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POSITIVE PITCH CONTROL FOR MULTI-UNIT ARTICULATED VEHICLES

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BACKGROUND

EFFORTS to improve the off-road performance of vehicles have in most cases been limited to the introduction of relatively minor changes to conventional designs. Improvements have in some cases been attempted by following another approach: that of studying vehicle concepts which deviate significantly from the conventional. The investigations of the Land Locomotion Division, Mobility Systems Laboratory, U.S. Army Tank-Automotive Command of multi-unit concepts to produce highly mobile off-road vehicles fall within the latter approach. This article is concerned with positive pitch control, a performance improving feature appropriate to multi-unit vehicle concepts which was formulated in this Division and implemented by the design and fabrication of test beds supported by the Land Locomotion Division on a contract basis. Pitch lock is defined as the ability to maintain a given relative position in the vertical plane between any two units of a multi-unit vehicle and positive pitch control is defined as the ability to control the relative position in the vertical plane between any two units.

PROGRESS

Pitch control has been incorporated in two separate concept studies: the Vicksburg Exercise "A" (VEXA) test rigs, [1] Figs. 1, 2 and 3, and the three-unit, articulated, spaced-link track COBRA, shown in Figs.4–7.

The characteristics of the VEXA test rigs are shown in Table 1.

TABLE 1.

Test rig	Wheel or track	Configuration	Unique feature	Gross weight (lb)	Cargo capacity (lb)
1	8×8	3 unit, articulated steering	Inching and pitch control between each unit	12,500	5000
2	10×10	2 unit, articulated steering	Inching and pitch control between first unit	12,400	5000
3	Tracks	2 unit, articulated steering	Inching and pitch control between each unit	14,200	5000

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The unique feature of the VEXA rigs of interest to this discussion is the pitch control between units. With the pitch control inactive, the units of the test bed assume a pitch attitude dictated by the terrain profile. With the pitch control activated, the operator can lock the units in a desired pitch attitude. He can, for example, lock both units horizontally to achieve a single unit, rigid frame, or he can positively control the pitch attitude between any two units of the test bed to modify the load distribution or to control attitude in approaching geometric obstacles such as a vertical wall.

The pitch control feature consists of hydraulic cylinders mounted above and below the articulated, steering joint. The cylinders, $3\frac{3}{4}$ in. bore $\times$ 12 in. stroke, are powered by the same source as the steering cylinders. The pitch lock, pitch-up and pitch-down controls are located in the instrument panel at the driver's station.

The most significant performance difference between the VEXA test rigs and either single unit or non-pitch controlled two-unit vehicles was demonstrated in snow tests involving attempts to negotiate vertical steps and vertical walled trenches.

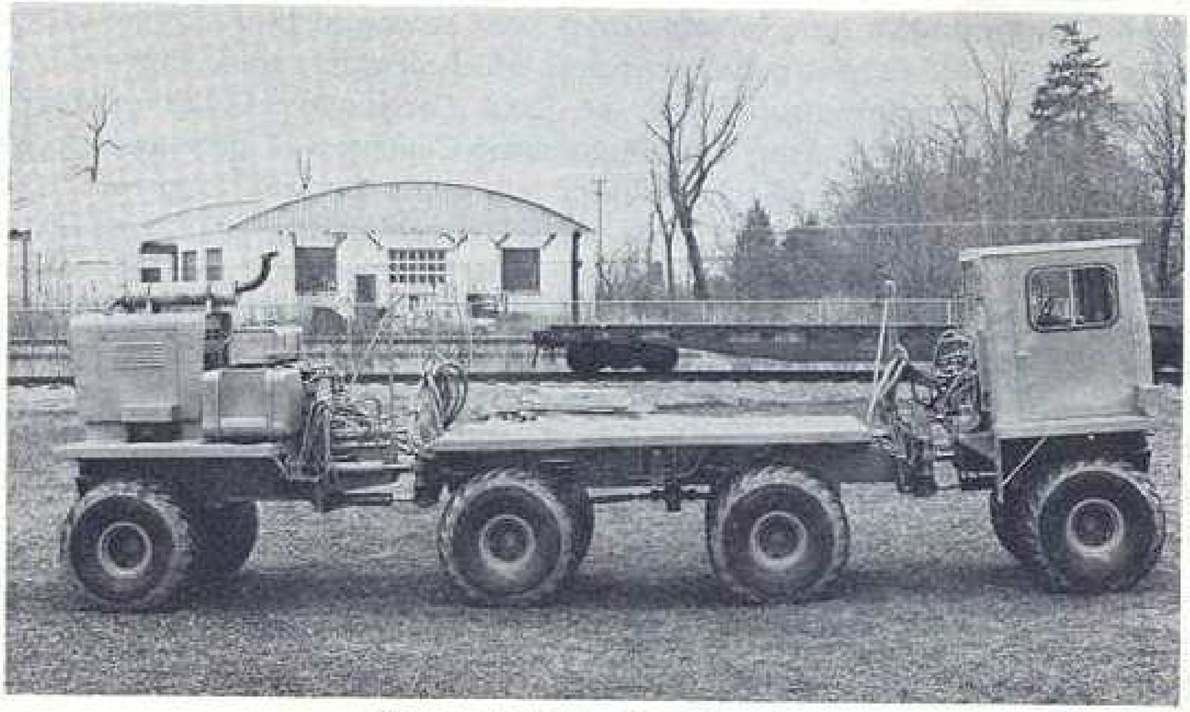

FIG. 1. 8 $\times$ 8 unit wheeled test rig.

FIG. 2. 10 $\times$ 10, 2 unit wheeled test rig.

