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MOWING PERFORMANCE OF BUSH CUTTER EQUIPPED WITH A FIXED BLADE, DEVELOPED TO PREVENT BODILY INJURIES IN OPERATION

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ABSTRACT

In order to prevent bodily injuries frequently suffered in using bush cutters, especially from spattered stones, we developed a unique new cutting system equipped with a fixed blade on top of the rotary blade, and checked into the mowing performance of the cutter. From experimental test of mowing efficiency and measuring test of physical stress (o_2 consumption and heartbeat rates), the new cutting system with a fixed blade proved that it keeps good cutting performance with lower peripheral speed of the rotary blade (22m/sec), compared to that of ordinary cutting blade, yielding more safety in operation. Weight of the cutter head is, however, heavier than that of ordinary machine by about 70% which increased a physical stress on the operator with slightly faster heartbeat rates. In mowing along edge of concrete wall, the operator enjoyed using the cutter with no anxiety, owing to function of the fixed blade.

Key Word: Bush Cutter, Fixed Blade, Rotary Blade, Mowing Efficiency, Physical Stress, New cutting system

INTRODUCTION

In Japan, bush cutters are widely used today in sectors of agriculture and forestry, greenery and gardening, and in the suburbs, all for cutting grass. And production of bush cutters in Japan reached about 1,650,000 units in 1991. With the remarkable prevalence of bush cutters, accidents in operation of the cutters are on the increase. Eye injuries, inflicted by stones spattered by bush cutters, have become one of the typical problems " S. Kimura (1986), T. Aramaki (1986)" . Bush cutters are regulated by a saftey regulation to have them equipped with a safety guard to protect operators from spattered stones. It is not uncommon, however, that the safety guard is removed from the bush cutter when in operation, for the reason that grass or weeds tend to get stuck between the guard and cutting blade and the guard gets in the way of mowing. From this standpoint, an improvement in safety function is sought.

Mowing by conventional bush cutters can be defined as a sort of impact cutting, where high rotating speed of cutting blade plays a significant role in keeping performance "J.Yamshita (1988)". High rotating speed over 6,000 rpm tends, however, to increase risks for operators to suffer bodily injuries from spattered stones. Such a high speed works against safety in operation. A cutting system, capable of mowing with lower speed of blade, is certain to be preferable. We developed a new cutting system, equipped with a fixed blade on top of the rotary blade, which is designed to hold and shear grass.

Experiments were carried out to know the mowing efficiency of the new cutting system. The physical stress on operators in mowing work was also studied and compared with conventional bush cutters without a fixed blade.

STRUCTURE OF TESTED BLADE AND ITS FUNCTION

Fig.1 shows some blades for bush cutters available on the present market in Japan. Blades most popularly used are the ones with 4 teeth and 8 teeth. Fig.2 shows the new cutting system with a fixed blade. Table 1 shows major specifications of the new cutting system.

The system comprises a gear case containing a pair of bevel gears (gear ratio 13:42), a fixed blade mounted on the gear case and a rotary blade placed underneath the fixed blade. The dual blades are designed to cut grass the way a pair of scissors do. To prevent the dual blades from getting stuck with grass in between, the cutting system is also equipped with a support to screw the fixed blade in and to be mounted on the gear case. The fixed blade comes into contact with rotary blade with pressing force of about 19.6 N from 4 pieces of coil springs placed in the fixed blade support.

Fig. 3-a and b shows shape of the fixed blade and rotary blade. The fixed blade (fig.3-a) has 23 cut-edges with curvature of R80 and wedge angle of 60° . The rotary blade (Fig.3-b) is a square plate with a cutting edge on each corner of the plate. Tip of cut edge, 2 mm wide in section, is designed to come into contact with the fixed blade and the contact gets loose toward center of the rotary blade. All this is so designed to reduce frictional resistance in running of the blade against the fixed blade.

Crossing angle of two straight lines, one connecting relative tip of cut edge and another extending along the angle of knife edge is defined as cutting angle and the angle is set at -25° .

It is also a characteristic of the new cutting system that the peripheral diameter of the rotary blade is smaller than the outside diameter of the fixed blade by 4 mm. This is to prevent the cutter from damaging trunks of trees in an orchard and to protect the rotary blade from foreign obstacles.

