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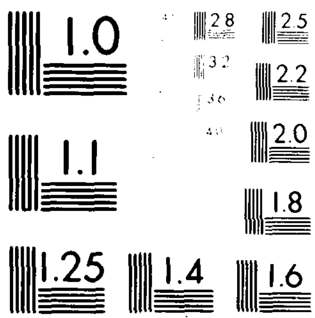

MICROCOPY RESOLUTION TEST CHART

HIGH PERFORMANCE VEHICLES

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Survivability on the modern battlefield has become increasingly difficult. The development of more lethal armament has pushed armor to the limit. Historically the increased armament threat has been challenged by improving the armor of the fighting vehicles, especially tanks, but the current situation requires a different approach. The proliferation of effective weapons on the battlefield has pushed tank weights to 60 tons, which is very near the practical weight limit.

There are several ways to increase survivability on the battlefield including reducing crew sizes and re-packaging the crew and equipment. Another possibility that is being explored is to determine the effect that mobility and agility have on vehicle survivability. The determination of the influence of mobility/agility on battlefield survivability is the subject of this paper.

The Armored Combat Vehicle Technology (ACVT) program was started several years ago and includes both the development of vehicle concepts with varying weights and performance and the testing of hardware to validate vehicle performance characteristics. The two test beds that have been built and are being tested are the High Mobility Agility Test Vehicle (HIMAG) and the High Survivability Test Vehicle (Light), (HSTV(L)). The HIMAG vehicle can accommodate many variations in engineering properties (vehicle weight, wheel travel, wheel base, etc.) and has been tested at vehicle weights from 32 to 45 tons. The HSTV(L) had a design weight of 19 tons and uses a gas turbine engine to obtain high performance at the light weight. Both of these vehicles were designed to have high mobility performance with complementing automotive and suspension systems. Each of these vehicles are equipped with a 75mm automatic cannon and the HIMAG vehicle will be used to evaluate several different fire control systems. The power/weight ratios of these test beds are at least equal to that of the XM-1 and have the same wheel travel, 15-16 inches from static to bump stop. Although these programs are interacting, they will be used to supplement the concept study, which is being pursued concurrently.

The concept study has many phases. Using the concepts developed by TARADCOM, individual vehicle performance will be predicted over a variety of terrains. These performance predictions will be made using the U.S. Army Mobility Model (1, 2) over selected terrains in West Germany and Jordan. These vehicle speeds are used as inputs to several other analytical models. The Army Systems Analysis Activity (AMSAA) uses the information in their DUEL model, which evaluates the probability of hits/kills when the vehicle and weapon performances are integrated. The BDM Corporation has developed a model (MOBAG) to evaluate the effectiveness of evasive maneuvers on survivability. A more complete description of this model is a mobility/agility armor anti-armor survivability model. The output from these various analytical models will provide input data for TRASANA, U.S. Army TRADOC's System Analysis Group, when they conduct a force-on-force war game. These war game results will assist in evaluating the effectiveness of mobility/agility on battlefield survivability.

Preliminary to all of these evaluations, TARADCOM developed a total of 25 vehicle concepts which met various requirements and would present a sufficient variation in performance for the mobility/agility evaluation procedure. The guidelines for the design of the 25 concepts were specific weight, automotive performance, and weapon selection. The range in vehicle weights were 16 tons, 23 tons, 40 tons, and 60 tons. The 16 ton vehicles are an attempt to accommodate the requirement of being helicopter transportable. The upper weight limit of 60 tons was selected to be compatable with the XM-1. The original goal was to have automotive performance that equaled the XM-1 and went up to the HIMAG level. The combination of power/weight ratio and wheel travel was designed to achieve these mobility levels, at a minimum. This was interpreted to mean horsepower/ton ratios of 25/1(XM-1) to 37.5/1(HIMAG) and 15-16 inch wheel travels. To meet these power levels, the engines and transmissions which would be available within the expected time frame were examined. The engines and their power outputs used in this evaluation were XM-1 (1500 HP), XM-2 (500 HP), a single rotor rotary (375 HP), a two rotor rotary (600 HP), and a turbo-compounded XM-2 (at 800 HP and 1000 HP). Using these engines, the desired goals of HP/ton ratios of 25/1 minimum were not met as some of the concepts increased in weight beyond the pre-selected values. The wheel travel of the concepts vary from 13 inches to 16 inches.