The markable obstacle crossing capabilities of the test rigs is attributed solely to the pitch control. For vertical steps, the front unit was lifted by the pitch control mecha-

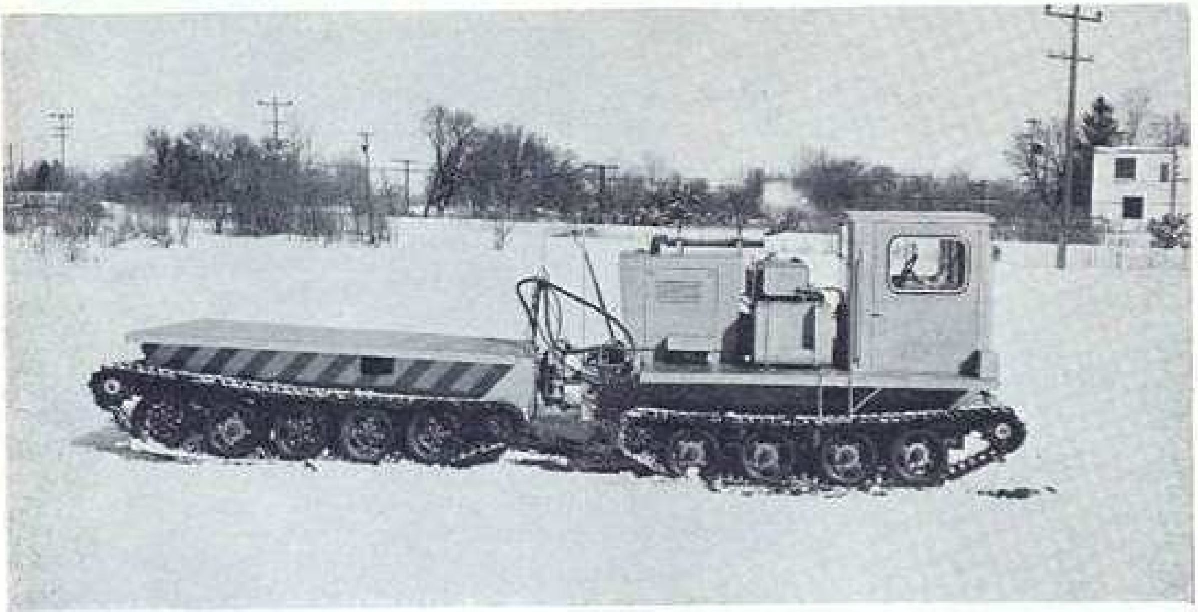

FIG. 3. Tracked, 2 unit test rig.

FIG. 4. Trench bridging, 8 ft wide.

FIG. 5. COBRA test bed.

FIG. 6. Trench bridging 10 ft wide.

nism and the test rig driven foward (traction from the rear units). With the front unit over the step, pitch control was released or reversed with the traction provided by the front unit enabling the rear unit to be pulled over the step. For trench bridging and crossing the pitch control was locked so that the units acted as a single, rigid frame test rig, Fig. 4.

The wheeled test rigs were equipped with terra-tires of 47 in. dia. for the 8×8 and 42 in. for the 10×10. All test rigs crossed vertical steps of 36 in. which were 0·86 and 0·77 of the tire diameters. The wheeled test rigs bridged 10 ft wide trenches while the tracked rig negotiated at 12 ft trench with pitch control locked.

Operation of wheeled vehicles in deep, soft snow with sinkages well in excess of one-half the wheel diameter had previously been unheard of, yet both the 8×8 and 10×10 maneuvered under such snow conditions. Progress was very slow, but with alternate pitching and moving forward, movement and maneurving was possible. Even though the wheeled test bed could be considered as operating in an environment normally restricted to tracked vehicles, these concepts were able to cope with the conditions in an impressive manner.

An additional demonstration of the usefulness of the pitch control feature occurred during slope operations. Compacted snow grades with a slope of 30 per cent offered no problems for the wheeled rigs. However, the tracked rig was not able to negotiate the slope because of loss of traction. By activating the pitch control and creating a more favorable ground pressure distribution the tracked rig negotiated the grade with ease.

FIG. 7. Vertical step crossing, 42 in.

The COBRA [2] is a vehicle concept developed by the Land Locomotion Division, Fig. 5. The COBRA test bed is a three-unit articulated spaced-link track vehicle, incorporating new concepts for increasing off-road performance, among which is positive pitch control between units. The units weigh 8800 lb each with payload capacity of 3400 and 3800 lb for the second and third units. The pitch control feature of each articulated unit is provided by a single 6×25 in. stroke hydraulic cylinder. With the controls on the instrument panel, the driver is able to lock or control the pitch attitude between units from 30° above to 30° below the "horizon", Fig. 5.

Tests to demonstrate the pitch control feature included crossing vertical steps, vertically-walled trenches and natural soil vertical walls. The Mark II POLECAT which was used as a comparison vehicle is an articulated, two-unit track vehicle without pitch control. The obstacles to be negotiated consisted of: a concrete vertical step, 42 in. high; a concrete vertically walled trench, 10 ft wide and with 22 in. walls; and a vertical, natural soil, bank approximately $5\frac{1}{2}$ ft high. The obstacles could not be negotiated by the COBRA with pitch control inactive, and the Mark II POLECAT. However, when the pitch control was actuated on the COBRA, locking the control to bridge the trench and raising the front unit to climb the vertical step, *NO* difficulties were encountered in crossing the three obstacles, as seen in Figs. 6 and 7.

The foregoing discussion illustrates how the addition of a simple pitch control device substantially improves the performance characteristics of multi-unit vehicles. For operation in adverse conditions consisting of geometric obstacles, i.e., ditches, banks, slopes, it is clear that the pitch control between units is necessary to fully utilize the advantages offered by multi-unit vehicle concepts.

REFERENCES

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