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Development of a Solar-Powered Robotic Lawn Mower

ABSTRACT

Lawn keeping has been a major issue in campus environment due to rising cost of diesel fuel and lack of man power to operate both tractor-mounted and motorized lawn mowers. An automated solar-powered robotic lawn mower was developed in this research work to solve this problem. The components of the mower include a frame, three caster wheels, two gear motors which provide the forward motion, a 12v DC cutter motor which rotates the cutting blade, 2202mAH limpo battery for power supply, a 16W solar panel for charging the battery, a charge controller, a Raspberry Pi 3 B+ microcontroller which controls the motors, and a VNC mobile app for setting inputs for control. The mover was locally fabricated at the Agricultural Engineering workshop of The Federal Polytechnic, Ado-Ekiti, and it was tested in an open field. The effective field capacity and field efficiency of the machine were found to be 0.13 m²/s and 88% respectively. The total cost of producing the mower was 185,800 naira. The mower is recommended for large scale production and for usage on campuses.

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Keywords: Solar, Mower, Motor, Mowing, Control, Program

1. INTRODUCTION

Lawn maintenance and landscaping play a crucial role in maintaining clean and attractive gardens and yards. As humans strive to adapt to their environment, they create habitats that are suitable for their survival. The natural environment that humans inhabit is often covered with vegetation, including trees or grasslands (Allie, 2021). As human intellect has evolved, significant efforts have been and will continue to be made to enhance the condition of habitats for various purposes, such as security and aesthetic value.

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A lawn mower is a mechanical device designed for cutting grass and maintaining the neat appearance of a lawn or yard. It typically consists of a motor or engine that powers one or more rotating cutting blades. When the mower is pushed or driven across the grass, the blades spin rapidly, effectively trimming the grass to a desired height (Siregar et al, 2018; Bagaihing et al.,2022). These blades could be powered by hand, by pushing the mower forward to operate the mechanical blades, or by an electric motor, solar power, or a small internal combustion engine. Some mowers also incorporate additional functions such as mulching or collecting the grass clippings. There are various types of blades used in lawn mowers. Rotary mowers have a single blade rotating around a vertical axis, while cylinder or reel mowers have multiple blades rotating around a horizontal axis.

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There are different types of lawn mowers available to cater for various needs and lawn sizes. Push mowers are manually operated, requiring the user to push them forward to cut the grass. They are suitable for smaller lawns and offer a cost-effective option. Self-propelled mowers, on the other hand, feature a drive system that propels the mower forward, reducing the effort required by the user. They are ideal for larger lawns or areas with uneven terrain.

36 There are also reel mowers and rotary mowers (Bhaskar, 2015). The most recent innovation
37 is the rotary mower, which research has shown to be more effective than reel mowers due to
38 its cleaner cutting and the option to collect grass clippings (Pirchio, 2019). The cutting blade
39 is a critical component of rotary mowers, which typically have openings on the side of the
40 housing for expelling cut grass. Some models are equipped with a grass collector at the exit
41 point. Although the blade is not usually sharp enough to provide a clean cut and may result
42 in brown tips, it is easy to remove, sharpen, or replace (Ogiemudia, 2016). Apart from
43 sharpness of the cutting blade, other factors identified as affecting the performance of a
44 mower include cutting height, frequency of mowing, mowing patters, clipping and mulching
45 (Kondratyuk and Komaha, 2020).

46 Other types of mowers include riding mowers and robotic mowers. Riding mowers are driven
47 like a small vehicle, allowing the operator to sit on them and cover large areas more quickly.
48 There is recent transition from manual or ride-on mowers to automatic electric or solar-
49 powered mowers and emergence of robotic lawn mowers (Vidyalakshmi et al., 2022). A
50 robotic lawn mower is designed to operate either entirely on its own or less commonly by an
51 operator by remote control. Additionally, the inclusion of ultrasonic sensors and light-
52 dependent resistors in a compact and affordable package makes the mower more
53 responsive to its surroundings. With the reduced costs and increased availability of Rasberry
54 Pi and Arduino microcontrollers which provide automation for the mower, traditional lawn
55 mower designs have been monitored and improved upon (Takami and Tajiri, 2018; Pirchio et
56 al., 2018)