The weapon selection included both a high velocity 75mm and 90mm, along with several missile systems. The cannons were configured in both externally mounted and turreted. Several crew sizes were used, with 2, 3 and 4 man crews depending upon the missions and the weapon selection. Vehicle concepts were designed to meet several specific mission requirements and these requirements dictated the weapon selection. The concepts were designed to meet at least one of six missions:

1. USMC Mobile Protected Weapon System
2. Main Battle Tank Replacement in Calvary Units
3. Calvary Vehicle with Anti-Armor Capability
4. Follow On to the Improved TOW Vehicle (ITV)
5. Light Tank in Light Division
6. Infantry Vehicle with Anti-Armor Capability

The protection level of each concept is different and is dictated by the gross weight limitation. The protection level was limited to the available "extra" weight after the essential elements have been included. The essential elements are defined as hull, suspension, power train, crew, weapon and ammunition (gun or missile), fuel, OVE, etc. Obviously, the lighter weight vehicles have less protection. Within the same weight range, crew size, weapons, and packaging may make the protection different.

One of the key elements for improving survivability through mobility/agility is the capability of achieving a high rate of speed and maintaining this rate of speed while performing a mission. The vehicle suspension system is very important to achieving the goal of high cross country speed, and adequate wheel travel is essential to high speed operation. The suspension system must be of a balanced design with appropriate combinations of wheel travel, spring rates, and damping rates. The suspension systems were designed to the latest guidelines from TARADCOM's Suspension Group. It is important to establish a ride limiting speed for each concept to ensure that the crew can still function while the vehicle is moving. For each concept, this ride limiting speed as a function of crew comfort was determined using a two-dimensional ride dynamic simulation model (3). The various vehicle parameters were estimated and the concepts were simulated while traveling over a variety of terrain roughnesses at various speeds. To evaluate the differences in vehicle/crew performance, the criteria of absorbed power in the vertical direction was selected based upon previous laboratory and field tests. In the early 1960's, the U.S. Army TARADCOM conducted many tests on people to determine the maximum vibration that could be tolerated comfortably (4, 5). There were over 1400 hours of testing with 31 volunteers being subjected to both random and sinusoidal inputs (6). When all of this data was reduced, it was concluded that an average absorbed power level of 6 watts in the vertical direction was the maximum comfortable limit for a sustained period of time. The absorbed power criteria is a method where the frequency of the induced acceleration is as important as the magnitude of the acceleration. This criteria of 6 watts average absorbed power at the driver's position has been used in field tests and simulations to evaluate ride dynamic performance of vehicles.

During these many field tests, several other observations have been made. Although the ride limiting speed was determined by using the 6 watts absorbed power criteria, it was noted that vehicle operators were willing to absorb higher levels of energy for a short period of time - up to 30 minutes. Using this data as a guideline, it was determined that an absorbed power level of 12 watts would be used in the situation where the driver was highly motivated, probably for self-survival. Another operational limit was noted during product improvement testing of the M60A1. At these tests, the M60A1 gunner did not attempt to fire the main weapon when he was subjected to more than 2 watts absorbed power. The exact reasons for this gunner response are not known and have not been documented but it provides a starting point for evaluating vehicles for fire-on-the-move capability. To summarize the ride dynamic evaluation, crew functioning vehicle speeds were determined for three different absorbed power conditions:

1. 6 watts at the driver's station.
2. 12 watts at the driver's station.
3. 2 watts at the gunner's station.

