# VIBRATION MEASUREMENT AND PERFORMANCE EFFICIENCY OF GRASS MOWER

**Ahmed A. A. Hamid**
**Instructor**
**University of Baghdad - Directorate of Dormitories**
ahmed.hamid23@yahoo.com

## ABSTRACT

**The experiment was conducted in field of the University of Baghdad, Jadryia region, Baghdad to measure vibration and performance efficiency of grass mower (machine cutting grass). Vibration in three axes are longitudinal X , lateral Y and vertical Z in four places of mower machine during cutting grass and Practical Productivity, Efficiency and Fuel Consumption measured in this experiment . Factorial design (3 x 2) used, mower speeds included 1.9 3.6 and 6.4 km/hr and engine load included idling and full load according to randomized complete design were used in this experiment. Least Significant Design (LSD) 0.05 was used to compare the mean of treatment. Result were showed that the mower speed 6.4 km/hr recorded high productivity (0.6557 ha/hr), low fuel consumption (1.62 l/ha), least efficiency ( 83.97 %), vibration values for three axes X,Y and Z (8.28, 7.85) and (5.35 m/sec$^2$) for mower seat, (6.25, 7.05) and (4.80 m/sec$^2$) for steering wheel and (14.78, 13.8) and (11.58 m/sec$^2$) for mower chasses and (21.45, 20.05) and (16.15 m/sec$^2$) for cover blades. Engine full load recorded high productivity (0.4080 ha/hr), efficiency (84.47%), and high vibration values for three axes X, Y and Z were (5.46, 5,03) and (3.56 m/sec$^2$) for mower seat , (4.56, 5.30) and (3.36 m/sec$^2$) for steering wheel, (13.30, 12.32) and (10.93 m/sec$^2$) for mower chasses and (18.13, 17.03) and (13.83 m/sec$^2$) for cover blades,Then these result a cross legislated permissible vibration exposure limits in the world.**

**Key word: Fuel consumption, Cutting productivity, Mower speed.**



# قياس الاهتزازات وكفاءة أداء آلة قطع الأعشاب

**احمد عبد علي حامد**
**مدرس مساعد**
**جامعة بغداد / مديرية الأقسام الداخلية**
ahmed.hamid23@yahoo.com

## المستخلص

**أجريت تجربة في حقول جامعة بغداد– منطقة الجادرية، بغداد لغرض قياس الاهتزازات وكفاءة أداء جزارة العشب (آلة قطع أعشاب ذاتية الحركة). قياس الاهتزازات بثلاثة اتجاهات رئيسة هي الطولي والجانبي والعمودي في أربعة مواضع للآلة أثناء قطعها للأعشاب وهي الاهتزاز في مقعد جزارة العشب وعجلة القيادة والهيكل وغطاء سكين القطع والإنتاجية العملية لقطع الأعشاب وكفاءة القطع واستهلاك الوقود لجزارة العشب. استخدمت تجربة عاملية (3×2) لعاملين هما السرعة الأرضية للجزارة وبثلاث سرع 1.9 و3.6 و6.4 كم/ساعة وتحميل محرك الجزارة بتحميلين هما الحمل القليل والحمل الكامل وفق تصميم القطاعات العشوائية الكاملة وبثلاث مكررات، اختبرت الفروق بين المتوسطات بطريقة أقل فرق معنوي على مستوى احتمالية 0.05. أظهرت النتائج أن سرعة جزارة العشب 6.4 كم/ساعة سجلت أعلى إنتاجية عملية للقطع 0.6557 هكتار/ساعة وأقل استهلاك للوقود 1.62 لتر/هكتار وأقل كفاءة 83.97 % وأعلى قيم اهتزاز للاتجاهات الثلاثة X و Y و Z وكانت 8.28 و7.85 و5.35 متر/ثا2 لمقعد جزارة العشب، و6.25 و7.05 و4.80 متر/ثا2 لعجلة القيادة، و14.78 و13.80 و11.58 متر/ثا2 لهيكل الجزارة، و21.45 و20.05 و16.15 متر/ثا2 لغطاء سكاكين الجزارة. التحميل الكامل للمحرك سجل أعلى إنتاجية عملية بلغت 0.4080 هكتار/ساعة وأعلى كفاءة 84.47% وأعلى قيم اهتزاز للاتجاهات الثلاثة X و Y و Z وكانت 5.46 و5.03 و3.56 متر/ثا2 لمقعد الجزارة، و4.56 و5.30 و3.36 متر/ثا$^2$ لعجلة القيادة، و13.30 و12.32 و10.93 متر/ثا$^2$ لهيكل الجزارة، و18.13 و17.03 و13.83 متر/ثا$^2$ لغطاء سكاكين الجزارة، تعد قيم الاهتزاز متجاوزة الحدود المسموح بها عالمياً.**