57 Lawn mowers could be powered by electricity or gas. Electric mowers can be corded or
58 cordless, utilizing electricity from an outlet or rechargeable batteries respectively. They are
59 generally quieter and produce zero emissions, making them environmentally friendly options.
60 Gas-powered mowers, on the other hand, run on gasoline or petrol, offering more power and
61 mobility. However, they require regular fueling and maintenance. Solar-powered lawn
62 mowers are superior to those powered by internal combustion engines because they
63 eliminate the emissions associated with internal combustion mowers, which contribute to
64 environmental pollution and the greenhouse gas effect responsible for exacerbating global
65 warming (Tint et al. 2015; Agressianto and Anshory, 2023).

66 Solar energy is a green and renewable energy source that does not require gasoline refills or
67 the periodic replacement of spark plugs. Solar lawn mowers could be utilised in rural areas
68 where electricity is not readily available. Nigeria, located in a tropical region with abundant
69 sunshine, is an ideal area for the utilisation of solar energy. Therefore, a solar powered
70 robotic lawn mower was designed and developed in this research in order to remove
71 drudgery involved in manual mowing and eliminate environmental pollution caused by the
72 use of gasoline powered mowers.

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75 **2. MATERIAL AND METHODS**

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77 **2.1 Materials**

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79 The materials used in the construction of the solar powered mower include the following:

80 i. Gear motors: Two gear motors were used to provide forward speed as shown in Fig 1a.
81 The gear motors are supplied with current from the battery. They are actuated by a motor
82 driver which is controlled by the programming code loaded on the Rasberry pi 3 board.

- 83 ii. DC motor was used in powering the cutting blade of the lawn mower (Fig 1b). It can
84 operate at a range of 12v to 24v. It has high torque for cutting and resisting obstacles during
85 cutting. The DC motor is powered by direct current from the battery and is also
86 programmatically controlled by the motor driver through the Raspberry Pi board.
- 87 iii. Raspberry Pi 3: The Raspberry Pi 3 is a microcontroller that controls the operation of the
88 mower. The DC motor, gear motor, motor driver, battery and switch are all connected to the
89 Raspberry pi 3 board. The Raspberry shown in Fig. 1c is programmed using the Python
90 programming language.
- 91 iv. Motor Driver: this is a module that controls the working speed and direction of the gear
92 two motors simultaneously as well as that of the DC motor. This driver is of model L293D
93 and is a 16 pin motor driver IC (Fig. 1d). It provides bi-directional drive currents at voltages
94 from 5v to 36v (Danny, 2019).
- 95 v. Battery: A limpo battery model 5500 of 2202mAH capacity was used as the power source
96 for the mower (Fig. 1e)
- 97 vi. Frame: This forms the chassis of the mower, in which other component is directly or
98 indirectly attached to. It was constructed by cutting the angle iron into a length of 300mm,
99 200mm, 206mm, and breadth of 300 mm and height of 200mm. The angle iron were bolted
100 together in order to make the mower portable. The frame is shown in Fig. 1f.
- 101 vii. Cutting Blade: A mild steel bar was used for the cutting blade and it was bolted to the DC
102 motor which rotates the blade at a speed of 1000rpm. The cutting blade is shown in Fig. 1g.
- 103 viii. Solar Panel: the solar panel provides charging source for the battery in order to ensure
104 continuous power supply to the mower. The solar panel has capacity of 16W and is shown in
105 Fig. 1h.
- 106 ix. Charge Controller: A charge controller was used to limit the rate at which electric current
107 is added to or drawn from the battery. It prevents overcharging and also protects against
108 overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk.

110 **2.2Method**

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112 **2.2.1 Design Consideration**

113 The following factors were considered in the design of the solar-powered autonomous
114 mower:

- 115 i. Rate of Operation: The rate of operation should be adequate to cover enough area per unit
116 time.
- 117 ii. Weight: The weight of the mower should be light in order to reduce the power requirement
118 for forward motion.
- 119 iii. Stability: It should be stable and not vibrate during operation
- 120 iv. Speed: The speed is limited to 0.5m/s in order for effective operation and control
- 121 v. Power: The mower is powered by a rechargeable battery in order to ensure continuous
122 operation for a long time.