All of these absorbed power levels are taken in the vertical direction only. The extremes in vehicle performance, based upon ride quality, are given in Figures 1 through 5. Figures 1 and 2 show performances based upon the driver limit of 6 and 12 watts absorbed power.

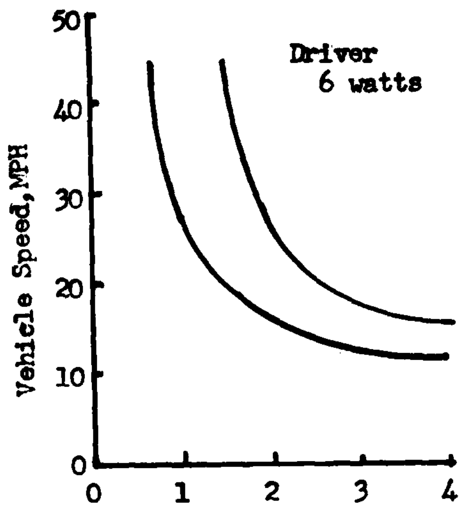

Fig. 1

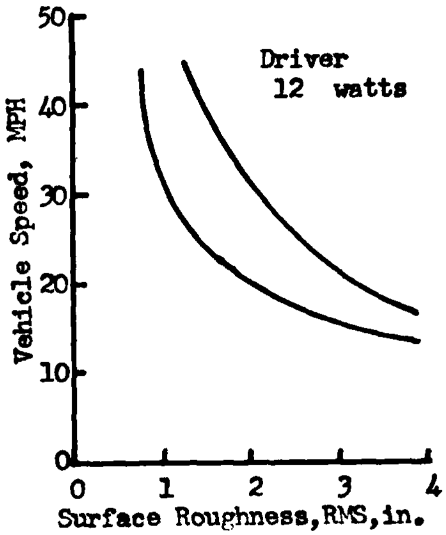

Fig. 2

The 25 vehicle concepts have wheel travels that range from 13 inches to 16 inches, measured from static to bump stop. It would seem that this difference in wheel travel would not make much difference in the ride quality. Also, the vehicle with the largest wheel travel should have the best ride dynamic response. These expected results are not always true as shown in Figures 1 and 2. All 25 concepts fall within the performance bands outlined but there is a significant difference between the best and the worst. In some cases, the speed difference is 15-20 miles per hour. There are several critical parameters that are more important than a wheel travel difference of three inches. The two most critical parameters are the location of the sprung mass center of gravity with respect to the center of the suspension system and the driver location. The driver position does not vary significantly in relation to the hull, but does vary up to 28 inches relative to the center of gravity. The vehicle center of gravity is located at a maximum variation of ±10 inches from the center of suspension. The ideal location is for the center of gravity and center of suspension to have the same relative position in the longitudinal direction (fore-aft). This results in equal wheel loadings and minimum disturbances to the hull when travelling cross-country.

The largest percentage of terrains that have been mapped fall within the surface roughness range of 1.5-2.5 inches root-mean square (RMS) elevation. Over the very rough terrains, those with RMS values greater than 3.0, all vehicles travel at approximately the same speed. This is because the roadwheels hit the bump stops regardless of the available wheel travel because the terrains have low frequency wave lengths. The same general trend of vehicle performance follows for driver limited speeds at 12 watts absorbed power.

Figure 3 shows the spread between the concepts at the fire-on-the-move (FOM) limit of 2 watts at the gunner's seat. The vehicle speeds are much lower for this FOM capability and the differences between vehicles is much greater due to the variety in gunner location. In some of the vehicles, the gunner is located very near the sprung mass center of gravity (and receives the best ride), and other, two-man vehicles have the gunner sitting next to the driver, which gives him the maximum vehicle motions. The driver and gunner in a side-by-side configuration is the least desirable location for maximum FOM vehicle speed.