**كلمات مفتاحية: استهلاك الوقود، إنتاجية القطع، سرعة جزارة العشب.**

## Introduction

There are millions gardeners and workers in the world use mower for cutting grass and weeds, therfore these implement are very important. The gardeners and maintenance workers of the municipal authorities use them daily, sometimes 8 hours a day. The lawn mower is a mechanical device that literally shaves the surface of the grass by using a rapidly rotating blade or blades. Mowing is an important consideration in the maintenance of grass as it keeps the grass short, helps with weed and pest control. The first lawn mower was invented by English textile worker named Edwin Budding in 1827 in Thrupp, Budding's mower was designed primarily to cut the lawn on sports grounds and extensive gardens (1). All companies and users (farmers and gardeners) in the world care in mowers work and performance in cutting grass not speed ground mower. America is the nation's largest irrigated crop, covering more than 40 million acres (1 acre = 4046.85 m² ), lawn mowers care for this expanse during the growing, Mowers consume 1.2 billion gallons (gallon US = 3.785411 litres) of gasoline annually, about 1% of U.S. motor gasoline consumption (2). Reach (3) found that fuel consumption in mower engine four-stroke was 12.19 ml/min . Reach (4) determined productivity and fuel consumption for three types mowers ,result showed 1.78 ha/h and 4.52 l/h for self propelled mower, 0.72 ha/ h and 2.20 l/h for oscillatory mower , 1.00 ha/h and 3.32 l/h for rotary mower. Mowers and tractors different in fuel consumption ,usually mowers low because have it one or two small diameter cylinders, small bore and stroke in engine. Small engine machines such as mowers have been estimated to be operated at 90 % or more of peak output for the majority of operational use (5). Lower engine RPM can reduce fuel consumption by 30 percent or more without impacting cut quality, mower with steering wheel efficiency cutting grass can reached more 80 percent(6). The shock and vibration may occur due to irregularities in the ground over which the mower is driven. Further, the shock and vibration may occur due to the many moving parts of the mower, such as the engine, the tires and the cutting blades (knives), Still further, the design of the mower's structural elements such as the chassis or frame and mower deck (cover of blades) may provide additional sources of shock and vibration. Currently, there are no legal standards that limit exposures to local vibration during leisure time in Iraq. In Iraq, unfortunately we do`nt have a healthy organizations or unions care to the employees such as tractor drivers and workers safety like other develop countries (7). Every year Many millions dollars loss for machines in the world, because the vibration is motion unacceptable in machines agriculture like tractors and mowers and other machines which lead damage, broken and wearing parts machines. Found (8) the vibration levels in three mowers was deferent for each to other and more than compare with limited allows, Lawn mowers gave high vibration levels (over $3\,m/\sec^2$). Found (9) in experiment a high vibration values for three dimension longitudinal , lateral and vertical was 9.8, 7.7 and 3.4 m/sec² with frequency 1 Hz. Vibration in agriculture machines is the important health problems causing hazard and effected the driver performance (10, 11,12 and 13). Found (10) and (14) in experiments vibration values were high when work with full load engine compare with idling engine. The aim of the experiment is to evaluate the performance efficiency of mower ( by measures the practical productivity, efficiency cutting grass mower and fuel consumption) and measure levels vibration in mower machine and compare The legislated permissible vibration exposure limits in the world.

## 1 - Material and Method

### 1-1 Grassland

The experiment was conducted to evaluated the performance efficiency and vibration of mower implement in the field of the University of Baghdad, Jadyria-Baghdad. There are some weeds grow with grass. Grassland near Tigris River about 280 m. The gardens was 31.7 m above sea level, and the weather temperature was measured 37 C° ( 98.6 F° ) and humidity was 20 % .

### 1-2 Experimental Design

Factorial Experiment (3 x 2) were used in this experiment included two factors. Mower speeds included 1.9, 3.6 and 6.4 km/hr and engine load included idling and foal load according to Randomized Complete Block Design (RCBD) with three replications. Least significant design (LSD) 0.05 was used to compare the mean of treatments. Statistical Analysis System (SAS) was used (15).

**1-3 Mower Grass cutting**

The mower which used in this experiment was Rotary Murray Mower made in USA 2010. The main parts blades that rotary horizontally and mounted directly to the crankshaft of it`s, engine power gasoline , cutter deck housing, four wheels two front wheels and two rear wheels and rear grass catcher. Mower was check every important parts spatial the seat driver and balance blades cutting and measure the pressure tires and work with full fuel tank and check mower seat with no broken springs seat (table 1).

**Table 1. Technical characteristics Mower.**

| | |
|---|---|
| Type ,Made, Year | Murray , USA , 2010 |
| Serial no. | 100719YG21539 |
| Cylinder no. | 2 |
| Cooling system | air |
| Engine power (hp) | 22 |
| Starting system | Key switch - super glow |
| Fuel tank (L) | Gasoline 13.6 |
| Type suspension seat | Mechanical spring |
| Speeds no | 6 forward and 1 rear |
| Cutting width (inch) | 48 |
| Mower driver mass (kg) | 76 * |
| Tires front size | 15 . 6.00-6 NHS |
| Tires front and rear pressure (psi) | 20 ** |
| Tires rear size | 20 . 8.00-8NHS |

***Mower driver mass when conduct the experiment**

**** Tires pressure during the experiment.**

**1-4 Choosing Mower Speeds**

The experiment was conducted with three speeds which choosing carefully in the grassland by limited point to be start treatment line grass length 30 m , we must leftover 5 m at least before this 30 m to give the speed ground mower stability in movement and cutting grass and determined time in second by stopwatch to cross the mower the distance (we calculated the time cutting grass for 30 m only), then calculated by the following equation :

$$S = D/T \times 3.6 \qquad (1)$$

Where *S* is speed measure in km / hr , *D* is distance treatment line grass limited equal 30 m , *T* is time to cross mower 30 m , 3.6 is factor conversion. Three speeds ground mower which choosing carefully in these experiment were 1.9, 3.6 and 6.4 km/hr.

**1-5 Practical Productivity and Efficiency**

Practical productivity is main property when evaluation performance machines agriculture like mowers, plows and others. Always with any mowing operation, for that matter - not all of our time is spent actually mowing, we will spend some time turning at the sides or ends of the lawn (or field), We may also slow occasionally to maneuver around trees, bushes or other obstacles, We may have to stop occasionally for chores like emptying a grass catcher or unplugging a machine or full tank fuel . All of these things reduce our efficiency compared with just driving in a straight line at optimum speed. Efficiency effect by two factors width and speed, Increasing speed does not result in a proportional increase in mowing rate because we still have to turn at the ends of the lawn and still have to maneuver around trees and obstacles. This nonproductive time becomes a larger percentage of total time as our speed increases, and our efficiency will drop with speed (16). Cutting efficiency can defined as the rate between practical productivity and theoretical productivity, and always the cutting grass efficiency least from One, can be calculated as follows (17):

$$Ce = Pp/Tp \times 100 \qquad (2)$$

Where *Ce* is cutting grass efficiency (percentage%) of mower, *Pp* is practical productivity for cutting grass measure unit hectare per hour (ha/hr), *Tp* is Theoretical productivity cutting grass measure unit ha/hr. Theoretical productivity define as a maximum productivity may be obtain when mower work in 100% percentage from speed, widthcutting and without losses time in the process , can be calculated as follows:

$$Tp = 0.1 \times Wt \times St \qquad (3)$$

Where 0.1 is factor conversion to hectare per hour, *Wt* is theoretical cutting width or designer cutting width 48 inch (122 cm) measure in meter, *St* is theoretical speed (limited speeds in the experiment) measure in km/hr.