MOWING EFFICIENCY

1. Experimental method

Test machines used were shoulder suspention type machines with engine 24.1 ml, maximum output 0.59 kw/6,5000 rpm, weight (without cutter head) 5.1 kg, gear ratio 14:19 for ordinary single blade and 13:42 for the cutting system with a fixed blade. We used the two blades to cut oat grass grown in uniform shape and size, to measure the two points as follows.

1) Mowing efficiency

We mowed oat grass grown in varing density for 5 minutes, setting engine speed at 8,000 rpm and 6,000 rpm before mowing, and mowing width at 1.8 m. Mowed area was measured and mowed area or mowing efficiency per minute was obtained.

2) Engine speed

The variation in engine speed in mowing work was also recorded into the pen recorder through an ignition tester.

2. Results and discussion

Fig.4 shows mowing efficiency for different types of cutting blade, obtained from mowing oat grass for 5 minutes with engine speed set at 8,000 rpm before mowing.

Oat grass was thick in high density, but stems were straight with relatively small diameter of 3.8 mm on an average, which contributed to reduction in cutting load. This condition made the mowing easy and high rate of mowing efficiency was achieved for a new cutting blade with 8 teeth. Also, little decline in the rate of mowing efficiency was observed in mowing with used blades of the same type. One of the blades had been used for 30 minutes and another one for 60 minutes. The used blades had abrasion of R2 and R4 on the tips of teeth, respectively. Abrasion on the used blades with fixed blade was R0.5 and R2, respectively.

With a new cutter equipped with the fixed blade, a little less mowing efficiency was obtained. The lower rate of mowing efficiency can be attributed to the following factors. ① Diameter of the rotary blade is smaller than that of 8 teeth blade by 5 mm.

② The cutter head including gear case and blades is heavier than that of 8 teeth blade by about 70%, which may affect mowing operation adversely. ③ Engine was set at high speed of 8,000 rpm, which might have caused the cutter blades to catch less grass, resulting in slower movement of the bush cutter. Above factors were considered to have decreased the mowing efficiency of the bush cutter with the new cutting system. In other words, mowing was conducted in a kind of "inch along" fashion, which is considered to have prolonged the time to move the cutter horizontally for mowing.

High rotary speed of the blade works to decrease the mowing efficiency of the new cutting system. The efficiency can, however, be recovered if the cutting angle of the rotary blade is retreated from -25° to the direction of 0°. Change in the angle will allow the cutter to catch more grass, reducing the time for mowing. This is the reason why mowing efficiency of the used blade having abrasion R0.5 from 30 minutes use proved to be higher than that of a new blade. Larger abrasion from 60 minute use deteriorated sharpness of the cutting blade and decreased the mowing efficiency.

Fig.5 shows comparison of mowing efficiency obtained from mowing oat grass with different type of cutting blade at engine speed set at 8,000 rpm and 6,000 rpm before mowing.

Engine speed varies depending on the cutting load. The average variation was used for the average engine speed in mowing test. From Fig.5, we can see that engine speed of 8,000 rpm set before mowing with an ordinary cutter (a new 8 teeth blade) went down to about 6,400 rpm, corresponding to peripheral speed of about 57 m/sec, in mowing. Engine speed of 6,000 rpm set before mowing dropped down to 4,500 rpm with a conspicuous decline in mowing efficiency. Cutting resistance accelerated by abrasion on the blade brought about a large decrease in engine speed in a high speed zone. With the new cutting system with a fixed blade, on the other hand, grass juice on the rotary blade worked as lubricant to decrease the functional resistance of the blade against the fixed blade and engine speed in mowing was higher than the speed set before mowing.

To ascertain our earlier observation that lower rotary speed of the blade allows the new cutting system to catch more grass and enhance the mowing efficiency, we set the engine speed at 6,000 rpm and checked into the mowing efficiency. We found that the effciency achieved from 6,000 rpm was superior to that from 8,000 rpm. The result was the reverse of the trend with ordinary bush cutters.

PHYSICAL STRESS

The difference in physical stress of the operator between the new cutting system and the ordinary 8-teeth blade attached to the bush cutter was examined. The evalution of physical stress in mowing work was done by measuring heartbeat rate and O_2 consumption .

1. Experimental method

Heartbeat rates were measured successively in the operator's physical state of a) rest, sitting on a chair, b) mowing work and c) recovery, sitting on a chair. Time between R-R waves on the electro-cardiogram was measured by a heartbeat memorizer, for conversion into number of R waves or heartbeats per minute.

