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SOME OBSERVATIONS ON SOIL SOIL-FAILURE BY LINEAR BLADE USING "STILT" SYSTEM

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ABSTRACT

Many investigations have been carried out concerning tillage tool performance, including energy requirement. Since the performance of tillage could also be evaluated through the change of soil, then it is necessary to investigate the soil cutting process and the pattern of soil failure. This study was conducted using indoor soil bin, STILT (Soil Tillage Tool Interaction) system.

The result shows that the soil bin experiments could provide the clear understandings about phenomena of soil failure. The movement of soil, the successive failures was clearly visualized. The relations between the horizontal and vertical forces to the linear motion blade, the shear force on the shear plane which devides soil layer into several segments were indicated by the fluctuation/vibration of the recorded resistance and forces. The results show that the horizontal force (Fx) and vertical force (Fz) develope their frequencies as the change of velocity of blade (10, 20, 40 mm/sec) for each cutting angle (35, 45, 60 degrees). Resultant force of Fx and Fz are much influenced by the cutting angle.

Keywords : Energy, Force, Soil, Tillage, Velocity.

INTRODUCTION

More than one-third of energy required in farm works is said to be consumed in tillage. Reduction of energy and draft in tillage operation has been one of the most keen targets of farm machinery system. Further more minimum energy and maximum draft can realize less than traction which could become a more economical farm machinery operation.

One of the most effective way to reduce soil resistance in tillage work is to introduce tensile failure in the soil cutting process by moldboard, disc plow and rotational machine tools. The priciple action of the conventional tillage machinery and equipments is to break soil layer and tissue with the compressive shearing or cutting action by afore-mentioned machine implements.

Soil bin, STILT system is so constructed as to be easier to observe the process and change of soil layer in compaction and failure by the mechanical forces. For these purpose, there has been many kinds of trials, apparatus and methods to be tested. Some of them, an observation of soil failure and an estimation of some inner forces occurred in a soil layer under the soil failure are simultaneously attempted. But these observation and estimation of soil failure are not developed, because soil itself is not uniform but complicated, so as not to be able to handled the soil phenomena like a fluid which consists of uniform solution. Soil is not a solid, elastic and plastic and then theoritically impossible to grasp its actual state of soil failure. An reproducibility in the experiment related to soil failure is scarcely expected. Here is an fatal disadvantage in an experiment of soil mechanical failure.

MATERIAL AND METHODS

Soil Bin Test Facilities

A new soil bin test facility has been contructed as a modification of previous type installed in The University of Tokyo, Japan. It is now installed in the Department of Agricultural Engineering of IPB, and is under conducting research in the fields of soil interaction with machine tools, and supporting the education.

This facility consists of seven units, that are (1) Soil preparation and compression units, (2) Soil bin unit, (3) Linear blade unit, (4) Rotary blade unit, (5) Soil constant measuring unit, (6) Control unit, (7) Measuring, data aquisition and analyzing unit (Appendix 1). These seven units are totally assembled to measure the performance of soil-tillage tools, but the soil static and dynamic failure under the interaction with soil-tillage tools could be studied with the adition of some innovative measuring instruments.

The Soil Bin Unit

Movable soil bin is controlled automatically by computer to go forth and back. Size of soil bin is 1500 mm length, 350 mm depth, and 200 mm width, so the total volume is 100 liters. The front wall is transparant with thick glass. The side wall can be opened by unscrewed nuts. This soil bin is set about 1 m higher from the ground sothat it is easier to observe soil conditions, soil movement and soil behaviour during experiments. As the bottom of soil bin supported with special type bearing, soil bin can be moved on the rail by the hydraulic cylinder with 1500 mm stoke and moving velocity 0-100 mm/sec. Cylinder capacity is more than 500 kg.