Practical productivity define as a rate of the real performance of mower in lands grass , depended on ground mower speed, width cutting and surveying grass unit, can be calculated as follows : $Pp = 0.1 \times Wp \times Sp \times \int t \qquad (4)$

Where *Wp* is practical cutting width grass (real or actual width which always least from theoretical or designer width) measure in meter in the land grass by feta ( measure tape ) with many replications in treatment. *Sp* is practical speed in km / hr , ʃt is coefficient useful time(coefficient of the used production working time) equal 80 – 90 % in these experiment was mean 85 % (2) .

**1 – 6 Measuring Fuel Consumption**

Fuel consumption was calculated volumetrically in this experiment by using a fuel consumption meter (18), which measure consumption quantity for one treatment line grass (30 m) by unit milliliter (ml) (see fig1).Tied fuel consumption meter between the tank fuel and engine, in these time we opened valve A to allow fuel (gasoline) full the Graduate burette (cylinder marker), when mower machine work and reach the start point line grass we close valve A and open valve B to allow gasoline go to engine, when we reach the end line grass treatment we close valve B and see the level fuel in cylinder marker and record the data, then open valve A and B again and replication that process three times for each treatment in the experiment.

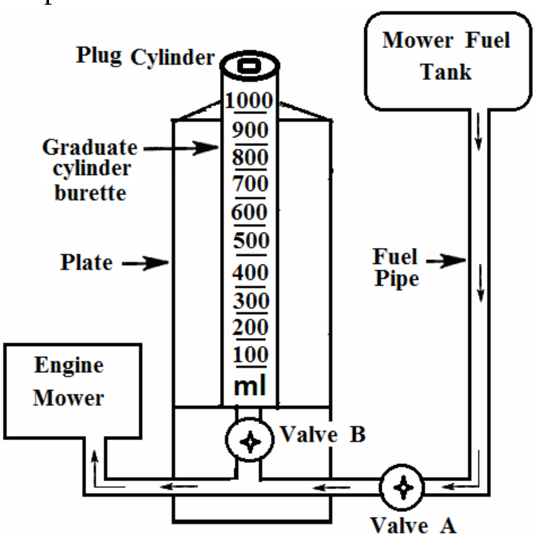



**Fig 1. Fuel consumption meter**

Fuel consumption can be calculated as following equation ( 19 and 20 ):

$$QF = Qd \times 10000 / Wp \times D \times 1000 \quad (5)$$

Where *QF* is quantity fuel consumption measure unit L/ha , *Qd* is quantity of fuel consumption during one treatment measure unit milliliter (ml) , 10000 and 1000 were factors conversion to Litre per Hectare.

**1- 7 Calibration Vibration Meter**

Vibration meter which used was type (VB - 8220 HA) made in Taiwan (fig.2) and we make calibration with another vibration meter and gives the same results in each reading. Vibration meter which used can save memory data measures and later we can call these data .


**Fig. 2. Vibration meter and sensor**

**1-8 Measurement of vibration in Mower**

There are two classifications for vibration exposure: whole-body vibration WBV (a term used to describe machinery vibration which effects seated or standing people) and hand - arm vibration HAV (Vibration that is transmitted through the hands and the fore arm). These two types of vibration have different sources, affect different areas of the body, and produce different symptoms . According to 2631-1-1997 Whole-body vibration is vibration transmitted to the entire body via the seat or the feet, or both, often through driving or riding in motor vehicles, which occurs when the body is supported on a vibrating surface (e.g., sitting on a seat which vibrates, standing on a vibrating floor or lying on a vibrating surface) (see fig. 3). Hand and arm vibration, on the other hand, is vibration transmitted into our hands and arms when using hand-held such as grip steering wheel mowers or tractors or other vehicle , too much exposure to Hand-arm vibration can cause hand-arm vibration syndrome HAVS (A collection of signs and symptoms resulting from exposure to hand-arm vibration) or carpal tunnel syndrome, but also from driving a tractors and other agricultural machines like mowers from steering wheel (21) (fig. 4).

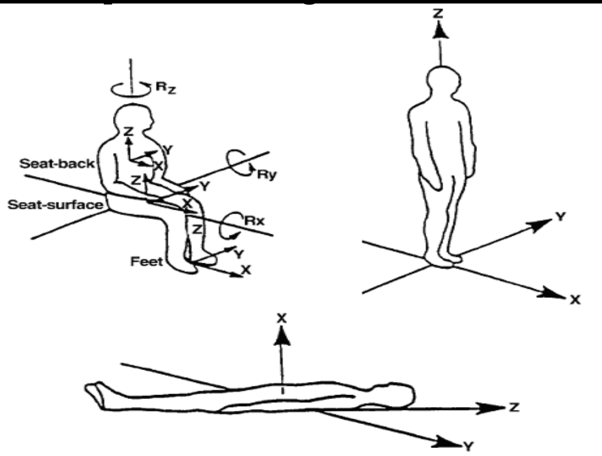



**Fig 3. Basicentric axes of the human body for translational ( X,Y and Z ) and rotational ( Rx, Ry and Rz ) whole body vibration . ( ISO 2631-1:1997)**

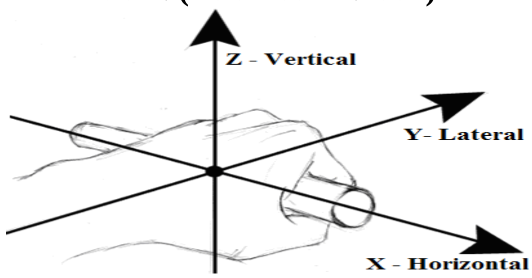



**Fig. 4. Axes for Measurement of Hand – Arm Vibration(Adapted from the Hand-Arm Vibration Guide, Griffin et al, 2006)**

The International Organization for Standardization (ISO) specifies that vibration should be measured in three directions or axes (longitudinal X, Lateral Y and vertical Z) as illustrated. Guidelines for measuring and evaluating human exposure and details of different analysis methods are given in ISO 2631-1-1997 for the whole-body vibration and ISO 5349-1-2001 for the hand-arm-transmitted vibration. ISO 8041(2003)and Japanese Industrial Standard JIS B 7760-1(2004) stipulate that the sensor should be installed in the same plane as the seat surface for measurement.

