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STUDIES ON VIBRATION CHARACTERISTICS OF THE RUBBER CRAWLER
--- Dynamic characteristics of the fixed track rollers and movable track rollers ---

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ABSTRACT

The Japanese type combine harvester has adopted rubber crawlers for the driving mechanism from first production. However, combine harvesters with movable track rollers in the rubber crawler system have been adopted recently for the purpose of stability at the time of climbing over the footpaths between rice fields, as the result of the machines becoming large.

However, the dynamic characteristics of movable track rollers have not been clarified. For this reason, the design of movable track rollers depends on trial and error. It is known that vibration characteristics of the vehicle with movable track rollers are different from the vibration characteristics of the vehicles with fixed track rollers even though the track roller arrangements are the same. Therefore, the theoretical analyses of movable track rollers must be hurried in order to formulate a reasonable track roller arrangement design.

The authors have studied the vibration characteristics of the rubber crawler vehicle with fixed track rollers. In this study, the dynamic model of the vehicle with movable track rollers is compared with the dynamic model of the vehicle with fixed track rollers. Next, motions are simulated to analyze the movable track rollers by expanding the motion equation which were constructed for the dynamic model of the fixed track rollers .

1. INTRODUCTION

Different methods are used to equip the rubber crawler system with the track rollers. The fixed track roller system is most usable due to the simplicity of structure, its ease and low cost of construction. However, the forces arising from the interaction between the rubber

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crawler and ground directly affect the vibration characteristics of the machine, when they act on a machine with only fixed track rollers. It is known that the arrangement of track rollers changes the vibration characteristics of the machine. Further the condition of the ground affects the machine in vibration. Therefore, the crawler system is equipped with many devices such as devices to control the machine to remain horizontal despite the unevenness and inclination of the field (Fig.1), devices for the support of the track rollers individually, and devices to maintain the stability of the machine climbing over ridges between rice field and other obstacles (Fig.2). All devices are not referred to in details for want of space. The investigation that follows is limited to making a comparison between the fixed track rollers system and the movable track rollers system in Fig.3 and 4.

2. DYNAMIC MODELS

Fig.3 shows a dynamic model with only fixed track rollers, and Fig.4 shows a dynamic model that is equipped with movable track rollers. The model in Fig.3 is directly affected by forces from the rubber crawler, because the track rollers are fixed to the machine. On the other, the model in Fig.4 is affected by forces from not only fixed track rollers but also resultant force on the 3rd and 4th track rollers, because the 3rd and 4th track rollers consist a movable mechanism. Comparing the models in Fig.3 and Fig.4, the magnitude of forces and the points of application are different even if the track roller arrangements are the same. As a result of that, it is evident that the difference of structure for the support of the track rollers cause various changes in the vibration characteristics of the moving machine.

3. SIMULATION

The dynamic consideration is omitted for the want of space. Motion simulation can be done by numerical calculation using the motion equations obtained based on the models.

The calculation method for the simulation in here is the RUNGE-KUTTA method based on the motion equations. The propriety of this method was confirmed by the experiments in the case of vehicles with the fixed track rollers. It is judged that this method can be applied to the simulation for vehicles with movable track rollers.

1)The conditions of the simulation

Fig.5 shows the track roller arrangements for simulations. The simulations are done by adopting the arrangements to the models in Fig.3 and 4 under the following conditions ;

(1)The arrangement of track rollers ;

5 arrangements shown in Fig 5

(2)Driving speed ;

3 speeds [3Hz(=0.252m/s), 6Hz(=0.504m/s), 9Hz(=0.756 m/s)]

[Hz: the frequency of the number of rubber crawler lugs passing beneath a track roller a second]

(3)The lug phase of the right and left rubber crawlers ;

3 phases [0.0 , 0.25, 0.5]

2)The results of simulation

Fig.6 and 7 show the examples of acceleration of pitching from the results of simulation ; Fig.6 shows the result of simulation for the model in Fig.3 , Fig.7 shows the result of simulation for the model in Fig.4. These figures reveal that the vibrations are different when the structures of the driving system are different even if the track roller arrangements are the same.

Next, the results of simulation are estimated using the R.M.S. values;

Fig.8 shows the R.M.S. values of displacement in the vertical direction. As regards the displacement in the vertical direction, the R.M.S. values become smaller in the case with movable track rollers than in the case with only fixed track rollers, and the differences in the magnitude of the R.M.S. value between the track roller arrangements are very smaller in the case with movable track rollers.