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126 **2.2.2 Design Calculation**

127 In order to determine the capacity of the battery and solar panel used, the total weight of the
128 machine, the torque required for cutting, torque required for forward motion and the total

129 power requirement for the lawn mower were calculated to be 67.5N, 6.75Nm, 1.58Nm and
130 0.27kW respectively.

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132 **2.2.3 Power and Control System Design**

133 The power system of the mower consists of a solar panel, charge controller, cooling fan,
134 battery and switch. The raspberry pi, motor driver, and cooling fan are powered by a 5V, 12V
135 and 7V supplied by the battery respectively. Fig. 2 shows the layout of the power system.
136 The solar panel charges the battery through the charge controller. Both the raspberry pi and
137 the motor driver are powered by the battery. The motor driver controls the flow of current to
138 the motors for the control of the forward, reverse, left and right motion. The programming
139 code written in Python loaded on the Raspberry Pi controls the motor driver which in turn
140 controls the motors. A mobile VNC (Virtual Network Computing) server was used as the
141 mobile interface for the mower as it supports Python programming language. The mobile
142 VNC was connected to the Raspberry Pi through WiFi.

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144 **2.2.4 Programming Code**

145 The programming code used to control the motors was written in Python Programming
146 Language and is loaded on a memory card inserted into the Raspberry Pi. The Raspberry Pi
147 has 40 GPIO (General Purpose Input and Output) pins. Three of the pins were connected to
148 the motor driver using jumper cables. Each of the pin corresponds to each of two gear and
149 one DC motor on the mower. The Raspberry Pi is connected to an Android Phone through
150 WiFi and a VNC mobile server was used as the graphical interface for controlling the mower
151 remotely. When the mower is started and the Raspberry Pi is switched on, the program for
152 starting and controlling the mower is started on the Android phone and the motors start
153 working to move the mower forward and to rotate the cutting blade. The mower can also be
154 stopped and the direction changed through the phone. The Python code for controlling the
155 mower is shown in Program Listing 1.

156 Program Listing 1

```
157 import RPi.GPIO as GPIO
```

```
158 import time
```

159

```
160 # GPIO pin numbers for controlling the motors
```

```
161 motor_pins = {
```

```
162     'motor1': {
```

```
163         'enable_pin': 17,
```

```
164         'forward_pin': 18,
```

```
165         'reverse_pin': 27
```

```
166     },
```

```
167     'motor2': {
```

```
168         'enable_pin': 22,
```

```
169         'forward_pin': 23,
```

```
170         'reverse_pin': 24
```

```
171     },
```

```
172     'gear_motor': {
```

```
173         'enable_pin': 5,
```

```
174         'forward_pin': 6,
```

```
175         'reverse_pin': 13
```

```
176     }
```

```
177 }
```

178

```
179 # Setup GPIO pins
```

```
180 GPIO.setmode(GPIO.BCM)
```

```

181 for motor in motor_pins.values():
182     GPIO.setup(motor['enable_pin'], GPIO.OUT)
183     GPIO.setup(motor['forward_pin'], GPIO.OUT)
184     GPIO.setup(motor['reverse_pin'], GPIO.OUT)
185
186 # Function to control the motors
187 def control_motors(motor1_direction, motor2_direction, gear_motor_direction):
188     GPIO.output(motor_pins['motor1']['forward_pin'], motor1_direction == 'forward')
189     GPIO.output(motor_pins['motor1']['reverse_pin'], motor1_direction == 'reverse')
190     GPIO.output(motor_pins['motor2']['forward_pin'], motor2_direction == 'forward')
191     GPIO.output(motor_pins['motor2']['reverse_pin'], motor2_direction == 'reverse')
192     GPIO.output(motor_pins['gear_motor']['forward_pin'], gear_motor_direction == 'forward')
193     GPIO.output(motor_pins['gear_motor']['reverse_pin'], gear_motor_direction == 'reverse')
194
195 # Example usage
196 try:
197     while True:
198         # Forward motion
199         control_motors('forward', 'forward', 'forward')
200         time.sleep(1)
201
202         # Reverse motion
203         control_motors('reverse', 'reverse', 'reverse')
204         time.sleep(1)
205
206         # Turn left
207         control_motors('reverse', 'forward', 'forward')
208         time.sleep(1)
209
210         # Turn right
211         control_motors('forward', 'reverse', 'reverse')
212         time.sleep(1)
213
214         # Rotate gear motor clockwise
215         control_motors('stop', 'stop', 'forward')
216         time.sleep(1)
217
218         # Rotate gear motor counter-clockwise
219         control_motors('stop', 'stop', 'reverse')
220         time.sleep(1)
221
222 except KeyboardInterrupt:
223     # Stop motors and cleanup GPIO
224     control_motors('stop', 'stop', 'stop')
225     GPIO.cleanup()
226 2.2.4 Operation and Testing of the Mower