The Linear Blade Unit

This unit is used for testing the tillage blade. In this system, linear blade tested is stationed at the testing position and with some slant while soil bin moves in straight line. This blade is an iron plate with 400 mm, 150 mm, 6.0 mm sizes and its cutting angle adjustable 0-90 degrees. The blade is so constructed that the position can be fixed adjustable for movable range of rotary blade by 30 cm upward, downward, reward.

This unit equipped with three forces-component transducer measures horizontal forces (Fx), vertical force (Fz) and moment around the horizontal axis (My). The bearing load is up to 500 kgf. Four pressures (max. 5 kgf/cm2) are installed on the contacting surface of the blade with the soil.

The Soil Praparation Unit

This consists of three kinds of components. Those are supplying and mixing soil and compressing to desirable hardness. A belt conveyor is equiped to bring the soil prepared previously into soil bin. The soil then is poured into mixer to have uniform soil texture and particles. After finishing of mixing of soil tested, material is fallen into soil bin through the down sloped opening.

The pressure unit consists of one pressure plate which uniformly pressurize soil prepared by three hydraulic cylinders. The pressure plates are operated by computer and automatically work up and down. The compacted soil by the pressure plate can be controlled 0-50 kgf/cm2. Each three pressure sensors are installed under the pressure plate and the bottom of soil bin to control uniformly pressuring soil layer.

The Experiments Process

Two kinds of soil were used, namely Regosol and Latosol soil. The physical component of the soil are shown in Table 1.

The soil tested were previously treated by sieving it with less than 2 mm dia. mesh. No matter how content of clay especially in Regosol soil, in mechanical property like shearing strength after compaction there were not existed the eminent difference among two soils.

Combination of Experimental Conditions

1. Kinds of soil : 2 (Regosol and Latosol)
2. Kinds of Moving speeds of soil bin : 3 (10, 20, 40) mm/sec.
3. Kinds of cutting angle of linear blade : 3 (30, 45, 60) degrees.

Visualization of Soil Failure Process

On out side surface of glass wall of soil bin in observant side, white color cotton string was fasten in a net of 40 mm mesh as standard scale for measuring the movement of pin which was previously installed in the soil. In one end of the small bamboo stick pins, of 3 mm dia, a 10 cm long with round white color plate was pasted facing to the glass wall for the observation. The pins were placed in a net of 80 mm mesh. A video recording with still camera was used for grasping the movement of the pin in the soil, the process of soil failure and soil exfoliation.

Data Collecting

Data collected during the process of soil cutting with the condition of cutting speed and cutting angle are vertical and horizontal forces of inclined linear blade and contact pressure with moving soil on the surface of linear blade. In the process of soil action, pressure on the pressure plate and on the bottom of soil bin are collected automatically in the computer system.

RESULTS AND DISCUSSIONS

Original Oscillograms of Soil Compaction Process

Fig.1 show the prosess of soil compaction for two kinds of soil. Compressed pressure recorded by the pressure sensors attached on the lower plane of the pressure plate and on the upper plane of the bottom of soil bin indicate around 1.0 - 1.3 kgf/cm2 and 0.5 - 1.0 kgf/cm2 respectively for both kinds of soil.

Pressure at pressure plate are approximately two times bigger than pressure at the bottom of soil bin. Table 2 indicates the time constant of the soil compaction prosses for both soils.

The ratios of time constant are about 0.73 times at compresion plate and 0.76 times at soil bin in Latosol smaller than in Regosol. After compaction process, the soils tested reach 10.6 of cone index in Regosol and 7.6 in Latosol.

Forces and Pressure at the Soil Breaking Process

Fig. 2 shows the original ascillograms. Horizontal axis is time elapsed in second and vertical axis is the value of pressure and forces. Vertical pressures of linear blade and three kinds of pressures on the surface of the blade presented in electric voltage.

Fig. 3 shows the time elapsed indication of the real time forces Fx at linear blade in two kinds of cutting speeds. In general, forces are almost bigger in Regosol than in Latosol. The fluctuation of the Fx force might depend upon the soil failure and this would be coincided with the depth of broken soil layer and the timing of failure and exfoliation of soils.