Measuring vibration in this experiment by put sensor vibration meter to measure three axes Horizontal X , Lateral Y and Vertical Z (7 , 10 , 14 and 22) (see fig.5 and 6) with three replications for each treatment during cutting grass in four important parts in mower :

1- Mower Seat .
2- Steering Wheel .
3- Mower Chassis .
4- Cover blades ( knives) cutting .

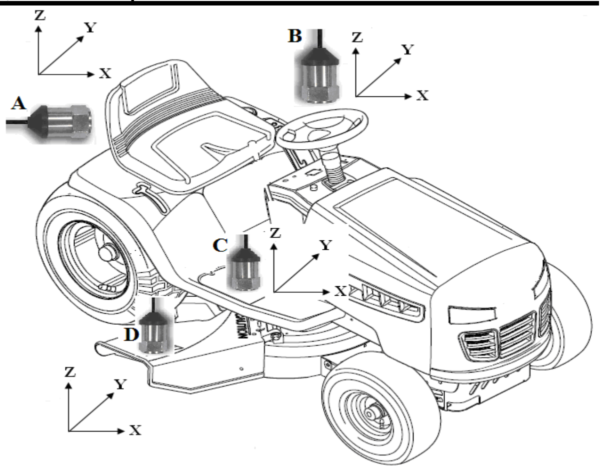
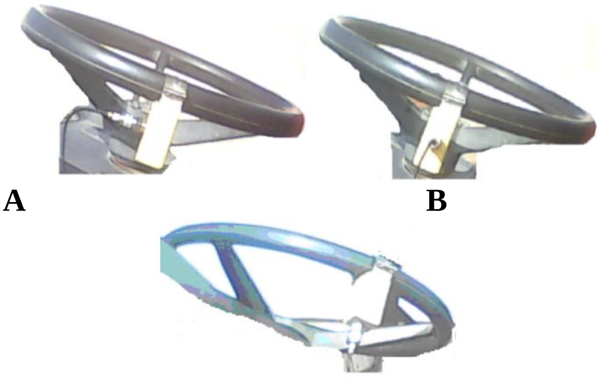



**Fig 5. Sensor location on mower to measures vibration A- mower seat, B- steering wheel, C- chasses, D, blades cover**



A B

C

**Fig 6. Sensor locations on steering wheel during measures directions A-longitudinal X, B- lateral Y and C- vertical Z**

The International Organization for Standardization (ISO), the American Conference of Governmental Industrial Hygienists (ACGIH), and the European Committee for Standardization (CEN) have developed standards and threshold limit values (TLV), which are considered to be health-based recommended maximum exposure levels (see tables 2). ISO 2621–1(1997) recommended the vibration exposure value were 0.63 m/sec² for 4 hour exposure duration , 0.5 m/sec² for 8 hour exposure duration and 3.5 to 5.8 m/sec² considered caution zone .

**Table 2 shows ACGIH exposure limits for hand arm vibration according to (23)**

| Exposure Duration (Hours) | Maximum Vibration Amplitude m/sec² |
|---|---|
| 4 to 8 | 4 |
| 2 to 4 | 6 |
| 1 to 2 | 8 |
| < 1 | 12 |

If under a worst-case scenario, the mower seat and steering wheel vibration have a vibration intensity of 12 m/sec². By ACGIH recommendations, the mower should not be operated for more than 1 hour per day. If, instead, the mower is assumed to have a vibration intensity that is in the middle of the range, say 6 m/sec², then the mower can be used from 2 to 4 hours per day, and our estimated daily duration of 3.5 hours of use would be acceptable. The legislated maximum permissible vibration exposure limits according to the European Committee for Standardization (CEN) are:

For whole body vibration:

-A daily exposure limit value ELV (is the maximum amount of vibration an employee may be exposed to on any single day) of 1.15 m/sec² standardized to an eight-hour reference period. By CEN recommendations, a mower driver daily exposure to whole body vibration (i.e. exposure over an 8 hour day) should not exceed 1.15 m/sec².

-A daily exposure action value EAV (is a daily amount of vibration exposure above which employers are required to take action to control exposure. The greater the exposure level, the greater the risk and the more action employers will need to take to reduce the risk) of 0.5 m/sec² standardized to an eight-hour reference period.

For hand-arm vibration:

-A daily exposure limit value of 5 m/s2 . standardized to an eight-hour reference period.

-A daily exposure action value of 2.5 m/s2 standardized to an eight-hour reference period.

## 2– Result and Discussion

### 2 – 1 Practical Productivity

Table 3. showed the Effect of mower speeds and engine load on practical productivity ha/hr. Result show significant effect of the mower speed on productivity, when mower speed increasing practical productivity was increased, mower speed 6.4 km/hr recorded higher productivity was (0.6557 ha/hr) , while speed 1.9 km/hr record lower productivity was (0.1965) ha/hr, that may be because mower speed is main factor in practical productivity in cutting grass processes . Result also showed significant effect for the Engine load on productivity, full load engine recorded higher productivity (0.4080 ha/hr) , while idling engine was (0.4070 ha/hr), that may be because mower cutting grass with full load engine give more steadiness and stability engine work, therefore a good ability blades for cutting grass,(Fig.7). Interaction between mower speed 6.4 km/hr and full load recorded higher practical productivity was (0.6563 ha/hr), while interaction between speed 1.9 km/hr with idling recorded lower value was (0.1962 ha/hr).