" Douglas Bag " method was employed for measurement of O_2 consumption. Basing on the results, we also obtained Mets (metabolic rates in mowing work / metabolic rates at rest). Test operators were two males experienced in using bush cutters.

2. Results and discussion

Table 2 shows operator's Mets, rate of increase in heartbeats and mowing efficiency, each measured in mowing oat grass for 5 minutes. The result indicated that pysical stress inflicted in use of the new cutting system with a fixed blade was heavier than that from an ordinary cutter blade. Rate of increase in heartbeats (heartbeats in mowing / heartbeats at rest) for the new cutting system was 149～162 % against 140～142 % for an ordinary blade.

The increase in heartbeats was apparently more for the new cutting system equipped with heavier cutting unit (head).

In the field of labor science, Mets (Metabolic Rates) is often employed to indicate labor intensity. Mets is obtained by dividing operator's weight and body surface area into O_2 consumption measured. The Mets for mowing work was 3.4～4.4 and 3.7～4.4 respectively for the new cutting system and the ordinary blade. Mets of this level is generally classified into hard labor "Jacques LeBlanc (1975)" .

Fig.6 shows variation in heartbeat rates measured in mowing " Echinochloa Oryzicola" , which are weeds growing in paddy fields across Japan. For reproducing mowing along concrete fence, we placed 6 concrete blocks in line in the field and mowed the weeds around and along the concrete blocks, each for one minute. In order to make the cutter heads weigh the same, a weight was placed on the gear case of an ordinary blade which is lighter than that of the new cutting system.

In the mowing work, heartbeat rates increased remarkably. Rate of increase in the beats for an ordinary 8-teeth blade (144%) turned out to be higher than that for the new cutting system (138 %).

It is known that the difference in physical stress of operator is dependent on the difference in weight of cutter heads and the magnitude of gyroscopic couple which arises from the revolution of the blades "J.Yamashita (1986)". In this particular experiment the effect of the cutter heads weight is not considered. Gyroscopic couple counts in this case. For example, the moment of inertia of the blade and the rotating speed of the blade for the new cutting system was about 1/2 and 1/3 of the ordinary 8-teeth blade, respectively. It is because of this factor that the new cutting system reduced the physical stress of operator.

Heartbeat rates in the second trial with the engine on before mowing recovered significantly. We moved on to mowing along the wall fence (concrete blocks). On starting the operation, heartbeat rates went up sharply in the same pattern as in normal mowing. The new cutting system is designed to function to reduce spattered stones and to give safety and comfort to operators. Consequently, increase in heartbeats in mowing along the wall fence with the new cutting system was 145%, up only 7 %, which proved to be of lighter physical stress. Increase in heartbeats with an ordinary blade was 155% or up 11%.

CONCLUSIONS

For the purpose of preventing frequent stone accidents in using bush cutter, we developed a new cutting system equipped with a fixed blade on top of the rotary blade, which is designed to catch grass and cut it the way a pair of scissors do. Experiments were carried out to know the mowing efficiency and the physical stress on the operators in mowing work, and the results were compared with conventional bush cutters without a fixed blade. The major results obtained are summarized as follows.

In test mowing of oat grass, with the new cutting system, higher mowing efficiency was indicated with engine speed 6,000 rpm (peripherals speed of the rotary blade 21.9 m/sec) than with 8,000 rpm (29.3 m/sec). The lower engine speed allowed the cutter to catch more grass and cut grass with better performance. The result was the reverse of the phenomenon with ordinary bush cutters.

Relation between a degree of abrasion on the rotary blade and mowing efficiency was investigated. A used blade with abrasion of about R0.5 allowed the cutter to catch more grass and to yield higher mowing efficiency than with a new blade.

The effect of using the new cutting system on the extent of operator's physical stress was also studied. Weight of the cutter head is heavier than that of conventional machines by about 70 %, which caused slightly heavier physical stress on the operator. However, in mowing along the edge of concrete fence, most of the struck stones were not scatterd and the operator was able to keep mowing with no mental stress or anxiety.