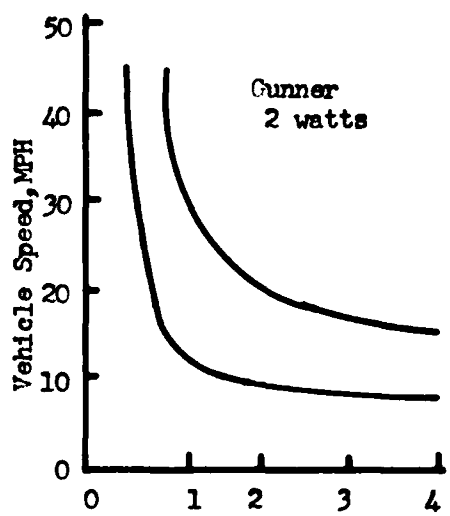

Fig. 3

(476)

The ride dynamic performance of all 25 concepts was included in the performance bands shown in Figures 1, 2 and 3. To illustrate the performance of individual concepts, Figures 4 and 5 represent the speed variations for given concepts. With some of the vehicles, the ride limiting speeds are nearly the same for the driver at 6 watts and the gunner at 2 watts absorbed power. Conversely, many concepts will have to slow down significantly when it is desired to fire-on-the-move accurately.

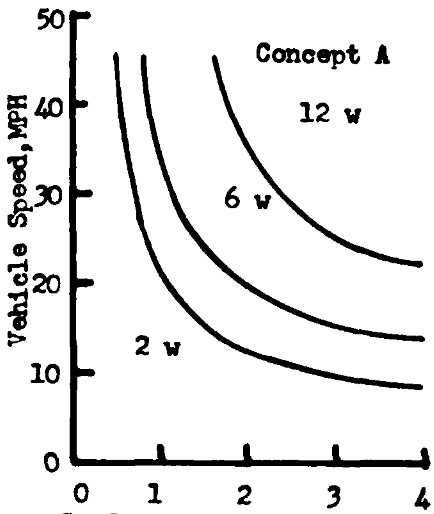

Fig. 4

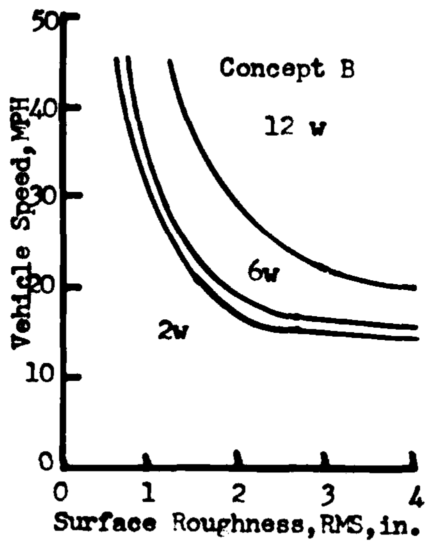

Fig. 5

The hypothesized advantage of the lightweight, high mobility vehicles is in the capability to reduce exposure time between defilade positions and perform evasive maneuvers to avoid being hit when fired upon. The reduced exposure time is a function of vehicle acceleration and elapsed time required to dash between cover positions.

For the concepts being evaluated, the performance envelopes for these two characteristics are shown in Figures 6 and 7. The difference in accelerations is significant and a function of both the vehicle weight and available power (7). The exposure windows used in the war games are based on field visibility data, but any reduction in time to cross these "windows" will increase survivability. It should be emphasized that the performance shown in

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Figures 6 and 7 are for hard surface, good traction soil conditions. Any deterioration in these soil conditions will degrade vehicle performance.