**Table 3. Effect mower speeds and engine load on practical productivity ha/hr**

| Mower speeds km / hr | Engine load Idling | Engine load Full load | Mean |
|---|---|---|---|
| 1.9 | 0.1962 | 0.1969 | 0.1965 |
| 3.6 | 0.3699 | 0.3707 | 0.3703 |
| 6.4 | 0.6551 | 0.6563 | 0.6557 |
| Mean | 0.4070 | 0.4080 | |
| L.S. D 0.05 | Mower speeds : 0.0003<br>Engine load : 0.0003<br>Interaction : 0.0005 | | |

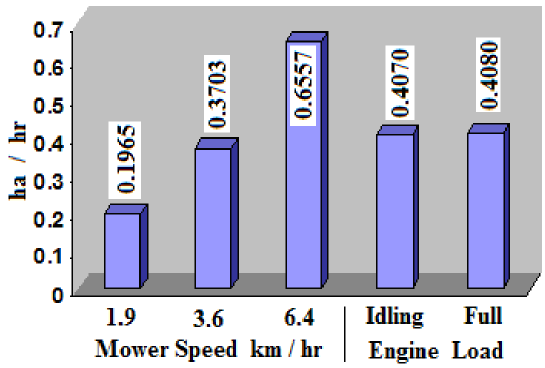



**Fig. 9. Relation mower speed and engine load with practical productivity**

### 2 – 2 Efficiency

Table 4. showed the effect mower speeds and engine load and on the efficiency of cutting grass %. Result showed significant effect for the mower speed in the efficiency cutting grass, mower speed 1.9 km/hr recorded higher efficiency (84.79 %), while speed 6.4 km/hr recorded lower efficiency (83.97 %), that may be because when increasing mower speeds decreasing coefficient useful time(coefficient of the used production working time). Result showed significant effect for the Engine load on efficiency , full load engine recorded higher efficiency (84.47 %) , while idling recorded lower efficiency (84.25 %), that may be because mower work with fuel load engine give more steadiness and stability engine work, therefore a good ability blades for cutting

grass.(fig. 10). Interaction between mower speed 1.9 km/hr and full load recorded higher efficiency was (84.95 %), while interaction between mower speed 6.4 km/hr and idling recorded lower efficiency was (83.90 %).

**Table 4. Effect mower speeds and engine load on efficiency cutting grass %**

| Mower speeds km / hr | Engine load: Idling | Engine load: Full load | Mean |
|---|---|---|---|
| 1.9 | 84.64 | 84.95 | 84.79 |
| 3.6 | 84.22 | 84.41 | 84.31 |
| 6.4 | 83.90 | 84.05 | 83.97 |
| Mean | 84.25 | 84.47 | |
| L.S.D 0.05 | Mower speeds : 0.0951<br>Engine load : 0.0777<br>Interaction : 0.1345 | | |

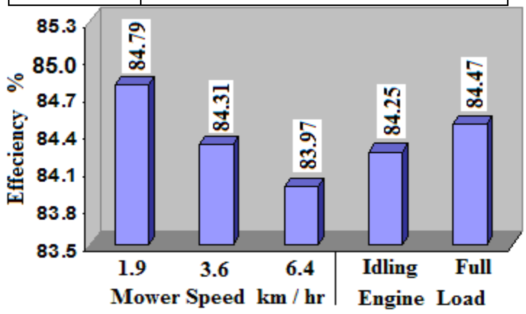



**Fig 10. Relation mower speed and engine load with Efficiency**

**2 – 3 Fuel consumption**

Table 5. showed the effect of mower speeds and engine load on fuel consumption L/ha. Result show significant effect for the mower speed on fuel consumption L/ha, mower speed 6.4 km/hr recorded lower fuel consumption (1.62 L/ha), while speed 1.9 km/hr recorded higher value (3.10 L/ha), that may be because increasing mower speeds that means more useful or estimate engine power and decreasing time require to complete work cutting grass. Result show significant effect to the Engine load in fuel consumption L/ha , idling recorded lower fuel consumption (1.97 L/ha), while fuel load recorded higher value (2.70 L/ha) , that may be because mower work with full load means maximum revelations per minute compare with mower work with idling engine . ( Fig. 11). Interaction between mower speed 6.4 km/hr and idling recorded lower fuel consumption(1.73 L/ha), while interaction between mower speed 1.9 km/hr and full load recorded higher lower efficiency (3.57 L/ha).

**Table 5. Effect mower speeds and engine load on fuel consumption L/ha**

| Mower speeds km / hr | Engine load: Idling | Engine load: Full load | Mean |
|---|---|---|---|
| 1.9 | 2.63 | 3.57 | 3.10 |
| 3.6 | 1.92 | 2.64 | 2.28 |
| 6.4 | 1.73 | 1.88 | 1.62 |
| Mean | 1.97 | 2.70 | |
| L.S.D 0.05 | Mower speeds : 0.0738<br>Engine load : 0.0603<br>Interaction : 0.1044 | | |

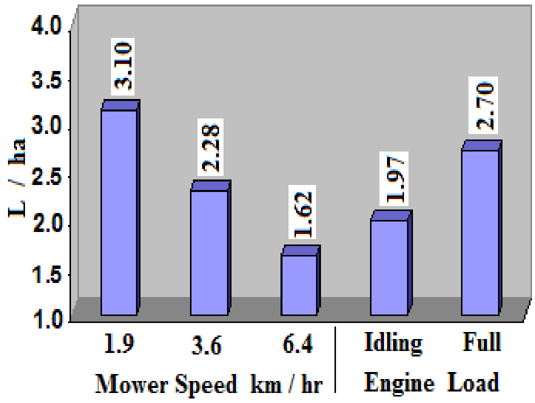



**Fig.11. Relation mower speed and engine load with Fuel Consumption .**

**2 – 4 Vibration in Mower**

**2 – 4 -1 Mower Seat**

Tables 6, 7 and 8. Showed the effect of mower speeds and engine load on vibration acceleration Longitudinal X , Lateral Y and Vertical Z in mower seat. Result showed significant effect of the mower speed on acceleration in mower seat in three axes X,Y and Z, mower speed 1.9 km/hr recorded lower acceleration values (1.85,1.55 and 1.10 m/sec ²), while mower speed 6.4 km/hr recorded higher values (8.28 , 7.85 and 5.35 m/sec ²) , that may be because when increasing mower speeds increasing vibration transmitted from chasses to mower seat in three axes X, Y and Z. and that agree with (7) (Fig. 12). Result show significant effect to the Engine load in vibration acceleration in mower seat on three axes X ,Y and Z, idling engine recorded lower acceleration (3.55, 3.26 and 2.23 m/sec²), while full load engine recorded higher values (5.46, 5.03 and 3.56 m/sec²) , that may be because when the engine work with full load (maximum revolution per minute) will increasing motion parts engine , therefore increasing acceleration transmitted from chasses to mower seat in three axes X, Y and Z ,and that agree with (11 and 14), ( Fig. 13) . Interaction between mower speed 1.9 km/hr and idling recorded lower acceleration in three axes X,Y and Z (1.60 , 1.30 and 0.80 m/sec $^2$) , while interaction between 6.4 km/hr and full load recorded higher values in three axes X,Y and Z (10.30 , 9.60 and 6.40 m/sec $^2$) .