```

227 The mower components were assembled and the final assembly is shown in Fig. 3. The
228 testing operation and testing of the mower was carried out in an open field. An area of 10m
229 by 1m was marked for the test operation. The mower was programmed and operated to
230 mow an area of 1m by 1m and the operation was done in 10 trials. The time spent in mowing
231 for each of the trials was recorded. The effective field capacity and field efficiency was
232 calculated for each of the trials.

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234 **3. RESULTS AND DISCUSSION**

235 The test result is shown in Table 1. It was observed that there was a little vibration of the
236 mower during the test because of unevenness of the land. Some grasses were not properly
237 cut because the blade was not sharp enough. The result obtained from the test carried out
238 shows that the mower was able to carry out the cutting operation of a 1m² lawn area for a
239 average of 7.58s. It was able to cut the total area of 10m² for 75.8s. The effective field
240 capacity and average field efficiency of the mower obtained from the test operation were
241 calculated to be 0.132m²/s and 88.01% respectively.

242

243 **4. CONCLUSION**

244 A solar powered robotic lawn mower has been designed, fabricated and tested. The
245 machine is easy to operate and maintain and its efficiency of the mower was found to be
246 satisfactory. The total cost of production is N185,800.00. It can then be concluded that the
247 solar powered robotic lawn mower give the user the ability to cut their grass with minimal
248 effort.

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250 **COMPETING INTERESTS**

251 There are no competing interests

252

253 **AUTHORS' CONTRIBUTIONS**

254 P. O. Ajewole designed the mower and supervised its construction and assembly. I. O. Oni
255 and P. F. Akinduro did the field tests, data collection and collation of the reports.

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257 **REFERENCES**

258

259 Siregar, I., Ridho, A., Gustia, D., Triono, A., and Shafira, Y. (2018). Product design of a lawn
260 mower tool for agriculture. IOP Conference Series: Materials Science and Engineering, 420,
261 012140. <https://doi.org/10.1088/1757-899x/420/1/012140>

262 Agressianto, B., and Anshory, I. (2023). Design of Pesticide Sprayers and Solar Lawn
263 Mowers. Procedia of Engineering and Life Science, 3.
264 <https://doi.org/10.21070/pels.v3i0.1365>

265 Allie (2021). Mowing and Turfgrass Health. The Lawn Institute.
266 <https://www.thelawninstitute.org/mowing-and-turfgrass-health/>

267 Takami, R., and Tajiri, T. (2018). Development of autonomous Lawn mower using GPS. The
268 Proceedings of JSME Annual Conference on Robotics and Mechatronics (Robomec),
269 2018(0), 1A1-C02. <https://doi.org/10.1299/jsmermd.2018.1a1-c02>

270 Pirchio, M., Fontanelli, M., Frascioni, C., Martelloni, L., Raffaelli, M., Peruzzi, A., Gaetani, M.,
271 Magni, S., Caturegli, L., Volterrani, M., and Grossi, N. (2018). Autonomous Mower vs. Rotary
272 Mower: Effects on Turf Quality and Weed Control in Tall Fescue Lawn. Agronomy, 8(2), 15.
273 <https://doi.org/10.3390/agronomy8020015>