Fig. 4 shows the sketching diagrams of the motion-traces of pin as the marker indicating soil movement against soil cutting action by linear blade. The movements shown as the degree from horizontal bottom surface of soil bin. The soil movements in regosol are almost bigger than in Latosol at various cutting angles and cutting speeds exept in 30 degrees in cutting angle in Latosol.

Fig. 5 shows relation of vector expressions of resultant force of linear blade and angle of soil movement. Magnitudes of vector in resultant force are longer in Regosol than in Latosol and angles of vector are almost bigger in Regosol than in Latosol in all the cutting angles and cutting speeds. Vectors of resultant forces in cutting angel 60 degree indicates minus degrees in both soils.

Fig. 6 indicates the angle diffrence of soil movement to the vector angle of resultant force. The relations between the angle difference and cutting on linear blade increases with the increase of cutting angle of blade in both soils. However, relation between angle diffrence and cutting speed almost shows opposite than the above-mentioned subjects.

Soil Failure

Soil failure by linear motion blade was observed through a glass side window of soil bin by taken photographs. In the beginning stage transiently in which the blade intruded into the previously compacted soil layer, soil breaking and shearing plane was occurred at a relative lower angle, several centimeters ahead of the point the blade, then the second breaking layer is developed just after the initial failure of soil at a relatively higher angle. This trasient period ordinarily continues 10 - 20 second and then is succeeded by stationary period in which soil failure lines continuously accurred with the regular intervals. On this failure line between soil segments shear interaction develops, and on the surface metal linear blade the friction force between soil layer accurs. Those continuous soil segments with inclined failure lines in both sides are moving behind and balanced with the own weight of soil segment and lift upward force normal to the planes of èach soil segments. This upward force N1 can be derived from the equation of soehme.

$$N_1 = [fx - (CA + Fa)\ \mathrm{Cos}\ \beta]/(\mathrm{Sin}\ \beta + \mu s \mathrm{Cos}\ \beta) \quad \cdots (1)$$

Where :

Fx = Horizontal component of resistance
C = Cohesion
A = Area
Fa = Acceleration force
β = angle of shear plane
μs = Friction coefficient of soil

Fa is caused by resistance due to acceleration and is expressed as follows.

$$Fa = \frac{r}{g}\ b\ t_0\ v_0 = \frac{\mathrm{Sin}\ \alpha}{\mathrm{Sin}\ (\alpha+\beta)} \quad \ldots.(2)$$

Where :

τ = Density of soil
b = Width of blade
t = Cutting depth
v_0 = Cutting velocity
α = Cutting angle

$$W = r\ b\ t_0\ [l_0 + l_1 + l_2)/2] \quad \ldots.(3)$$

Where :

$$t_0 = t \, Sin \, (\alpha + \beta)/Sin \, \beta$$
$$l_1 = t \, Cos \, (\alpha + \beta)/Sin \, \beta$$
$$l_2 = t_0 \, tan \, \alpha$$

β can be calculated by the theory of Soehme.

$$\beta = 45 - \frac{\phi}{2}$$

Where :

ϕ = Internal friction angle of soil

From these equations horizontal resistance force, normal force t the shear plane, shear angle might be estimated with the data of soil characteristics. Actually the occurence of these clear failure lines and shear planes should be depended upon the combinations of experiment conditions , and especially a content of water, the ratio of clay and sand, angle, dimensions of the blade and velocity of linear blade and soil compaction etc.

Analysis of force to linear blade Fx and Fz

Fig. 9 and 10 show the relations of Fx and Fy frequencies depended upon velocity of blade and cutting angle. Fx and Fz develop their frequencies as the increase of velocity of blade for both Regosol and Latosol soils. The higher increasing rate could be observed in the smaller cutting angles more than in bigger cutting angle. But this rate more rapidly increases in Regosol soil than Latosol soil.

