Vehicles for Traversing the Twilight Zone

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The Army has been looking for the "go anywhere" vehicle for many years. It has succeeded in developing vehicles that will go on land and in the water, but so far, a completely satisfactory one that will traverse that "in between" area has not been found. This "in between" area, or twilight zone, is a combination of soft soil and water where the soil is not solid enough to provide conventional vehicles with sufficient support and traction nor fluid enough for a vehicle to execute its amphibious capabilities.

The soil strength, both the bearing and traction capacities, is a function of the shear resistance. The shear resistance is measured by a cone penetrometer and is expressed in terms of the cone index. The twilight zone is in the area of 5-10 cone index. To give a comparison of how soft or marshy this is: water has a cone index of 0 and man when standing will sink in mud with a cone index of 20.

Traversing the soft terrain has always been a problem. In the mid-1940's, the U.S. Army Engineer Research and Development Laboratories began development of several types of crawler tractors to increase their mobility in soft terrain. Various methods of increasing the ground contact area were attempted before finalizing on a track shoe that was approximately twice the original width. This extra width decreased the ground bearing pressure from 9 to 4.5 psi which enabled the low ground pressure tractor to surpass the standard tractor in all mobility tests conducted over snow and muskeg in Canada.

The performance of wheel vehicles was also investigated in soft terrain during the same period. Several traction devices tested on military vehicles were chains, snap-on tracks, and retractable lugs for single or dual tandem wheels. These traction aids improved the performance of the wheel vehicles but did not satisfy the requirements for mobility in soft terrain.

During 1965, in a continuing effort to increase mobility in marginal terrain, USAERDL within three months designed and fabricated three vehicle concepts in-house and monitored the design and fabrication of a fourth under a research and development contract. These vehicles were designed to transport three men and their equipment over marginal terrain, have a limited range and life expectancy, and be inexpensive. All were to have speeds of 10-12 mph on land and 3-4 mph in the water and have frontal armor protection against small arms fire. In addition, the configuration was to be such that three vehicles could be carried internally in the CH-47, Chinook helicopter.

ABSTRACT

Four vehicle concepts have been developed to traverse the twilight zone and increase mobility in marginal terrain. These vehicles have a low ground bearing pressure and shallow draft. They were designed to transport three men and their equipment, have a limited range and life expectancy, and be inexpensive. Each vehicle has frontal armor protection from small arms fire and is designed to be carried internally in the CH-47 helicopter. The four vehicle concepts have undergone a feasibility test over various types of terrain and exhibited enough mobility to warrant modification and retesting to obtain additional performance data on the various drive configurations.
The four vehicle concepts developed for traversing the marginal terrain are the drum concept, the drum-belt concept, the track concept, and the track-pontoon concept. The weights of these vehicles are 2000 lb for the drum concept to approximately 2500 lb for the other concepts, and the dimensions are approximately the same, 10 ft long, 6-1/2 ft wide, and 5 ft high. All the vehicles have a low ground bearing pressure of approximately 1.5 psi and a shallow draft.

All vehicles have undergone the first phase of feasibility testing. In these tests, each concept had deficiencies which hindered the performance over one or more of the test courses. These vehicles have been modified and testing will be resumed in the fall of 1966. The present configuration of each vehicle is described in the following paragraphs.

**VEHICLE CONCEPTS**

**Drum Vehicle** - This concept features four large drums, articulated steering, and aluminum construction except for the steel armor (Fig. 1). The drums are 30 inches in diameter, equipped with overlapping grousers and filled with polyurethane foam. The foam not only prevents the drum from flooding in case it is ruptured, but adds structural rigidity allowing use of thinner materials. The four drums have sufficient buoyancy to float the vehicle with its payload.

The front drums and the rear drums are powered individually by a hydraulic motor driving through a differential. Power for the motors is supplied by two variable displacement pumps driven by a 30 hp air cooled engine with an interconnecting linkage between the two pumps to synchronize the speed of the motors.

The front drums are rigidly suspended from the front structure which houses the operator and passenger compartment, while the rear drums, with supporting structure, are free to articulate. This vehicle is unique because it can articulate 90 deg not only in the horizontal plane but also 90 deg downward in the vertical plane. Since the drums are powered hydraulically, drive shafts and universal joints do not limit the articulation in either direction.

