

2. KRASH, Structural Crashworthiness user's manual. National Technical Information Service, Springfield, Virginia 22161, U.S.A.
3. CVS, Crash Victim Simulation program user's manual. National Technical Information Service, Springfield, Virginia 22161, U.S.A.

Acknowledgment

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AN INSTALLATION FOR THE ACCELERATION AND GUIDANCE OF HEAVY TRUCKS FOR CRASH TESTS

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Abstract

To evaluate the performance of roadside barriers and bridge parapets, a facility has been developed for the acceleration and guidance of heavy trucks to high speeds. Motive power is provided remotely by a winch system that is driven by two 500 hp electric induction motors with a 3MVA supply. The characteristics of these motors are controlled during acceleration for most efficient operation and accuracy of final velocity. The vehicle is towed along a guidance rail capable of handling the side and vertical loading imposed.

Recent test programs have included a wide range of impact requirements with vehicle masses ranging from 150 tonnes down to one tonne and speeds ranging from 10 mph to 100 mph. The maximum energy design specification for the system was for a 38-tonne articulated truck at 50 mph.

Introduction

Roadside barrier and bridge parapet designs require practical testing of their performance in containing and redirecting vehicles which impact them. Depending on the specification, the impact vehicle can be drawn from the full range of vehicles used on the roads, that is from the small car weighing less than one tonne to the maximum permissible truck with a weight of about 40 tonne. Impact speeds tend to be high, 50 to 70 mph, as the roadside hardware is normally installed on fast major roads.

Other transportation problems, such as the movement of nuclear materials, also require facilities for large scale impact tests the following features need to be considered.

1. Target Representation. The length of barrier -- its installation in the ground -- end conditions for a tension barrier -- bridge deck simulation for a parapet.
2. Vehicle Selection. Typical of range or extremes of size -- type of load for trucks -- weight distribution.

3. Impact location/direction. At a specific point on barrier, i.e., a joint -- impact angle.
4. Impact Speed. Accuracy required.
5. Test Monitoring. Electronic instrumentation on vehicle and target -- high speed film coverage -- static measurement.

The representation of the test length of barrier is dependent on its design and is also influenced by previous experience. The test facility should be designed with space for the construction and installation of these barriers. This can involve extensive civil works.

The selection of the type of vehicle is governed by the expected performance of the barrier, national standards for this testing and the range of traffic conditions.

This paper will concentrate on the main tasks for a test facility, of directing and accelerating a test vehicle to impact at the requested position along a barrier and at the specified speed. Aspects of test monitoring will also be addressed.

General Description

There has been a facility for performing large scale crash tests on the site of the Motor Industry Research Association (MIRA) in the United Kingdom, since 1968. This is an outdoor facility and it was originally equipped with a guidance rail and winch to accelerate cars up to 70 mph for impact with various post-and rail safety barriers and concrete barriers. This installation was used for a large number of tests during the '70's.

However, with a growing requirement for "high containment" testing with heavier vehicles, the facility was uprated in 1982 with the collaboration of the Transport and Road Research Laboratory (TRRL). The performance specification was for the heaviest truck of 38 tonne allowed on the United Kingdom roads at a speed of 50 mph. In devising a system to conduct such test various methods of propulsion and guidance were investigated.

An established method, which is used by other testing agencies, is to have remote control for the vehicle brakes, steering and transmission. The vehicle is then accelerated under its own power to the required speed. The "driver" normally controls the vehicle from a car following close behind. Because the distance required for a fully laden truck to reach speed can be in excess of 0.5 mile this precluded using the technique on the MIRA crash site where distances of only 1200 feet were available. It implied that a remote propulsion source was needed.

Various sources of motive power were examined, such as, rocket propulsion and winches powered by electric motors, diesel engines or hydraulic motors. The first option was rejected on the grounds of safety hazard to a busy Proving Ground site.

Cost became the deciding factor when considering the winch options. Used electric motors were readily available in the power range required and their installation and control was likely to be less expensive than diesel engines or hydraulic motors.

The vehicle guidance system followed the design that had been used for many years at MIRA, but suitably uprated to cope with the heavier vehicles.

In summary, the developed heavy vehicle test system employed a 1100 foot

guidance rail along which the vehicle was towed by a 1000 hp electric winch. A schematic drawing of the crash site is shown in Figure 1 and the various features of the system are described in the next sections.

Electric Winch

In round figures, to accelerate a 40 tonne truck to 50 mph in 1000 ft implies an acceleration of 0.1g. This means an average pull of four tonne is needed on the truck. The power required varies with the speed and will peak at 1000 hp at the end of the run.

The electric winch was conceived simply as an electric motor driving a cylindrical drum onto which the winch wire was wound. The speed of the winch wire would be a function of the motor rotational speed and the drum diameter.