Estimatiom of the width of each soil segment

Fig. 11 and 12 show the calculated lenght of peak to peak in Fx dan Fz oscillograms. In both Fx and Fz and two kinds of soil have the same tendencies which in the highest cutting angle, length of peak to peak rapidly inceases due to the increase of velosity of blade. But in the lower cutting angles velocity of blade might not much affect the length of peak to peak. This length might coincide with the width of each soil segments separated with the inclined shear planes. From the stand point of pulverating and crushing a soil, higher frequency of Fx and Fz and narrower width of soil segments are better, but from the review of resistance force to linear motion blade, lower cutting angle take clearly precedence.

CONCLUSIONS

1. Resultant force of Fx and Fz are much influenced by the cutting angle and the vectors of resultant force take angles gradually decreasing. At cutting angle 60 ^{o} the direction of the vectors takes counter-clockwise angle a little below from an horizontal axis and then angles between soil movement and resultant forces developed.

2. The phenomena of soil failure by the linear motion blade might be possible to be estimated by Soehme's equation which explained the relation between normal force to a shear plane occurred by the movement of linear motion blade, frictional force on the blade and acceleration force of soil segments.

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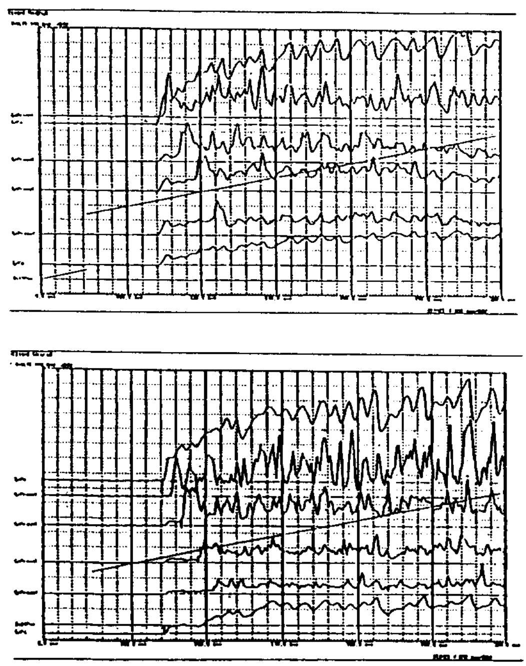
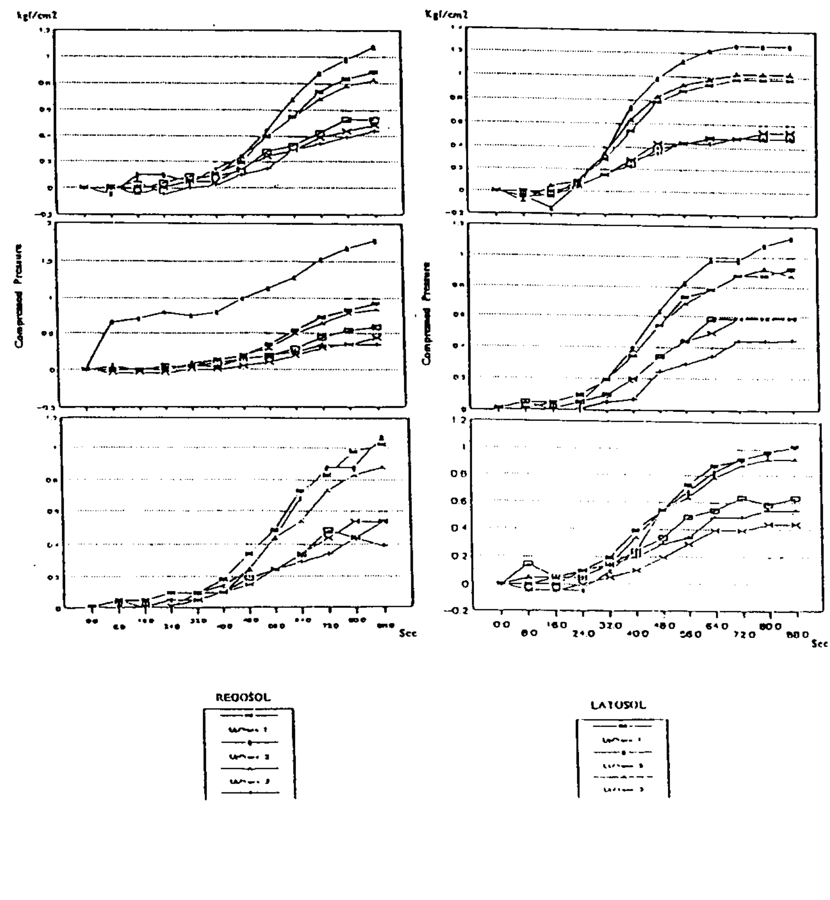