Fig.9 shows the R.M.S. values of displacement in pitching. As regards the displacement in pitching, the tendency is similarly to pitching, but the R.M.S. values become much smaller in the case with movable track rollers.

Fig.10 shows the R.M.S. values of acceleration in the vertical direction, and Fig 11 shows the R.M.S. values of acceleration in bouncing. As regards acceleration in the vertical direction, the larger the driving speed become, the larger the R.M.S. values become. The R.M.S. values in the vertical direction are not so different between the track roller arrangements. However, as regards acceleration in pitching, the R.M.S. values become much smaller in the case with the movable track rollers.

As regards the influence of lug phase of rubber crawlers, the larger the lug phase become, the little smaller the R.M.S. values of displacement in the vertical direction (Fig.12) and pitching (Fig.13) of the vehicle with movable track rollers become. However, the influence of the rug phase in the case of the vehicle with only fixed track rollers is not so clear as in the case of the vehicle with movable track rollers. The R.M.S. values of acceleration in vertical direction and pitching are similarly to displacement.

From the result of simulation, it is clear that vibration of the vehicles is reduced by equipping the rubber crawler system with movable track rollers. Especially, it is effective in reducing vibration in pitching.

CONCLUSIONS

1. It is probable that the vibration characteristics between the vehicle with fixed track rollers system and the vehicles with movable track rollers are compared by motion simulation.
2. It is clear that vibration is reduced by equipping the rubber crawler system with movable track rollers. Especially, it is effective in reducing vibration in pitching.
3. If motion simulation is made good use for the support of the design to judge the quality of track roller arrangements, it is presumed that the time for the design will be shorted and that the cost of production will decrease because the design for track roller arrangements become easy.

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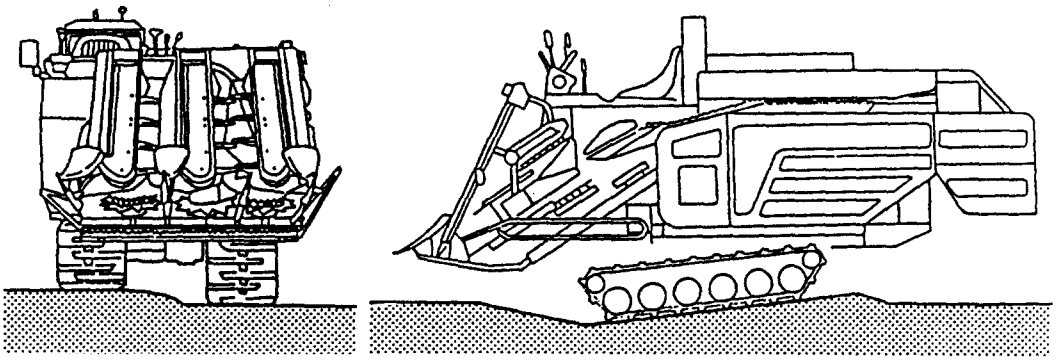