274 Pirchio, M., Fontanelli, M., Labanca, F., Sportelli, M., Frasconi, C., Martelloni, L., and Grossi,
 275 N. (2019). Energetic aspects of turfgrass mowing: comparison of different rotary mowing
 276 systems. *Agriculture*, 9(8), 178. <https://doi.org/10.3390/agriculture9080178>

277 Bhaskar, H. .B, (2015). "Manually Operated Rotary Lawn Mower" *International Journal of*
 278 *Innovations in Engineering Research and Technology*, 2 (1), ISSN: 2394-3696

279 Bagaihing, E., Mangesa, D. P., and Bale, J. S. (2022). Feasibility Study of Production of
 280 Double Blade Grass Cutting Machine. *International Journal of Business, Technology and*
 281 *Organizational Behavior (IJBTOb)*, 2(3), 183–194. <https://doi.org/10.52218/ijbtob.v2i3.191>

282 Vidyalakshmi R, Janani Preethy R., Snega P. J., Sri Daya Neethi R., Suji M. (2022).
 283 Automated Solar Powered Lawn Mower Using IoT. (2022, November 18). *International*
 284 *Research Journal of Modernization in Engineering Technology and Science*.
 285 <https://doi.org/10.56726/irjmets31317>

286 Tint P., Tarmas, G., Koppel, T., Reinhold, K., and Kalle, S. (2012). Vibration and noise
 287 caused by lawn maintenance machines in association with risk to health, *Agronomy*
 288 *Research Bio system Engineering Special Issue 1(2012)* 251-260.

289 Dutta, P. P., Baruah, A., Konwar, A. and Sepat, V. (2021). A Technical Review of Lawn
 290 Mower Technology. *ADB U Journal of Engineering Technology (AJET)*. 4. 2016.

291
 292 Ogiemudia, O. G., Sadjere, G., Chughiefe, L., and Ariavie, G. (2016): Design and
 293 Improvement of a Solar Powered Lawn Mower from Locally Sourced Material in Benin City,
 294 Edo State, Nigeria. *ELK Asia Pacific Journal of Mechanical Engineering Research*, 2(1).
 295 [https://www.coursehero.com/file/219725384/396911763-Design-and-Improvement-of-a-](https://www.coursehero.com/file/219725384/396911763-Design-and-Improvement-of-a-Solar-Powered-Lawn-Mower-From-Locallypdf/)
 296 [Solar-Powered-Lawn-Mower-From-Locallypdf/](https://www.coursehero.com/file/219725384/396911763-Design-and-Improvement-of-a-Solar-Powered-Lawn-Mower-From-Locallypdf/)
 297
 298 Kondratyuk, D. and Komaha, V. (2020). Determination of the Main Parameters of the Rotary
 299 Mowwer Cutting ApparatusUS. *ENGINEERING, ENERGY, TRANSPORT AIC*, 3(110), 77–
 300 85. <https://doi.org/10.37128/2520-6168-2020-3-8>
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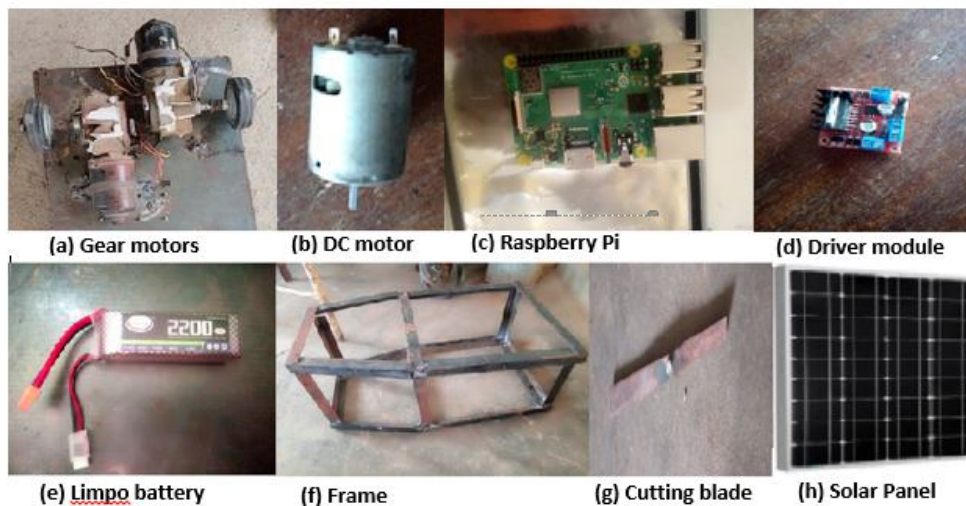