Fig. 1 ORIGINAL OSCILLOGRAM of PRESSURES to LINEAR BLADE



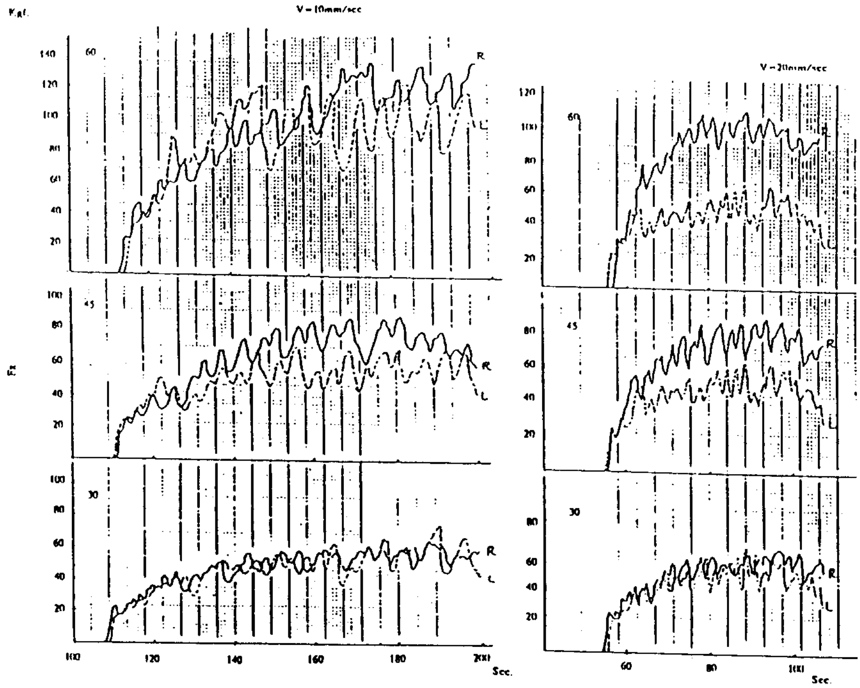


Fig. 3 OSCILLOGRAM of PRESSURES in LINEAR BLADE

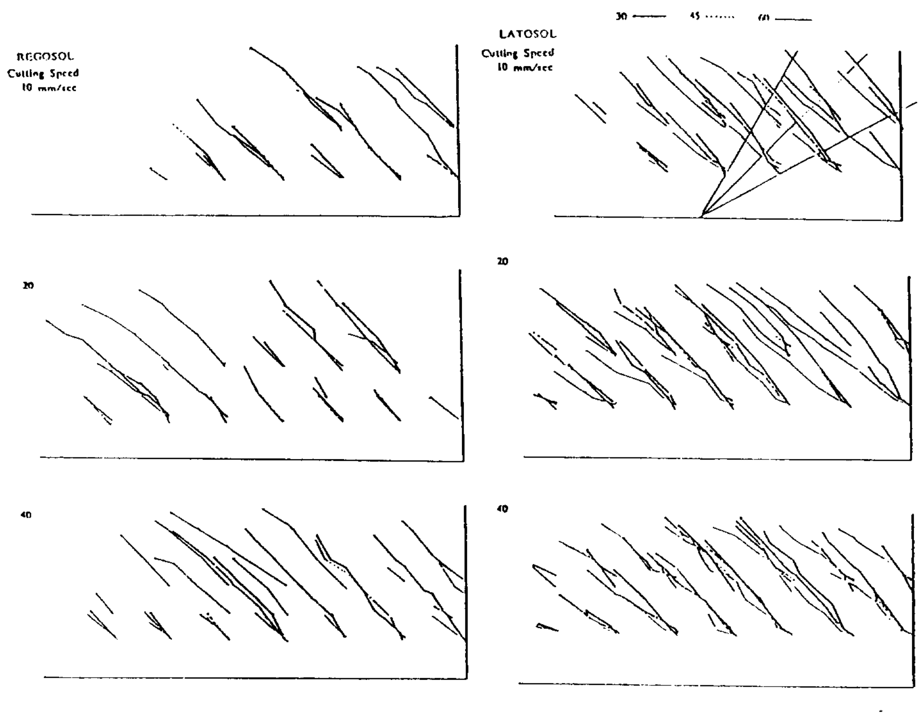


Fig 4 TRACES of PIN MOVEMENT

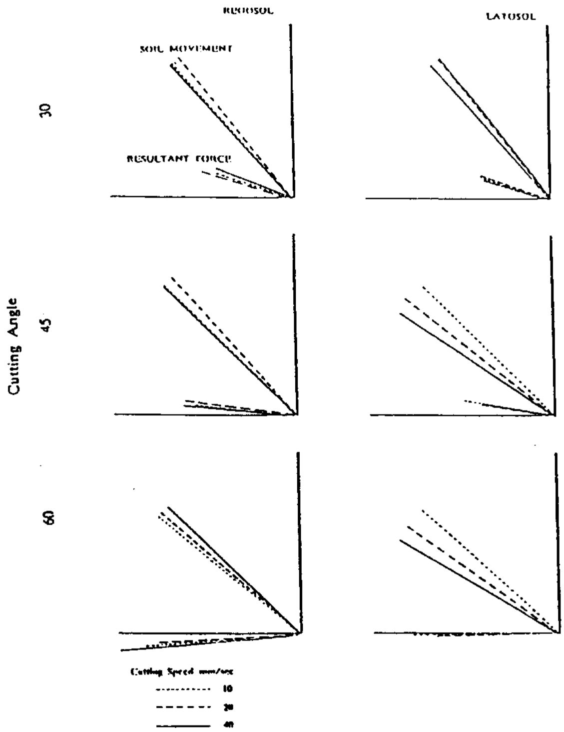