Fig.1 The mechanisms to control the machine to remain horizontal

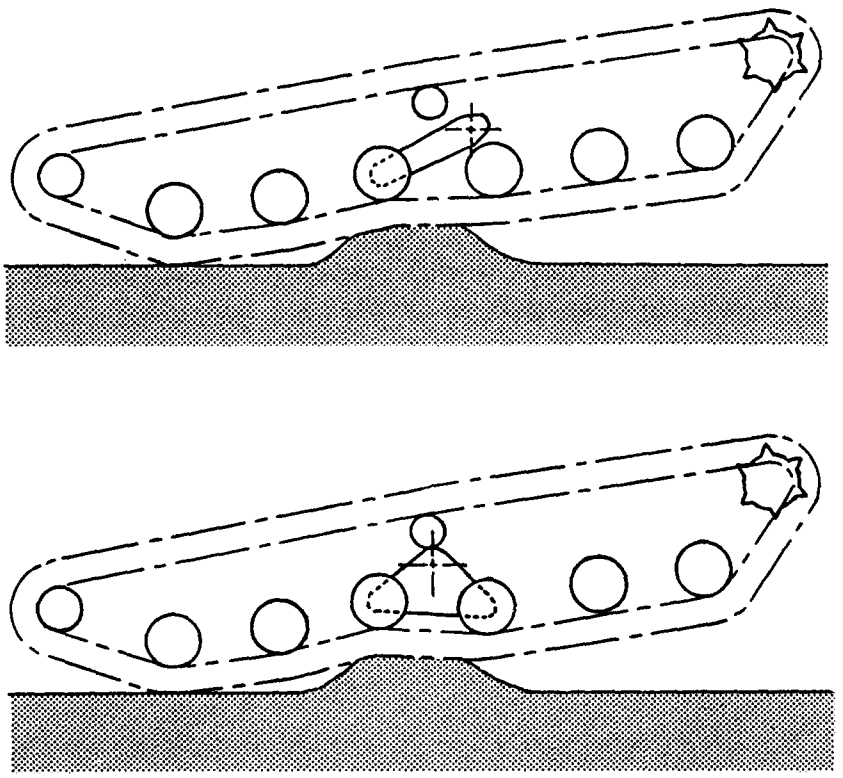


Fig.2 The mechanisms can maintain the stability of the machine in case of climbing over ridges between rice fields, and other obstacles

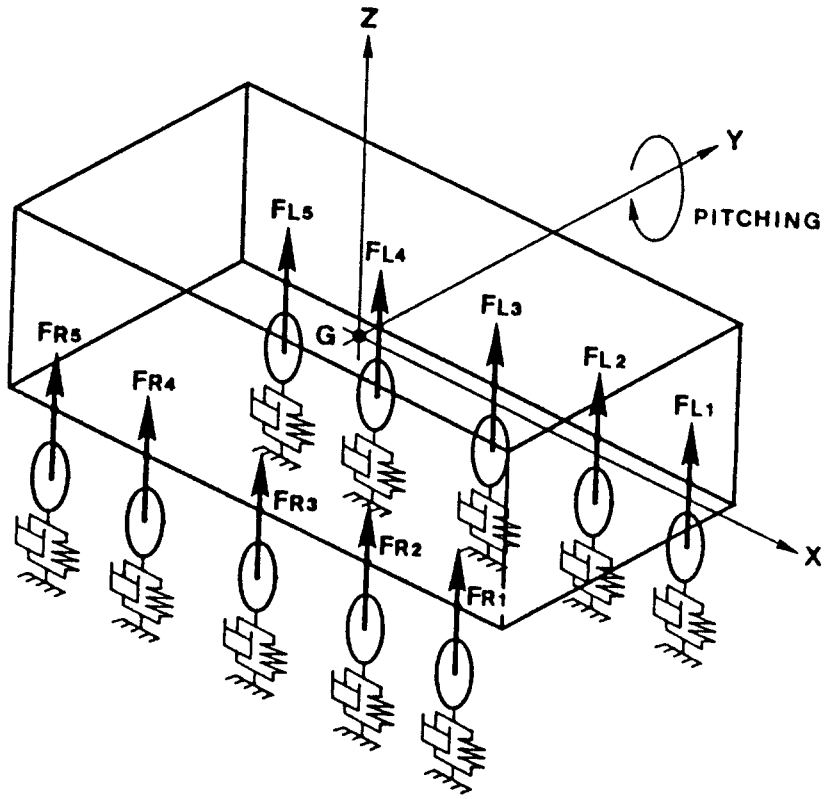


Fig.3 Dynamic three-dimensional model (1)