**Table 6. Effect mower speeds and engine load on vibration acceleration Longitudinal X in mower seat**

| Mower speeds km / hr | Engine load Idling | Full load | Mean |
|---|---|---|---|
| 1.9 | 1.60 | 2.10 | 1.85 |
| 3.6 | 2.80 | 4.00 | 3.40 |
| 6.4 | 6.26 | 10.30 | 8.28 |
| Mean | 3.55 | 5.46 | |
| L.S.D 0.05 | Mower speeds : 0.454<br>Engine load : 0.3707<br>Interaction : 0.6421 | | |

**Table 7. Effect mower speeds and engine load on vibration acceleration Lateral Y in mower seat**

| Mower speeds km / hr | Engine load Idling | Full load | Mean |
|---|---|---|---|
| 1.9 | 1.30 | 1.80 | 1.55 |
| 3.6 | 2.40 | 3.70 | 3.05 |
| 6.4 | 6.10 | 9.60 | 7.85 |
| Mean | 3.26 | 5.03 | |
| L.S.D 0.05 | Mower speeds : 0.3322<br>Engine load : 0.2712<br>Interaction : 0.4697 | | |

**Table 8. Effect mower speeds and engine load and on acceleration Vertical Z in mower seat**

| Mower speeds km / hr | Engine load Idling | Full load | Mean |
|---|---|---|---|
| 1.9 | 0.80 | 1.40 | 1.10 |
| 3.6 | 1.60 | 2.90 | 2.25 |
| 6.4 | 4.30 | 6.40 | 5.35 |
| Mean | 2.23 | 3.56 | |
| L.S.D 0.05 | Mower speeds : 0.3246<br>Engine load : 0.265<br>Interaction : 0.459 | | |

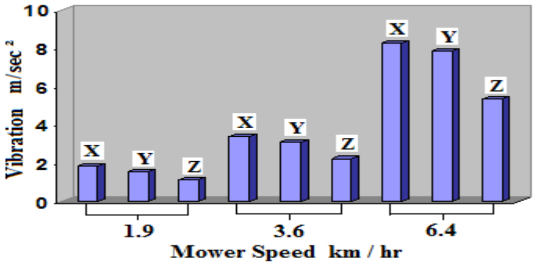



**Fig 12. Relation mower speed with Vibration in mower seat**

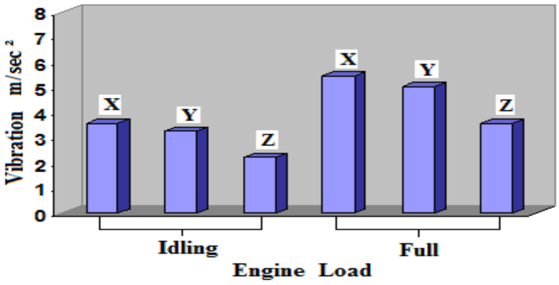



**Fig 13. Relation engine load with Vibration in mower seat**

**2-4-2 Steering Wheel**

Tables 9, 10 and 11. Showed the effect mower speeds and engine load and interaction in acceleration Longitudinal X, Lateral Y and Vertical Z in Steering Wheel. Result showed significant effect to the mower speed in acceleration in three axes X, Y and Z, in steering wheel , mower speed 1.9 km/hr recorded lower acceleration values (1.70, 2.00 and 1.00 m/sec$^2$), while mower speed 6.4 km/hr recorded higher values (6.25, 7.05 and 4.80 m/sec$^2$), that because the relation between mower speeds and vibration in steering wheel is proportional directed (Fig 14). Result show significant effect to the Engine load in acceleration in steering wheel in three axes X,Y and Z, idling engine recorded lower acceleration (2.56, 3.00 and 2.00 m/sec$^2$), while full load engine recorded higher values (4.56, 5.30 and3.36 m/sec$^2$), that because when the engine work with full load (maximum revolution per minute) will increasing motion parts engine , therefore increasing acceleration in steering wheel, and that agree with (11 and 14) (Fig. 15). Interaction between mower speed 1.9 km/hr and idling recorded lower acceleration in three axes X, Y and Z (1.20, 1.40 and 0.60 m/sec$^2$), while interaction between 6.4 km/hr and full load recorded higher values in three axes X,Y and Z (8.20, 9.10 and 6.00 m/sec$^2$).

**Table 9. Effect mower speeds and engine load on vibration acceleration Longitudinal X in Steering Wheel**

| Mower speeds km / hr | Engine load Idling | Full load | Mean |
|---|---|---|---|
| 1.9 | 1.20 | 2.20 | 1.70 |
| 3.6 | 2.20 | 3.30 | 2.75 |
| 6.4 | 4.30 | 8.20 | 6.25 |
| Mean | 2.56 | 4.56 | |
| L.S.D 0.05 | Mower speeds : 0.3125<br>Engine load : 0.2551<br>Interaction : 0.4419 | | |

**Table 10. Effect mower speeds and engine load on vibration acceleration Lateral Y in Steering Wheel**

| Mower speeds km / hr | Engine load Idling | Full load | Mean |
|---|---|---|---|
| 1.9 | 1.40 | 2.60 | 2.00 |
| 3.6 | 2.60 | 4.20 | 3.40 |
| 6.4 | 5.00 | 9.10 | 7.05 |
| Mean | 3.00 | 5.30 | |
| L.S.D 0.05 | Mower speeds : 0.4221<br>Engine load : 0.3446<br>Interaction : 0.5969 | | |