Fig. 5 RELATION between RESULTANT FORCE to LINEER BLADE and SOIL MOVEMENT

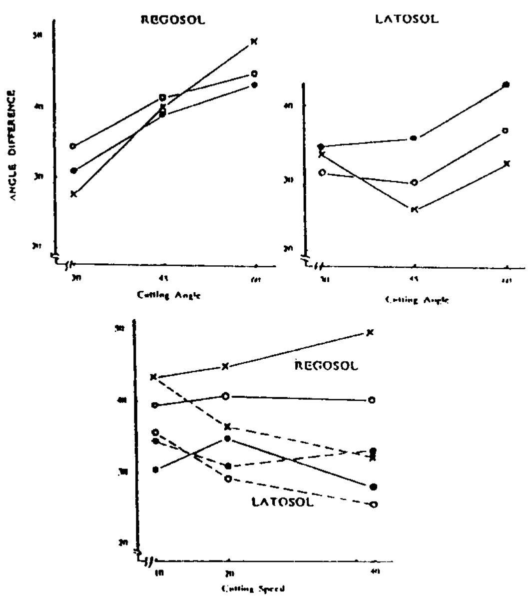


Fig. 6 ANGLE DIFFERENCE between SOIL MOVEMENT and RESULTANT FORCE

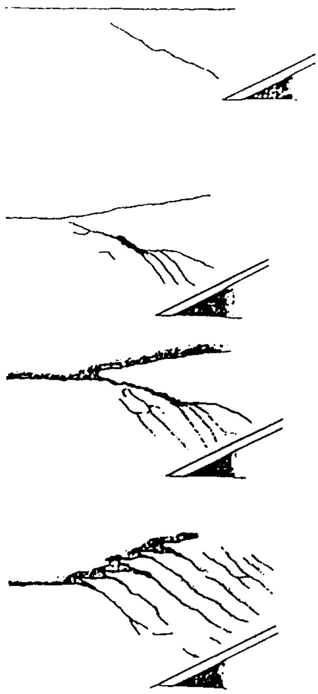