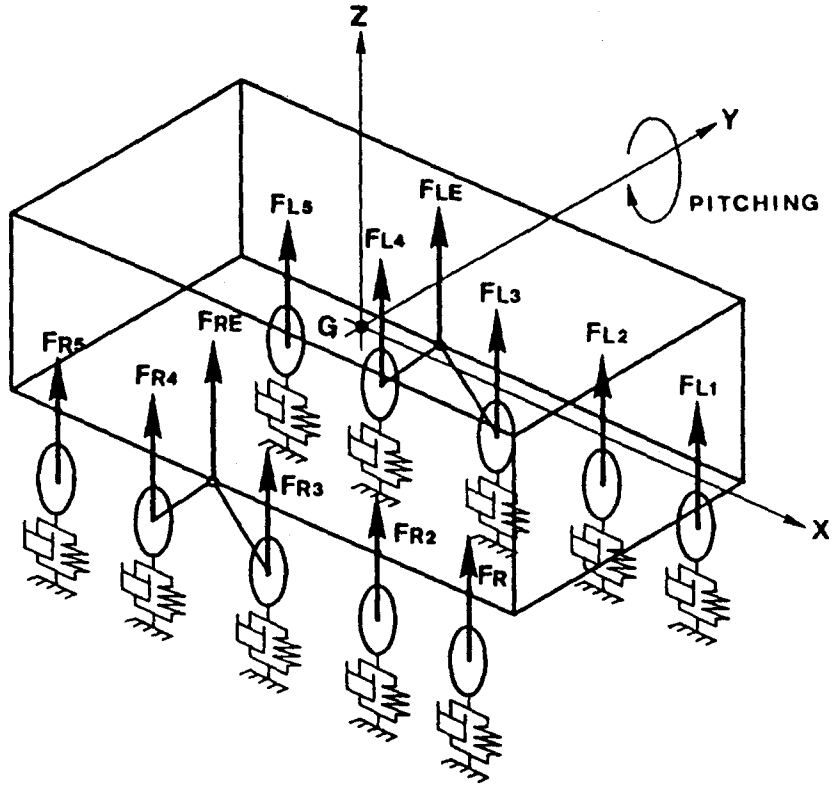
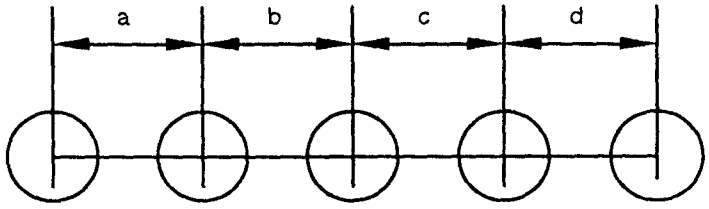


Fig.4 Dynamic three-dimensional model (2)



	a	b	c	d
No.1	280	196	168	196
No.2	217	217	168	217
No.3	210	210	210	210
No.4	168	252	252	168
No.5	189	231	231	189

(mm)

Fig.5 The track roller arrangements for simulation

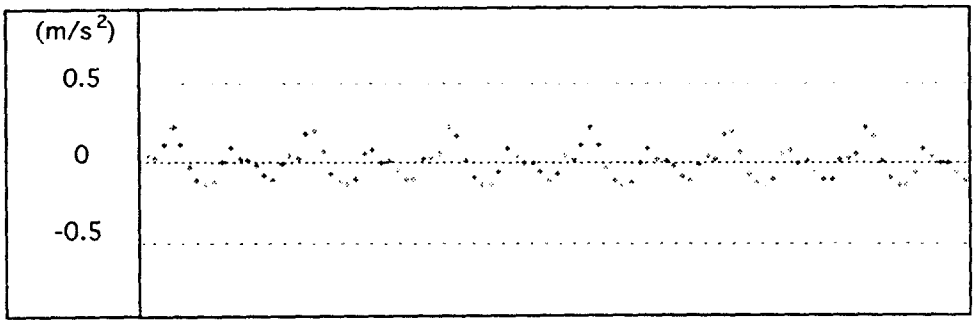


Fig.6 An example of simulation result of acceleration of pitching for the model in Fig.3
[Track roller arrangement: No.2, Driving speed : 6Hz, Phase :0.0]

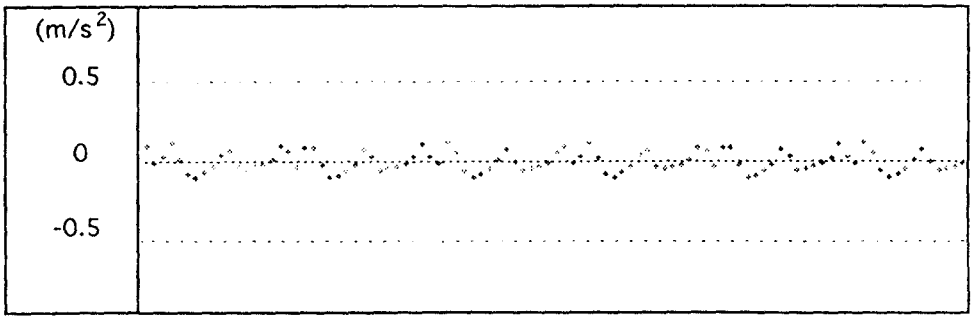
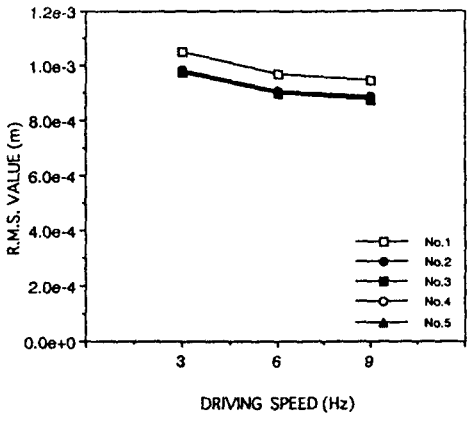
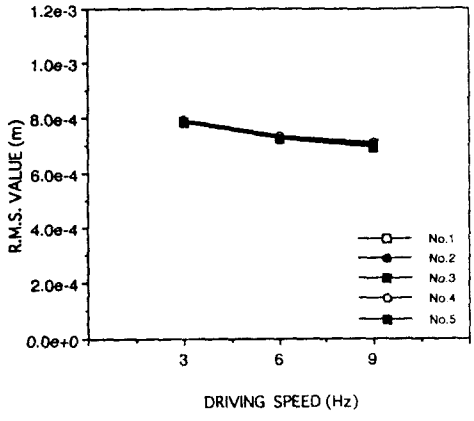