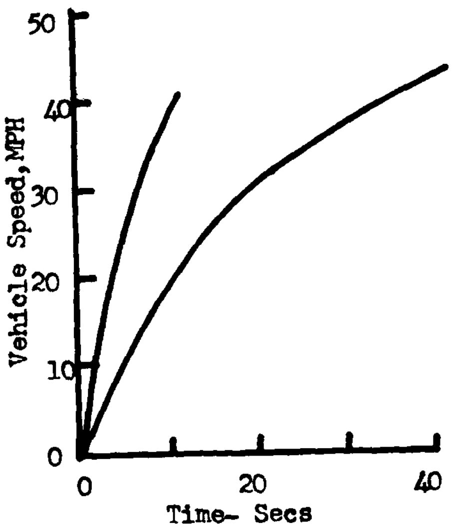

Fig. 6

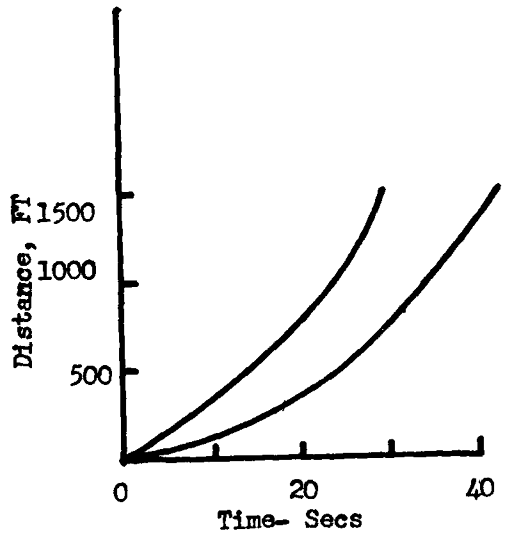

Fig. 7

The automotive performance of the concepts has been addressed, but how this performance will be used for evasive maneuvers has not. To evaluate the potential of performing evasive maneuvers while being fired upon, the BDM mobility/agility (MOBAG) model will be used. This model integrates the total systems, including detection, being acquired by a threat, firing on by the same threat, and the probability of being hit/killed. This model uses line of sight and visibility data taken during field exercises to determine the exposure windows during an attack upon a fixed defender position. The maneuvers employed while crossing these exposure windows will be varied to evaluate increased performance. As a pre-processor to this MOBAG evaluation, the vehicle concepts were simulated doing several sine wave maneuvers over the terrain that might be encountered. The particular sine wave maneuvers vary in wave length from 50 to 250 meters and in amplitude from 3.5 to 15 meters. For each of these maneuvers, the vehicle longitudinal and acceleration, lateral acceleration, and vehicle attitude with respect to direction of travel are recorded and used by MOBAG. The MOBAG model uses the basic assumption that the most significant parameter to avoiding being hit is the vehicle lateral acceleration. Therefore, for each exposure window, the vehicle path and defender position are used to determine the angle for which the vehicle velocity and accelerations must be corrected. All potential evasive maneuvers are evaluated for each concept/exposure window combination to determine which single maneuver maximizes survivability.

These data will provide the basis for evaluating the effectiveness of mobility/agility on vehicle survivability. In conclusion, the capability to design vehicles with wide ranging weight, power train performances, and armor to meet specific U.S. Army requirements has been demonstrated. The potential of these concepts to perform the task for which they were designed is currently being evaluated. There are many ways to approach the problem of increasing battlefield survivability, and you now have been exposed to a system for evaluating survivability as influenced by high performance vehicles.

REFERENCES

1. Staffs of US Army Engineer Waterways Experiment Station and US Army TACOM, "AMC '71 Mobility Model", TACOM Report No. 11789, July 1973.

2. P. Jurkat, C. Nuttall, P. Haley, "AMC '74 Mobility Model", TARADCOM Report No. 11921, May 1975.

3. F. Hoogterp, "Interactive Vehicle Dynamics and Ride Evaluation Package", TARADCOM Report No. 12413, November 1978.

4. F. Pradko, R. Lee, V. Kaluza, "Theory of Human Vibration Response", ASME Paper 66-WA/BHF-15, December 1966.

5. R. Lee, F. Pradko, "Analytical Analysis of Human Vibration", SAE Transactions, Vol 77, Paper 680091, 1968.

6. W. Lins, "Human Vibration Response Measurement", TACOM Report No.11551, June 1972.

7. J. Wollam, "Interactive Drive Train Model", TARADCOM, unpublished.