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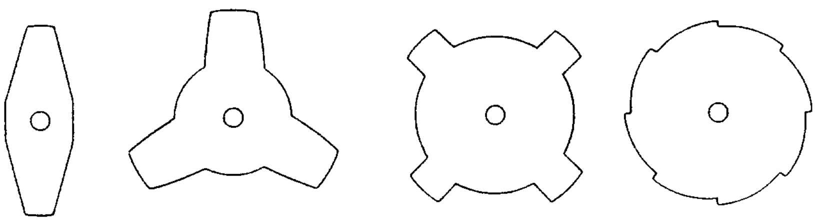
Table 1 Specifications of the new cutting system with a fixed blade

	Fixed blade	Rotary blade
O.D.×Thickness (mm)	231×1.6	226×1.4
Weight (gr)	442	262
Hardness (H_RC)	59~61	56~58
Materials	SKS 51	SKS 51
Weight of gear case (gr)	530	
Gear ratio	13:42	

Table 2 Mets, rate of increase of heartbeats and mowing efficiency in mowing work

		Mets	Rate of increase of heartbeats (%)	Mowing efficiency (m^2 / min)
Cutting system with a fixed blade	New blade	3.7	150	5.47
	Blade used for 30 min	4.1	149	7.24
	60 min	4.4	162	7.09
Ordinary blade (8-teeth blade)	New blade	3.4	140	7.42
	Blade used for 30 min	3.8	142	6.34
	60 min	4.4	141	6.84



Cutter blade	Ordinary 2-teeth blade	Ordinary 3-teeth blade	Ordinary 4-teeth blade	Ordinary 8-teeth blade
O.D. × Thickness (mm)	233 × 1.4	230 × 1.4	230 × 1.4	230 × 1.4
Weight (gr)	170	242	302	392