Fig.7 An example of simulation result of acceleration of pitching for the model in Fig.4
[Track roller arrangement: No.2, Driving speed : 6Hz, Phase :0.0]

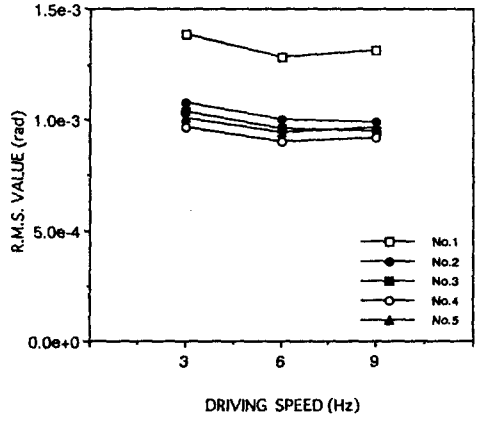


The vehicle with onlt fixed track rollers

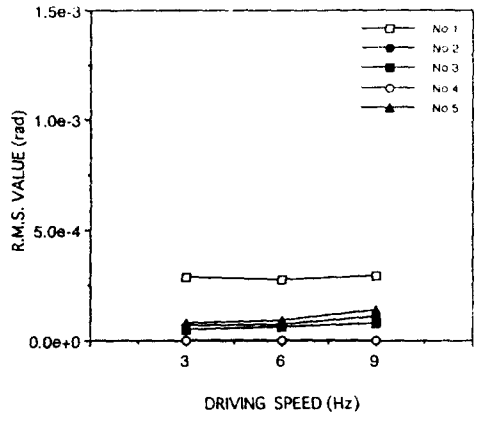


The vihecle with movable track rolles

Fig.8 The R.M.S. values of displacement in vertical direction

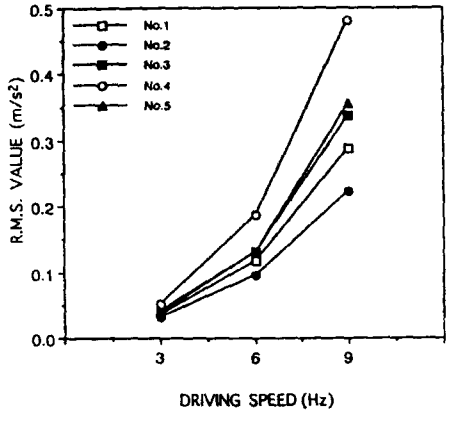


The vehicle with onlt fixed track rollers

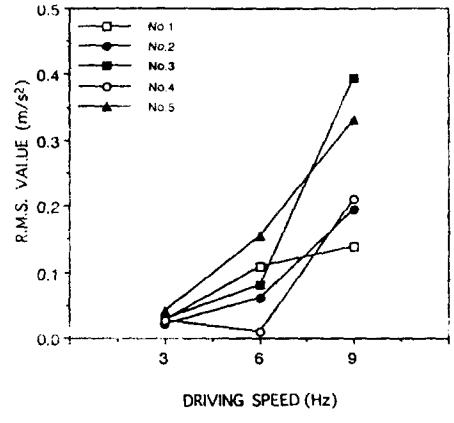


The vihecle with movable track rolles

Fig.9 The R.M.S. values of displacement of pitching

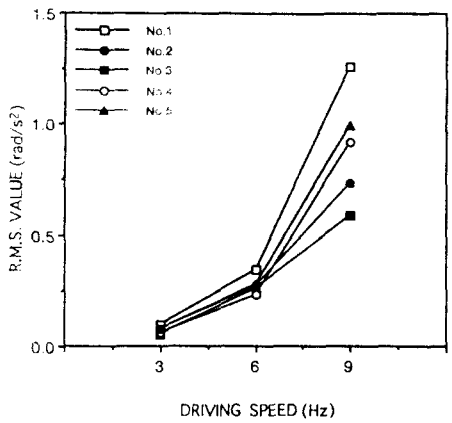


The vehicle with onlt fixed track rollers

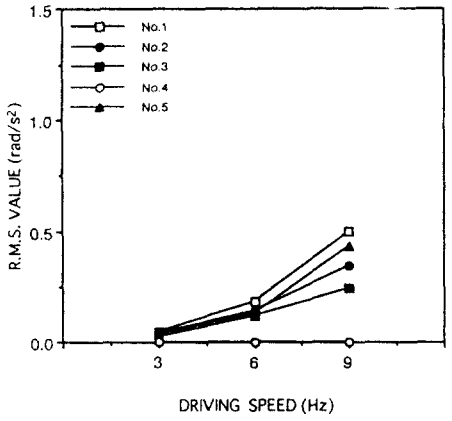