Fig. 7 Sequent process of soil failure by linear motion blade

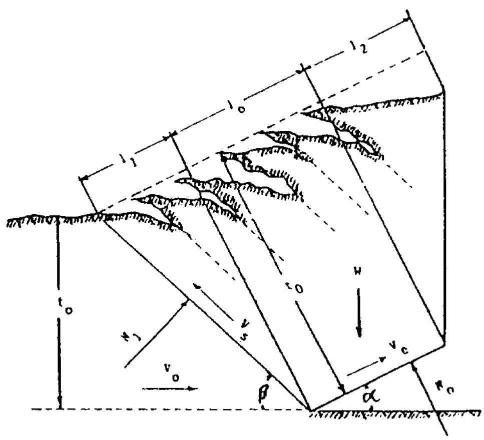


Fig. 8 Soil cutting by linear motion blade

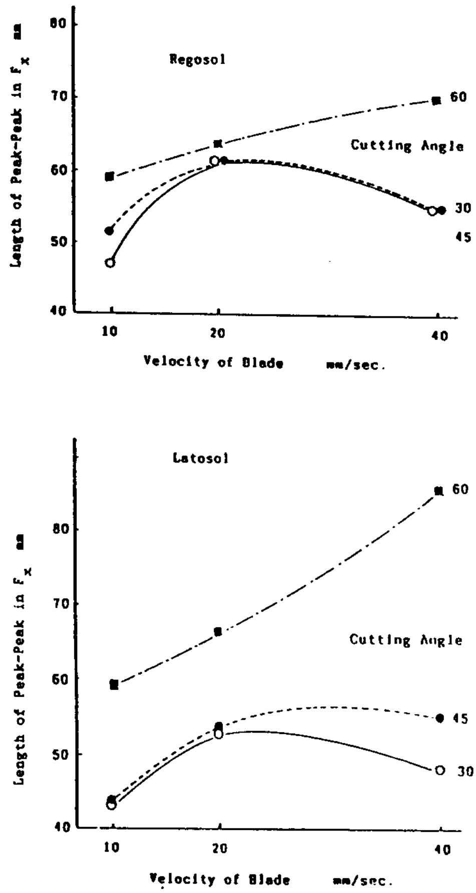


Fig.11 Length of peak to peak estimated from fluctuations of F_x

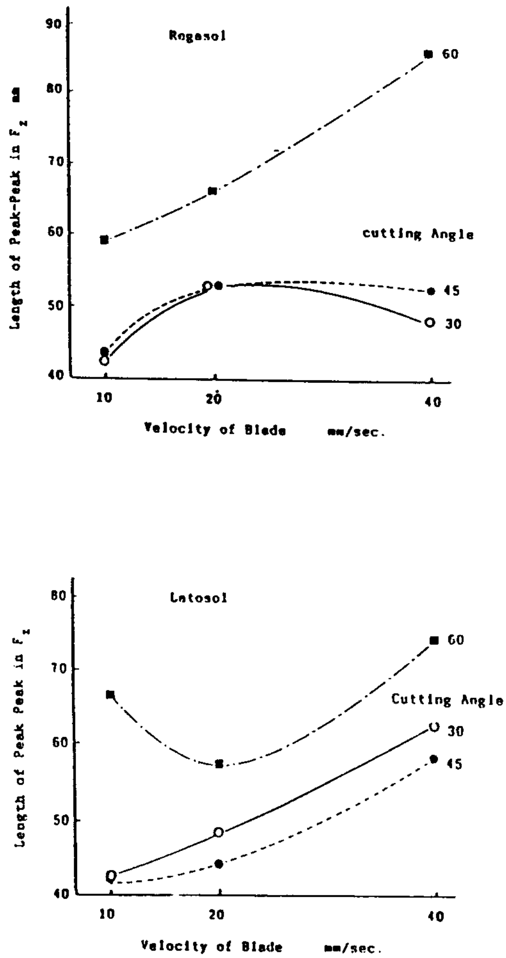