With vertical articulation, all wheels will remain on the ground and provide tractive effort although the center of the vehicle may drag when crossing a large log or mound of earth, whereas when the center of a conventional wheel vehicle with a rigid frame and a small ramp breakover angle becomes lodged on an obstacle, traction is supplied by only the front or rear wheels depending on the center of gravity and the fulcrum point (Fig. 2).

**Drum-Belt Vehicle** - This concept is a combination of drum and track-type vehicle (Fig. 3). The four drums, 30 in. in diameter, are filled with polyurethane foam and have diagonal, overlapping grousers welded to the outer portion with provisions for a belt drive on the inner portion. The grousers provide aggressive action while the belts transmit power from the rear to the front drums and provide additional traction and support for the vehicle in soft terrain. The belts are made of 12 in. wide conveyor belting with spring steel bars fastened to them which are used for guiding the belt on the drums and to prevent slippage between the drum and the belt (Fig. 4). Tensioning of the belt is accomplished by a center idler acting downward on the top of the belt. Tensioning the belts this way is less efficient than increasing the center distance between the drums, but this method permits the operator and passenger seats to be lowered which in turn lowers the center of gravity and silhouette.

The rear drums are powered independently by a two-speed
Fig. 4 - Grousers and belts on drum-belt vehicle

Fig. 5 - Track vehicle

Fig. 6 - Track-pontoon vehicle

hydraulic motor which is powered by a split flow variable displacement pump. The pump is driven by a 20 hp military standard air cooled engine through a reduction box.

This type of drive has the advantage of providing power to all drums while steering. With controlled differential speed between one side and the other, an infinitely variable turning radius can be obtained. When the vehicle is in water or soft soil, the drums on one side can run in one direction while the drums on the other side can run in the opposite direction.

Tract Vehicle - The body of this concept is similar to a boat hull with a track mounted on each side (Fig. 5). As mentioned earlier, a limited life and inexpensive vehicle were part of the requirements, so the body was fabricated from wood and coated with fiberglass. The vehicle has rigid suspension and is supported by ten road wheels, five on each side. The track is made of 14 in. wide, 2 ply nylon conveyor belt with either aluminum or wooden grousers fastened to it. Power is supplied to the tracks by an 18 hp air cooled engine driving through a variable speed transmission and the rear mounted drive sprockets.

Steering of this track vehicle is accomplished by de-clutching and braking one track and powering the other, a type of steering known as “skid steer.”

Propulsion of the vehicle in the water is provided by the tracks and a 9 in. propeller. The weedless propeller, which is partially enclosed in the hull, is not as vulnerable to obstacles in the water, and its action is similar to a hydrojet.

Track-Pontoon Vehicle - The fourth concept was procured under contract from Quality Marsh and Equipment Co. of Thibodaux, La. This vehicle has two pontoons, one on each side of the body with a track rotating around it (Fig. 6). The pontoons, an aluminum weldment filled with polyurethane foam, have a recess in the bottom for the chain to ride in to keep the track from coming off. The tracks are made of sections of aluminum channel bolted to the flanges of a conveyon chain. With the buoyancy provided by the pontoons and the high ground clearance, the body of the vehicle does not normally touch the water while swimming.

Conventional track vehicles have road, or boggie, wheels which distribute the weight onto the track. These wheels become clogged with mud and vegetation when operated in marshy terrain thereby increasing the weight and rolling resistance which eventually may cause the vehicle to stall. This concept, using pontoons and no road or boggie wheels, has less tendency to collect foreign matter than does a conventional vehicle.

This vehicle has been reworked to include a turbocharged air cooled engine which develops 45 hp at 3600 rpm. The engine is a military standard that has been modified to add a turbocharger and new heads with larger fins for more cooling. Power is transmitted from the engine through a three speed mechanical transmission into a standard military jeep differential and rear axle. To steer the vehicle, one track is stopped and the other is powered through the differential. The conventional shoe brakes have been removed and multi-disc brakes are used to provide the additional braking effort required for steering.
Prior to testing, the vehicles were driven into a CH-47 helicopter, secured, flown to the test site, and unloaded. Only two vehicles were carried internally at one time, but dimensionally, three could be carried. The track-pontoon vehicle is seen being unloaded from a helicopter in Fig. 7.