**Table 11. Effect mower speeds and engine load on vibration acceleration Vertical Z in SteeringWheel**

| Mower speeds km / hr | Engine load Idling | Full load | Mean |
|---|---|---|---|
| 1.9 | 0.60 | 1.40 | 1.00 |
| 3.6 | 1.80 | 2.70 | 2.25 |
| 6.4 | 3.60 | 6.00 | 4.80 |
| Mean | 2.00 | 3.36 | |
| L.S.D 0.05 | Mower speeds : 0.2429<br>Engine load : 0.1984<br>Interaction : 0.3436 | | |

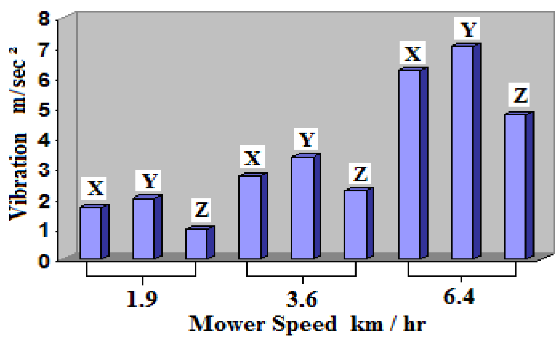



**Fig 14. Relation mower speed with Vibration in steering wheel**

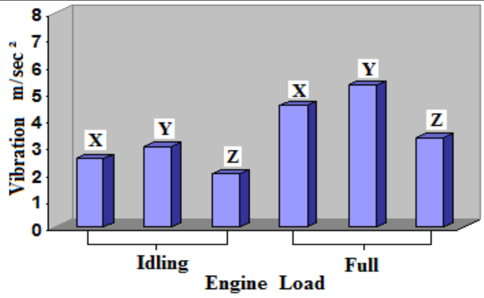



**Fig 15. Relation engine load with Vibration in steering wheel .**

### 2 – 4 -3 Mower Chasses

Tables 12, 13 and 14. Showed the effect mower speeds and engine load on acceleration Longitudinal X, Lateral Y and Vertical Z in Mower Chasses. Result showed significant effect to the mower speed in acceleration in three axes X, Y and Z, in mower chasses, mower speed 1.9 km/hr recorded lower acceleration values (7.90, 7.43 and 6.40 m/sec²), while mower speed 6.4 km/hr recorded higher values (14.78, 13.80 and 11.58 m/sec²), that because reach transmitted vibration to chasses from engine mower and from reacting earth against wheels mower which cross by wheels to chasses and all these vibration increasing with increase mower speeds ( Fig 16). Result show significant effect to the Engine load in acceleration in steering wheel in three axes X, Y and Z, idling engine recorded lower vibration (8.88, 8.20 and 6.78 m/sec²), while full load engine recorded higher values (13.30, 12.32 and 10.93 m/sec²), that because when the engine work with full load (maximum revolution per minute) will increasing unacceptable motion parts engine , therefore increasing acceleration in chasses,(Fig 17). Interaction between mower speed 1.9 km/hr and idling recorded lower acceleration in three axes X,Y and Z (6.10, 5.60 and 4.60 m/sec²), while interaction between 6.4 km/hr and full load recorded higher values in three axes X, Y and Z (17.30, 16.20 and 14.00 m/sec²).

**Table 12. Effect mower speeds and engine load on vibration acceleration Longitudinal X in Chasses**

| Mower speeds km / hr | Engine load | | Mean |
|---|---|---|---|
| | Idling | Full load | |
| 1.9 | 6.10 | 9.70 | 7.90 |
| 3.6 | 8.30 | 12.90 | 10.60 |
| 6.4 | 12.26 | 17.30 | 14.78 |
| Mean | 8.88 | 13.30 | |
| L.S.D 0.05 | Mower speeds : 0.4429<br>Engine load : 0.3617<br>Interaction : 0.6264 | | |

**Table 13. Effect mower speeds and engine load on vibration acceleration Lateral Y in Chasses**

| Mower speeds km / hr | Engine load | | Mean |
|---|---|---|---|
| | Idling | Full load | |
| 1.9 | 5.60 | 9.26 | 7.43 |
| 3.6 | 7.60 | 11.50 | 9.55 |
| 6.4 | 11.40 | 16.20 | 13.80 |
| Mean | 8.20 | 12.32 | |
| L.S.D 0.05 | Mower speeds : 0.32<br>Engine load : 0.2613<br>Interaction : 0.4526 | | |

**Table 14. Effect mower speeds and engine load on vibration acceleration Vertical Z in Chasses**

| Mower speeds km / hr | Engine load | | Mean |
|---|---|---|---|
| | Idling | Full load | |
| 1.9 | 4.60 | 8.20 | 6.40 |
| 3.6 | 6.60 | 10.60 | 8.60 |
| 6.4 | 9.16 | 14.00 | 11.58 |
| Mean | 6.78 | 10.93 | |
| L.S.D 0.05 | Mower speeds : 0.4113<br>Engine load : 0.3358<br>Interaction : 0.5817 | | |