Fig.12 Length of peak to peak estimated from fluctuations of F_z

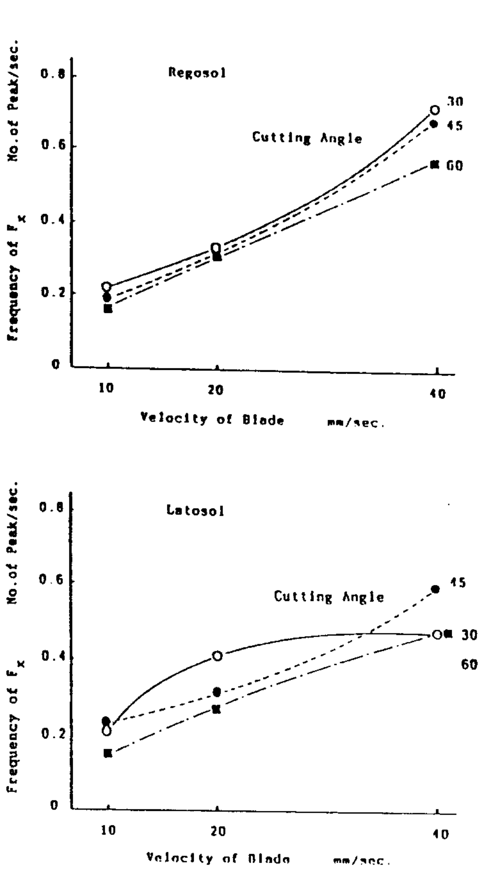


Fig. 9 Fluctuations of F_x to linear motion blade

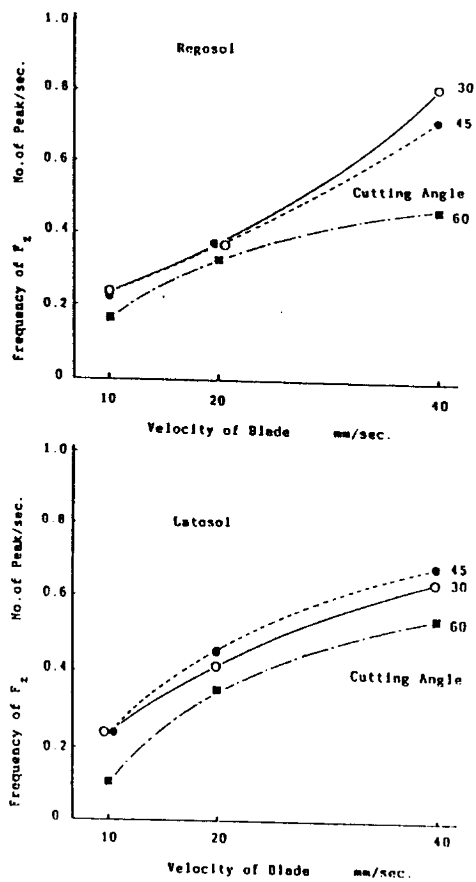


Fig. 10 Fluctuations of F_z to linear motion blade