TESTING OF VEHICLE CONCEPTS

The initial feasibility tests were conducted on the four vehicles the latter part of the summer of 1965. The vehicles were tested over level and sloping turf, bare soft soil, rice paddies with associated dikes and soft soil paddy floors, marshes, and deep water. In some tests, a true evaluation of the vehicle performance could not be made because the vehicle did not have sufficient power to demonstrate its full potential. However, these vehicle concepts exhibited enough mobility in marginal terrain to warrant modification and retesting to obtain additional performance data on the various drive configurations.

Drum Vehicle - With the large drums, articulated steering, and simple controls, this vehicle was easy to operate and had good mobility on the level and sloping turf. In the bare soft soil having an average cone index of 10 from 0-12 in., the penetration of the vehicle was only 3-4 in., but it experienced difficulty because of insufficient power. In the marsh, the vehicle had very little trouble on the level terrain as the vegetation was bent over forming a mat to ride over. However, where there were rises or dikes, the engine again stalled preventing the vehicle to negotiate the course. The articulating steering of the vehicle in the water was not as effective as expected. Although the vehicle could pivot steer by locking one of the rear drums against the body, controlled steering was difficult and maneuvering in the water was not satisfactory. Uneven weight distribution affected controlling the vehicle in water as it would turn in the direction it was leaning and when trying to counteract this by the articulated steering, the vehicle would travel off course on a diagonal. To correct this steering problem in the water, it is planned to install brakes on the rear drums and use them independently rather than the articulation.

Drum-Belt Vehicle - This vehicle had good maneuverability in the water as it could pivot steer and move around obstacles without any problem. Although the original water speed was only 1 mph, by adding a buoyancy tank on the rear of the vehicle so it would float level and deflecting the water off the rear drums to provide a forward thrust, the water speed was increased to 2 mph. Experiments are still being conducted to increase the speed of the vehicle in the water.

The mobility on level and sloping turf and in the simulated rice paddies was satisfactory. The vehicle negotiated the marsh and channels satisfactorily, but the vegetation did accumulate underneath the drive chain and forced them off the sprockets. Since this vehicle has a shallow draft, it was able to cross a channel the same width as the length of the vehicle without difficulty. Whereas, other vehicles with a large percentage of the vehicle under water became immobilized as they could not obtain sufficient traction to climb the vertical walls of the channel.

In the soft soil test, mud built up between the drum and belt limiting the power supplied to the front drum. When this occurred, the rear drums would dig deeper, and the vehicle became immobilized. A positive means of driving the front drum by the belt is now used and appears to be working satisfactorily, but only limited tests have been conducted to date.

Track Vehicle - This concept had a better water speed than the other as might be expected with its body configuration and a propeller assisting the tracks for propulsion. In water, steering was unsatisfactory using the tracks, so a rudder was installed, but maneuvering was still difficult. The penetration in bare soft soil with an average cone index reading of 10 from 0-12 in. deep was only 2-3 in. Difficulty was encountered with the track and the vehicle was suspended from additional testing.

Track-Pontoon Vehicle - This vehicle did exceptionally well in the marsh. It negotiated the channels, went over the rises and through the high vegetation without any difficulty. In the water, the tracks in their original configuration did not provide sufficient propulsion to move or steer the vehicle at an acceptable level which made maneuvering extremely difficult. However, with the installation of sheet metal to deflect the water picked up by the tracks and cutting holes in the front portion of each of the pontoons for water ballast so the vehicle would float level, the speed was increased to 2 mph. With the increase of track propulsion in the water, the steering and handling characteristics were greatly improved.

In soft soil with an average cone index of 10 from 0-12 in., the vehicle penetrated only 2-3 in.; however, mud built up on top of the pontoon locking the track which stalled the engine. This problem appears to be eliminated since cutting three large Vs in the top of each pontoon and adding wipers to the track shoes to eliminate the mud. On the level and sloping turf and in the rice paddies, the vehicle performed very good.
The four vehicle concepts were designed primarily for transporting personnel in marginal terrain, however, an equally important requirement is to transport cargo to outpost positions for resupplying rations and ammunition. Also envisioned is the application of mounting small artillery or stretchers for returning the wounded from the battlefield.

An artist illustration of a support vehicle using the track-pontoon concept is shown in Fig. 8.

SUMMARY

The information obtained in designing and testing the four vehicle concepts -- the drum, the drum-belt, the track, and the track-pontoon -- may not be the final solution in providing a vehicle that would traverse the twilight zone, and the ultimate, a "go anywhere vehicle," but it is felt it is a step forward.