The vihecle with movable track rolles

Fig.10 The R.M.S. values of acceleration in vertical direction

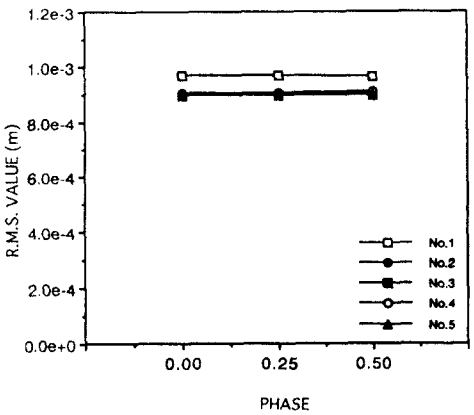


The vehicle with onlt fixed track rollers

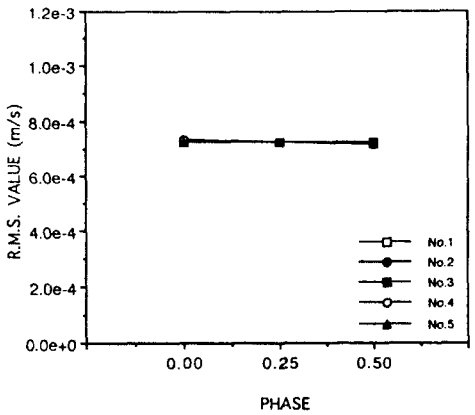


The vihecle with movable track rolles

Fig.11 The R.M.S. values of acceleration of pitching

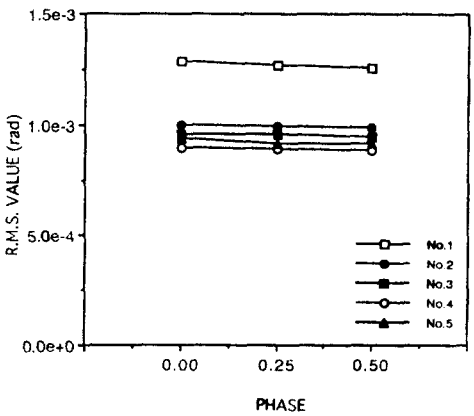


The vehicle with onlt fixed track rollers

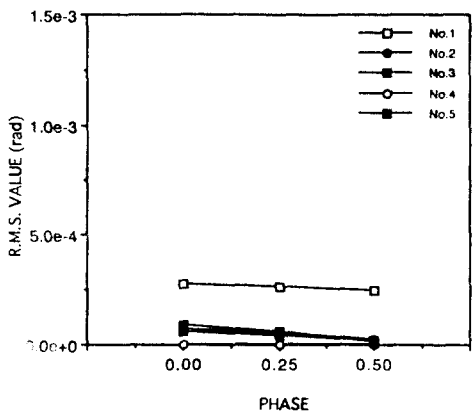


The vihecle with movable track rolles

Fig.12 The R.M.S. values of displacement in vertical direction



The vehicle with onlt fixed track rollers



The vihecle with movable track rolles

Fig.13 The R.M.S. values of displacement of pitching