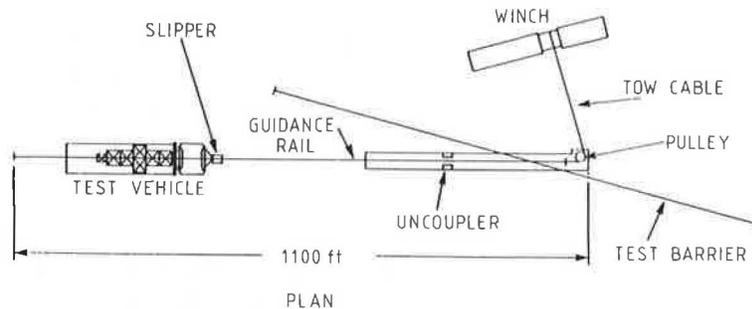


FIGURE 1 - Schematic of Crash Test Site

The decision was made, on the grounds of reduced cost and availability, to use a simple AC induction motor drive rather than a system involving the use of power-controlled commutator motors. It is difficult to achieve precisely controlled acceleration performance with the simple system but the sophisticated alternative would have been very special, on long delivery and considerably more expensive.

The particular type of electric motor specified was a "slip-ring" induction motor. This differs from the very simple "cage" motor in that the rotor coils are brought out to slip-rings to allow resistance to be introduced into the rotor circuit (Figure 2). A cage motor is ideally suited to a constant speed application but not to tasks where high accelerating torque is required. In contrast, the slip ring machine is suitable for both acceleration and constant speed work. In the acceleration phase the external resistance is varied in order to maximize the available torque and to limit starting current to acceptable levels.

The performance characteristics of a slip ring induction motor are shown in Figure 3. With zero resistance in the rotor and the motor at its "full load torque" operating point, any slowing of the motor due to increased load is immediately matched by a large increase in torque. Similarly, any reduction in load is matched by a rapid decrease in torque. However, if the motor accelerated from zero speed with this characteristic the average torque would be low and the required current very high.

Introduction of a given magnitude of resistance into the rotor circuit causes the torque peak to occur lower in the speed range and, in fact, it can be made to occur at zero speed. Even more resistance causes a reduction in torque at zero speed.

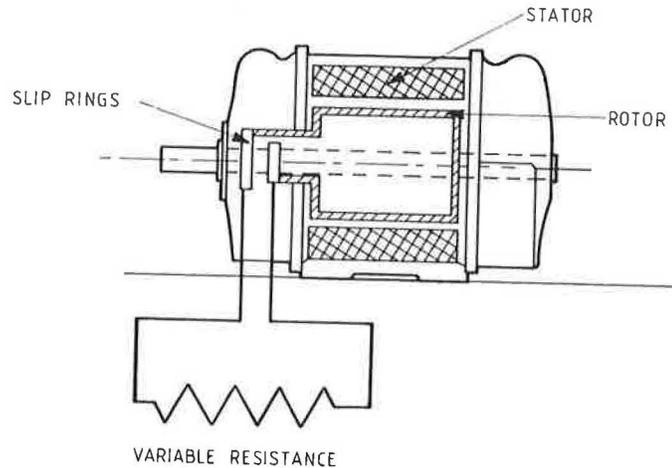


FIGURE 2 - Slip Ring Induction Motor (Simplified)

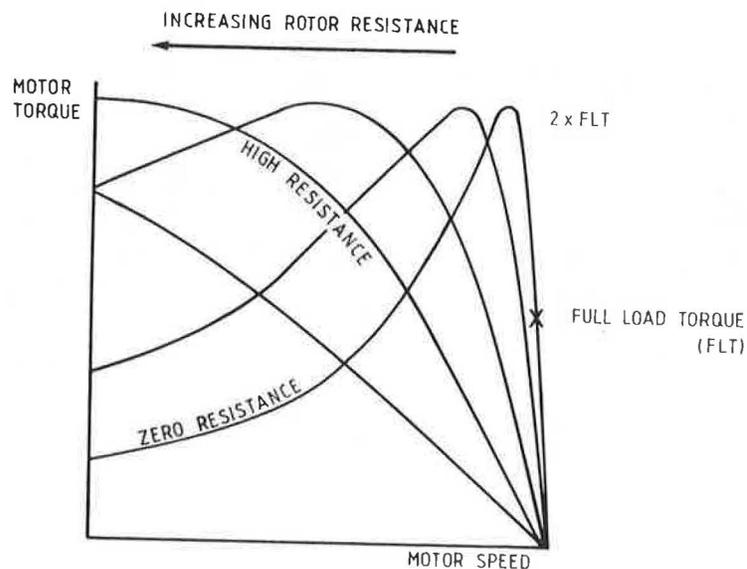


FIGURE 3 - Induction Motor Performance Curves

In concept, the operation of a slip ring induction motor as a winch requires varying the rotor resistance from a high to low value as the motor accelerates, so that the maximum torque follows the motor speed. Once the motor reaches its operating speed, this is held very accurately by the very steep torque-speed characteristic. Final vehicle velocity can be considered to be only a function of the winch rope winding diameter. Figure 4 shows the typical performances of the winch system in accelerating a heavy vehicle. acceleration of heavy trucks

The final design for the winch system was, to a certain extent, dependent on available used motors. Two reconditioned 500 hp motors, having the specified characteristics were found in Europe and they were mounted each end of the winch drum shaft (Figure 5). This construction had some advantages in that just one of the motors could be used for light duties with a reduction in power requirements.