Fig.1 Cutter blades available on the market

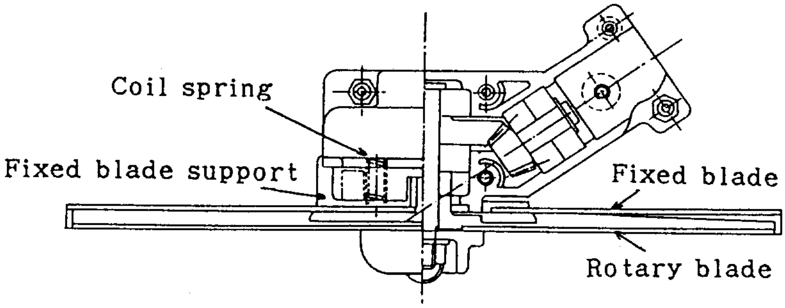


Fig.2 Newly developed cutting system with a fixed blade

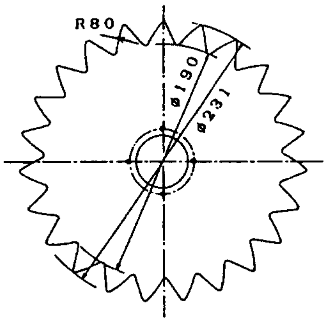


Fig. 3-(a) Fixed blade

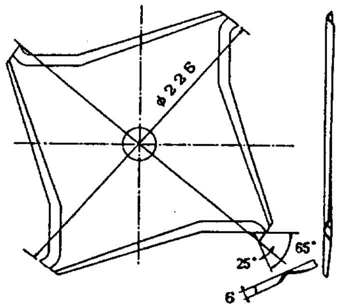


Fig. 3-(b) Rotary blade

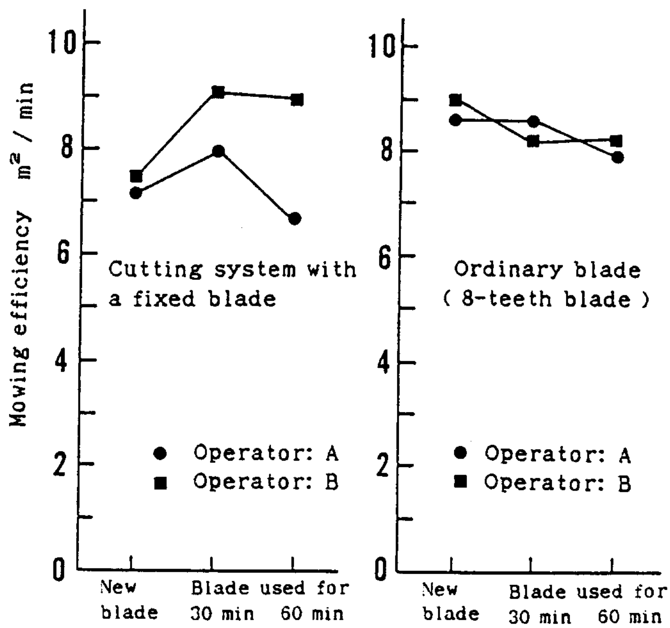


Fig.4 Relationship between shape of blades and mowing efficiency

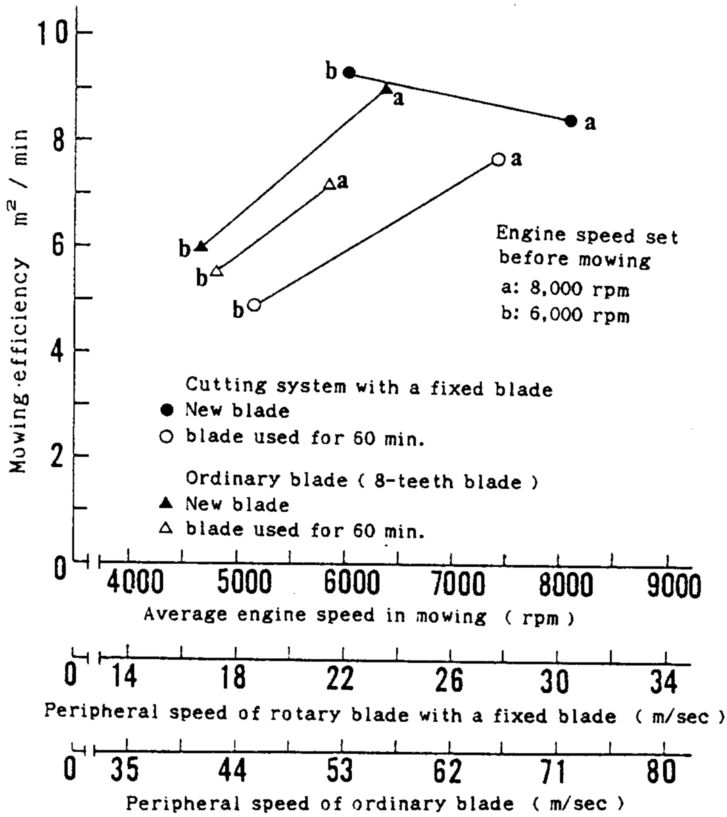


Fig.5 Relationship bettween engine speed in mowing and mowing efficiency

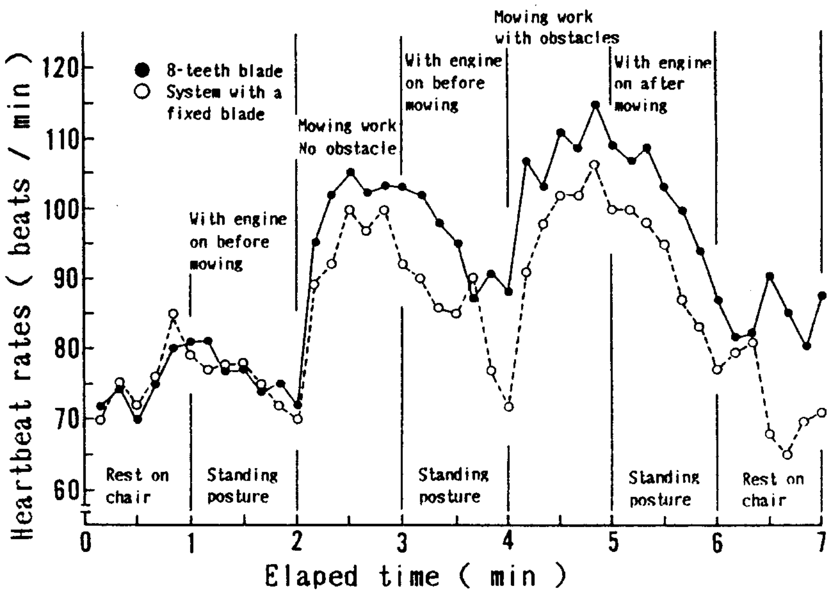


Fig.6 Variation in heartbeat rates in mowing with two different cutter blades