface design, and there is a considerable amount of study of these topics at Penn State and elsewhere. However, the field of driver behavior in skidding and awareness of skid potential has hardly been tapped. For this reason, a skid simulator is currently being developed with in-house funding at Penn State's Transportation Center. This one-degree-of-freedom simulator will require the driver to cancel random left and right yaws by means of the steering wheel and to control simulated skidding using the wheel and the pedal controls. By proper programming and use of motion, control, and visual variables, it should be possible to signal a potential skid to the driver and to train him to react properly to this feeling of "breakaway," counteracting the skid before it develops into loss of control. Correlation between driver behavior in the simulator and on the skid pad may provide some of the missing information. In addition, a simulator allows mathematical modeling and replicable training conditions that are difficult to achieve in an actual vehicle.

The skid simulator consists of the forward sections of an automobile mounted on a pivot to provide yaw at the command of an analog computer. The vehicle used was sectioned from just behind the front seat back and from the firewall forward, leaving the front bench seat, floor boards, front doors, dashboard, steering wheel, brake pedal, accelerator pedal, and roof intact. It rotates on 4 hard-rubber wheels, which are tangent to circles about a pivot point located just behind the front seat of the vehicle.

The drive system is shown in Figure 2. It consists of a rotating arm attached to the undercarriage of the vehicle and extending 5 ft out from the pivot point. At the end of the arm is a nut assembly free to rotate in the horizontal plane. The nut assembly is driven by a 1-in. diameter standard threaded steel rod that is attached to a universal joint and driven by a reversing electric clutch. The input to the reversing clutch comes from a constant-speed, 2-hp, 3,600-rpm ac motor.

The reversing clutch drive consists of an input shaft and an output shaft with two field and coil assemblies. By activating the appropriate coil, the output shaft is rotated either clockwise or counterclockwise. The analog computer will produce an output error signal $\Delta\theta$. This error is the difference between the desired yaw angle as computed by the mathematical analog and the actual yaw angle as measured at the pivot point. Transducers mounted on the steering wheel, brake pedal, accelerator pedal, and pivot point provide inputs for the computer simulation.

Figure 2. Skid simulator schematic diagram.



ANTICIPATED RESEARCH PROGRAM

Although the ultimate test is the driver's behavior in his own car during an unexpected skid, a simulator of this type may help to establish a behavior pattern that is appropriate to skid prevention without the time, expense, and possible hazard of actual training. After operational definitions have been developed, comparisons of trained and untrained drivers in actual skid-pan operations will be necessary for beginning the validation research. Long-term validation studies are likely to be the only source of statistically significant data relative to the effectiveness of training on a skid simulator.

One serious practical problem is that the frequency of skidding during driving is low enough that the potential value of training may be lost after a relatively short intervening period. Cost-effectiveness of skid training will undoubtedly require a low unit cost for periodic retraining, and practical programs must optimize the training cycle for convenience and potency over time.

A research program in skid simulation and training should include the following:

1. An expanded definition for vehicle handling "feel" with objective correlates;
2. A definition of, and threshold values for, incipient skid detection or "breakaway";
3. Development of a simple heuristic mathematical analog for realistic yaw motions in a skid simulator;
4. Validation of driver behavior in a vehicle after training in a yawing skid simulator and after various time lapses;
5. Theoretical integration of subjective qualities into a formal skid simulation analog based on the heuristic; and
6. Development of skid training programs that are both practical for widespread use and effective in teaching skid prevention and control.

It should be possible to simulate different types of vehicles and even different models within a vehicle type. A further extension of the modeling may include the skidding of articulated vehicles, where the trailer first swings freely and then influences the course of the vehicle pulling it. The different types of skids may also be demonstrated, including the power skid and recovery of steering control during and after a skid.

CONCLUSION

The in-car phase of driver skid training is necessarily expensive. Although any large-scale training of drivers could be done more economically on a simulator, the simulation must first be validated in the real driving situation. It is likely that actual experience will provide further refinement to the necessary skills, and emergency drivers such as police, firemen, ambulance drivers, and rescue teams will continue to require some in-car experience, even with a useful simulator. In addition, heavy vehicles, especially articulated vehicles, will present problems that will make simulation more difficult.

Commercial drivers of all types probably could benefit from skid training and practice, whereas wholesale in-car training of private drivers is less likely to be cost-effective. Since the potential saving in accident losses attributable to skidding probably exceeds 2 billion dollars per year, a reasonable investment, nationally, is indicated in skid prevention and control.

Little is known about driver perception of, or reaction to, incipient skidding or about the effectiveness of various types of skid training. The skid simulator, if it proves to be a valid representation of an actual vehicle skid, may provide both definitive data and a technique for convenient, low-cost training for emergency drivers, for problem drivers, and, ideally, for the general driving public upon routine renewal of driver licenses.

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