Fig. 1: Mower Components

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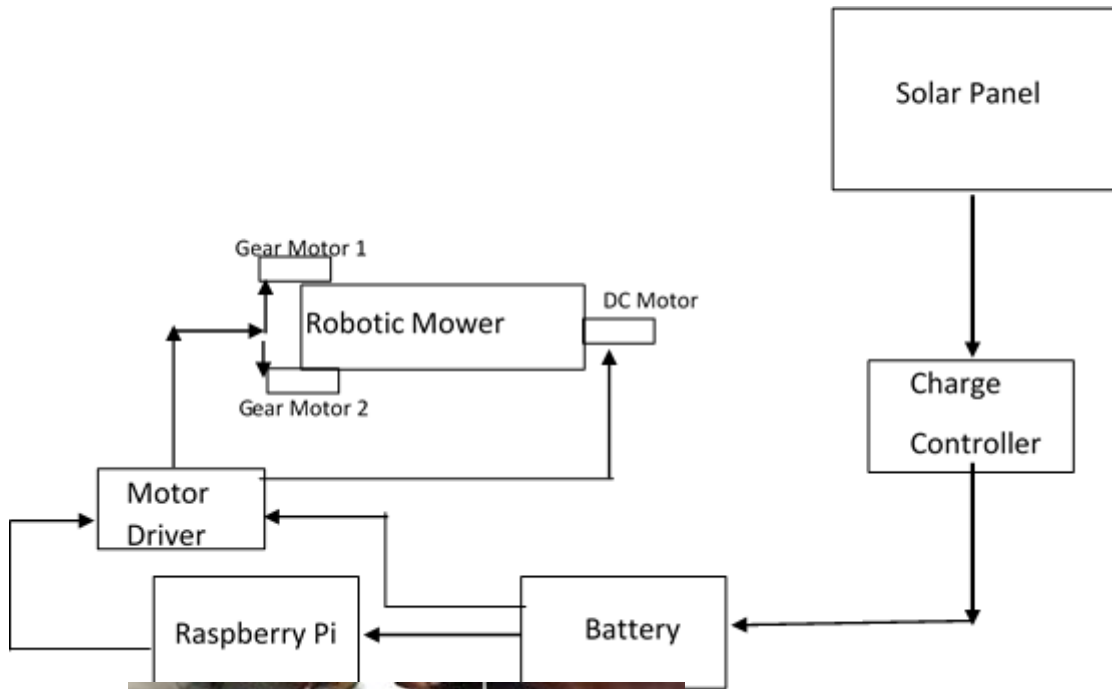


Fig. 2: The mower power and control system layout



Fig. 3: The constructed mower

Table 1: Cumulative result of mowing

Mowing Trial	Area (m ²)	Time Mowing (s)	Effective Field Capacity (m ² /s)	Theoretical Field Capacity (m ² /s)	Field Efficiency (%)
1	1	7.20	0.1389	0.15	92.60
2	1	7.80	0.1282	0.15	85.47
3	1	8.00	0.1250	0.15	83.33
4	1	7.60	0.1316	0.15	87.73
5	1	7.50	0.1333	0.15	88.87
6	1	7.60	0.1316	0.15	87.73
7	1	7.60	0.1316	0.15	87.73
8	1	7.60	0.1316	0.15	87.73
9	1	7.40	0.1351	0.15	90.07
10	1	7.50	0.1333	0.15	88.87
Average		7.58	0.1320	0.15	88.01

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