Design and analysis of a revised grass trimming device

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This paper presents design methodology for fabrication and testing of a petrol-operated grass trimming device under Indian scenario. Components like driveshaft spindle, its bushed sleeve and trimming head system were developed from available workshop scrap material. During operation, optimal hand-handle position over a different engine speeds and cutting thread lengths was predicted so as to minimize operator’s fatigue.

Keywords: ANOVA, Exhaust muffler, Fuel consumption, Hand vibrations, Noise levels

Introduction

Existing engine trimmers suffer from high initial cost, high levels of engine noise, high fuel consumption rates and high operator’s fatigue in long-run. Bulski et al. studied noise control issues in the device carrying cutting blades. Hagen et al. studied flow behaviour occurring within triple blade lawnmower deck. Drutowski & Fetzer analyzed noise from lawnmowers. Timushev et al. modelled a 2-phase lawnmower flow system for determining average aerodynamic characteristics using computational fluid dynamics analysis by acoustic vortex method by predicting sound power data. Mallick analysed existing trimming device from operator’s fatigue point of view. Atkins investigated design of blade profiles in grass cutting devices so as to minimize cutting forces. Mallick et al. studied effects of engine noise on operators health.

This study presents fabrication of a nylon threaded-grass trimming device and a methodology is proposed to select an optimal configuration to minimize operator’s fatigue levels.

Experimental

Grass Trimming Device (GTD)

GTD is a modified version of existing petrol line-trimmers containing four subassemblies together with a handle system: i) Engine subassembly; ii) Driveshaft subassembly; iii) Gear drive subassembly; and iv) Trimming head subassembly (Fig. 1).

Engine Subassembly

GTD uses a light-weight, low emission, single-cylinder, 2-stroke single cylinder spark ignition engine (Fig. 2). It comprises of an engine block having piston cylinder, cylinder head, oil reservoir for storage of lubricating oil and cam housing. A connecting rod is attached to piston and crankshaft on either end. Cylinder head has an intake and exhaust ports. A valve cover is laid over cylinder head forming valve chamber. Valve-actuating assembly comprises of one rocker arm and push rod. One end of push rod extends into valve chamber so as to engage rocker arm. A cam is mounted for rotation in cam housing. Cam is connected to crankshaft and driven at a speed less than the crankshaft. A pre-designed forced draught muffler is connected at the end of silencer box to minimize evolved noise during operation.

Driveshaft Subassembly

It is made-up of a central steel drive spindle (diam, 5 mm; length, 153 cm) surrounded by a bushed outer aluminum hollow sleeve. Left end of drive spindle is connected to engine shaft. This lubricated hollow sleeve (149 cm long) has an internal recess to hold spindle firmly. There are slots at the ends and middle of length on internal spindle for proper gripping with outer sleeve. Other end of spindle shaft is attached to a bevel gear unit.
Gear Drive Subassembly

This is a cast-in subassembly having two bevel gears. One bevel gear is attached to the end of driveshaft, while other is fixed to bottom shaft carrying cutter head. Both drive and cutter shafts are laid at some angle such that when driving spindle is at some angle, cutter shaft would be in a plane parallel to the ground. Gear ratio of present system was found as 1.46.

Trimming Head Subassembly

Trimming head carries a nylon thread holder. Reel of thread can be conveniently adjusted based on cutting conditions.

Handle comprises of an adjustable rod mounted centrally about aluminium sleeve shaft. Direction and height of handle can be adjusted as per the convenience.

Results and Discussion

Testing of GTD

Working ability of GTD (Fig. 3) was analyzed through performance under various tests. Experiments were carried out under stable speed of cutter in a particular throttle setting for 60 s and speed of rotating trimming head was noted down with a tachometer.

Hand Vibration Analysis

Operator for long hours of working often shift hand positions on handle so as to relieve fatigue. In order to measure arm vibrations, a low frequency-range accelerometer was mounted on operator’s left hand with a tape. Accelerometer placement on the hand gives more consistency in measurements as compared to placement over handle. Accelerometer was connected to a calibrated digital gauge for free movement in grass lands as per the requirement. In experiments, nylon thread length was varied (10-20 cm) and engine speed was varied (3300-5100 rpm) each in three levels. Before experiments, speed range of GTD was surveyed in normal trimming work. In each case, three hand positions were evaluated through layout of experiments (Table 1).

Hand positions are defined with respect to the position of left hand on handle. In first position (P1), left hand holds handle at the extreme end, while in second (P2) and third (P3) positions, left hand is respectively at a distance $1/4$th and $1/5$th of the total length from extreme end. Right hand is always at the right end of handle. Hand vibration measurement can be performed along three directions, so as to measure static accelerations for all modes of operation. In present study, only largest single axis component was noted down. Magnitudes of velocity (first time integral of acceleration), which were significant than accelerations along Y-axis, were noted down as output parameters in various hand positions (P1, P2 and P3) on handle (Table 2).

Fig. 1— Line diagram of grass trimming device

Fig. 2— Engine subassembly

Fig. 3— Grass trimming device assembly
Analysis of variance (ANOVA) investigated most influential parameters to the process factor-level response. Larger F-value indicates that variation of corresponding process parameter makes a big change on performance characteristics (Table 3). Calculated F values indicate that length of nylon thread is a significant parameter for minimizing hand vibrations in all positions. Engine speed has relatively less influence. In P3, both length of thread and engine speed have equal significance compared with P1 and P2. The p-values show probability that all factor levels (length of thread and engine speed) have same mean yield. From p values, it can be accepted that length of thread and engine speed have same mean yield as both are quite higher than 0.05.

**Rate of Fuel Consumption**

To study the effect of using nylon thread on the rate of fuel consumption, comparative experiments were carried-out with respect to conventional metallic two-bladed cutter. Two similar set of grass lands were chosen each for nylon thread and metallic blade. For obtaining several data samples, each grass land was divided into four similar sizes of areas. Rate of fuel consumption was estimated in both cases. Fixed operating parameters include: engine speed, 4250 rpm; length of thread, 20 cm; and hand position, P1. Average rate of fuel consumption (Table 4) with nylon thread (0.00817) is found less than that of metallic cutter (0.0105) for same engine rating and trimming operation. Effectiveness of trimming was found better in normal straight cutting work.

**Engine Noise**

GTD was tested by a noise-level meter at all three speeds. A hand-held sound level meter (model: SLM 340; make: AZ instruments, Germany) was used for measuring sound level with a resolution of 0.1 dB. Average noise level during operation with nylon thread was found 78 dB with the available engine silencer.
An additional muffler was designed in this study to absorb output noise conveniently by creating a small back pressure without appreciable reduction in output power. A noise level of 5-7 dB was reduced with added muffler unit.

Conclusions
Fabrication and testing aspects of a petrol-operated GTD is presented in this paper with an objective to minimize operator’s fatigue, petrol consumption and noise levels. ANOVA showed that hand vibrations during operation were significantly influenced by length of nylon-thread than speed of engine in three hand-handle positions considered. P2 was advisable for minimum hand vibrations. Optimum values of operating parameters for minimum hand vibrations in all positions were: nylon thread length, 20 cm; and engine speed, 3300 rpm. Rate of fuel consumption with nylon thread over an equivalent trimming operation using metallic cutter was comparatively low (22%). Exhaust additional muffler unit reduced engine noise level by 6 dB.

References