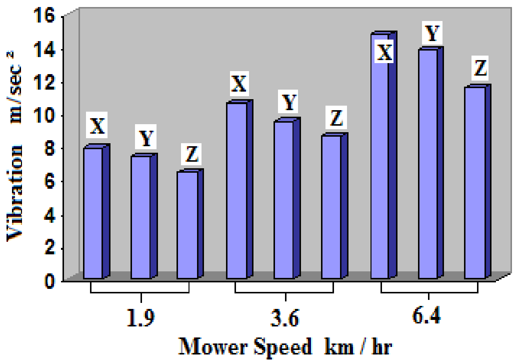



**Fig 16. Relation mower speed with Vibration in chasses**

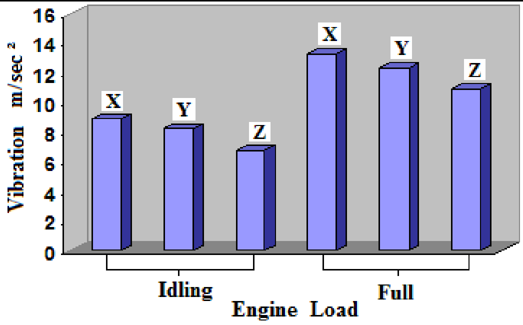



**Fig 17. Relation engine load with Vibration in chasses**

**2 – 4 – 4 Cover blades ( knives) cutting**

Tables 15, 16 and 17 showed the effect mower speeds and engine load on acceleration Longitudinal X, Lateral Y and Vertical Z in Cover blades (knives) cutting. Mower Chasses. Result show significant effect to the mower speed in acceleration in three axes X, Y and Z, mower speed 1.9 km/hr recorded lower acceleration values (10.15, 10.90 and 8.25 m/sec²), while mower speed 6.4 km/hr recorded higher values (20.05, 21.45 and 16.15 m/sec²), that because reaction between blades and grass in moment cutting which increasing with increase the mower speeds, (Fig. 18). Result show significant effect to the Engine load in acceleration in steering wheel in three axes X,Y and Z, idling engine recorded lower vibration (12.60 , 13.63 and 10.36 m/sec²), while full load engine recorded higher values (17.03 , 18.13 and 13.83 m/sec²), that because when the engine work with full load will increasing unacceptable motion parts engine, which transmitted to chasses then reach to cover blades, (Fig 19). Interaction between mower speed 1.9 km/hr and idling recorded lower acceleration in three axes X,Y and Z (8.90, 9.70 and 6.90 m/sec²) , while interaction between 6.4 km/hr and full load recorded higher values in three axes X, Y and Z (23.30, 24.70 and 18.00 m/sec²).

**Table 15. Effect mower speeds and engine load on acceleration Longitudinal X in Cover blades (knives) cutting**

| Mower speeds km / hr | Engine load | | Mean |
|---|---|---|---|
| | Idling | Full load | |
| 1.9 | 8.90 | 11.40 | 10.15 |
| 3.6 | 12.10 | 16.40 | 14.25 |
| 6.4 | 16.80 | 23.30 | 20.05 |
| Mean | 12.60 | 17.03 | |
| L.S.D 0.05 | Mower speeds : 0.559<br>Engine load : 0.456<br>Interaction : 0.790 | | |

**Table 16. Effect mower speeds and engine load on acceleration Lateral Y in Cover blades (knives) cutting**

| Mower speeds km / hr | Engine load | | Mean |
|---|---|---|---|
| | Idling | Full load | |
| 1.9 | 9.70 | 12.10 | 10.90 |
| 3.6 | 13.00 | 17.60 | 15.30 |
| 6.4 | 18.20 | 24.70 | 21.45 |
| Mean | 13.63 | 18.13 | |
| L.S.D 0.05 | Mower speeds : 0.4413<br>Engine load : 0.3603<br>Interaction : 0.3603 | | |

**Table 17. Effect mower speeds and engine load on acceleration Vertical Z in Cover blades (knives) cutting**

| Mower speeds km / hr | Engine load | | Mean |
|---|---|---|---|
| | Idling | Full load | |
| 1.9 | 6.90 | 9.60 | 8.25 |
| 3.6 | 9.90 | 13.90 | 11.90 |
| 6.4 | 14.30 | 18.00 | 16.15 |
| Mean | 10.36 | 13.83 | |
| L.S.D 0.05 | Mower speeds : 0.4129<br>Engine load : 0.3371<br>Interaction : 0.5839 | | |

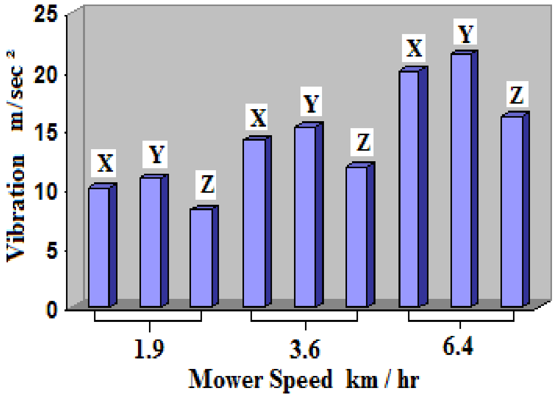



**Fig 18. Relation mower speed with Vibration in cover blades ( knives)**

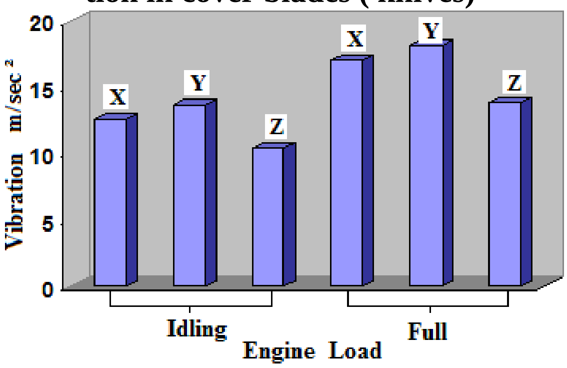



**Fig.19. Relation engine load with Vibration in cover blades ( knives)**

From the above results we conclude from this experiment mower work with high ground speed 6.4 km/hr and full load result to high practical productivity compare with another speeds and idling load, Further, mower work at speed 1.9 km/hr with full load result to high efficiency cutting compare with another speeds and idling load, Still further, work with high speed 6.4 km/hr and idling load reduced fuel consumption compare with full load and rest speeds .Whole body vibration transmit from mower seat and hand-arm vibration transmit from steering wheel in three axes longitudinal X , lateral Y and vertical Z to mower driver will be inter the body driver in speed 1.9 km/hr was under legislated permissible vibration exposure limits in the world , But the rest speeds a cross legislated permissible vibration exposure limits. According to ISO 2631-1:1997 vibration in mower chasses was very high in all speeds, that will be inter via the feet driver (see fig. 7- C- chasses). I recommend using the mower under speed 6.4 km/hr with full load because they give higher practical productivity and reduce the fuel consumption. Necessity reduce vibration exposure limits by give the driver rest at least 30 minute after mower working 2.5 hours. Can also reduce transmitted vibration to driver from seat and feet by put seat cushion made from Polymer – seat gel above mower seat (see fig 18), and put rubber space under feet they will be reduce vibration transmitted to driver. Recommend more studying in Iraq.

**Fig. 19. An air polymer-based gel seat cushion.**

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