The motor "no load" speed was normally 750 rpm and a winch drum base diameter of 20 in was designed for 50 mph with three rows of 0.75 in steel rope.

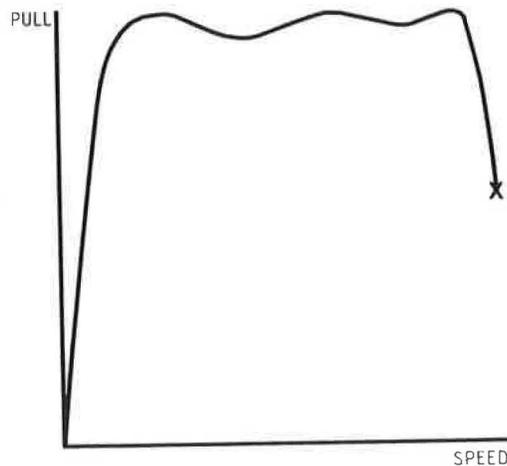


FIGURE 4 - Typical Winch Performance during Acceleration of Heavy Vehicle



FIGURE 5 - Winch Motor and Drum

Higher speeds were achieved by increasing the drum diameter with semicircular split drums. Drums exist for 50, 60, 70, 80 and 100 mph. Tests at speeds lower than 50 mph were obtained by using a 2:1 reduction pulley system.

Electrical Power Supply

For the first year of operation, the winch was energized from large mobile electricity generators; two 1.5 MVA generating sets were required for maximum system performance but their behavior under the inevitable "surge" conditions was not wholly satisfactory. Early in 1984, in view of the workload and the shortcomings and expense of hiring generators, a permanent electrical supply was connected to the site.

Guidance System

For guidance the vehicle is connected by two short ropes from each end of its front axle to a "slipper" which runs along the guidance rail. The steering of

the vehicle is normally left free. The end of the winch rope attaches to the slipper and the vehicle is hauled along the rail to the impact point. If the



FIGURE 6 - Vehicle Guidance System

vehicle deviates from its path one of the short ropes goes more taut and provides a lateral force to bring the vehicle back. Consideration of the control fences required for a 40 tonne truck dictated a 10 tonne strength for the rail in any direction.

The rail consists of two I-beams in 20 ft. lengths, welded together along their length. These were fixed to the ground with masonry bolts. The slipper is provided with rollers and bearing surfaces to operate on the rail section. Figure 6 shows some aspects of the guidance system.

Vehicle Disconnection

A cam system is provided some short distance before the impact point to disconnect the winch rope and the two short ropes to the vehicle from the slipper. The vehicle then free-wheels into the target.

Test Monitoring

Data from impact tests is obtained by two main methods, high speed photography and instrumentation.

Each test is normally photographed by up to twelve high speed cameras operating at 250 frames per second. Higher or lower speeds are used dependent on ambient lighting levels. Because the site has a substantial electrical supply for the winch, there is also provision for several hundred kilowatts of lighting for localizing high speed photography, whatever ambient lighting conditions prevail.

The relatively short run-up distance for vehicles means that umbilical cable systems can be used for on-board instrumentation although damage to cables after the impact can be expected. Accelerometers and angle rate sensors are the normal transducers installed at the center of gravity of the vehicle. Anthropometric dummies are seated in cars and measurements made to the specification of FMVSS 208 during the impact.

Instrumentation is also mounted in the safety barrier or bridge parapet under test by TRRL, to record forces or strains in the structure.

Performance Conclusion

MIRA in collaboration with TRRL has designed and constructed a test facility for conducting impacts tests with heavy vehicles at high speed. Recent test programs have included a wide range of impact requirements with vehicle masses ranging from 140 tonne down to one tonne and speeds ranging from 10 mph to 100 mph. Typical tests with the system are given in Table 1. Experience of using the winch system has demonstrated that speed accuracies of better than -0 to +2 mph can be expected even at speeds of 100 mph. This speed accuracy is relatively independent of vehicle mass due to the consistent terminal speed of the induction motors used to power the winch.

PAYLOAD	DISTANCE	SPEED
1.5 ton car	350 ft	70 mph
16 ton truck	650 ft	50 mph
38 ton truck	1000 ft	50 mph
2.5 ton sled	600 ft	100 mph
16 ton truck	320 ft	50 mph

Table 1 - Typical Winch Performance