TKP3501
Agricultural Mechanization & Irrigation

Topic 5: Power Efficiencies and Measurement

Ahmad Suhaizi, Mat Su
Email: asuhaizi@upm.edu.my
Learning outcomes

- Student will be able to identify the parameters used to calculate the farm and machinery efficiency.
- Student will be able to do a calculation on the farm efficiency.
Why we have to consider the farm efficiency?

Factors to consider....

- **Machine**
  - Width of the implement
  - Efficiency of the implement

- **Time for**
  - Turning
  - Transfer the load (yield)
  - Operator
Farm operation

Width

Speed
How to evaluate the machine performance in the field?

- Terminologies related to the ability of machines
- The rate at which each machine can complete field jobs is a method for determining the cost per hectare for that operation.
- Theoretical field capacity (TFC)
- Effective field capacity (EFC)
- Field efficiency (FE)
Theoretical field capacity of an implement is the rate of field coverage that would be obtained if the machine were performing its function 100% of the time at the rated forward speed and always covered 100% of its rated width.

Effective field capacity is the actual average rate of coverage by the machine, based upon the total field time.

Field efficiency is the ratio of effective field capacity to theoretical field capacity, expressed as percent. It includes the effects of time lost in the field and of failure to utilize the full width of the machine.
Theoretical time per acre or hectare is the time required by theoretical field capacity.

Effective operating time is the time duration when the machine actually operate. It is more than theoretical time if the width of operation is less than the actual width of the machine.
Theoretical Field Capacity (TFC)

- \( \text{TFC (ha/hr)} = \text{speed (km/hr)} \times \text{width of implement (meter)} \)
Theoretical field capacity

- TFC is calculated as follows;
- Width of implement, \( w \) m (from end to end of blade, made easier to measure by executing a path. The width of implement’s body is not formal) multiplied by a constant speed \( s \) m/min.
- The unit is normally hectare per hour
The EFC of a machine or implement may be calculated as follows;

\[ \text{EFC} = \frac{V \times W \times FE}{10} \]

Where

- **EFC** = Effective Field Capacity in hectare/hr
- **V** = Speed of implement in kilometer/hr
- **W** = width of implement in meter
- **FE** = Field efficiency in percent
Effective field capacity (EFC)

- EFC is the relationship between width of implement or machine, % width actually used, speed, and the time lost in the field during operation.
- It is impossible to use maximum implement width for those implements such as harrow, tillage implements, grass cutter, and combine harvester without occasional miss.
- Overlap has to occur and the level of overlap is a function of speed, ground condition and the operator expertise. There are situations whereby crop yield is abundant such that the combine cannot maximize the use of header width even at minimal speeds.
Machines meant for row crops uses 100% of its width compared to implements for open fields. Row crops machines are row planter, inter-row cultivator, and seed planter.

Open field implements cannot avoid overlapping field coverage. E.g. rotary tiller.

The width of implements with multiple units is calculated by multiplying width of space between unit with the number of units. So that the space next to end units are covered.
Maximum speeds possible is subjected to factors such as types of field works and the available engine power. A harvesting machine’s speed is dependent on the ability to handle harvested materials.

The time lost is a variable that is difficult to quantify in the estimation of field capacity. Field time may be lost due to adjusting the machine or during parts lubrication, breakdown, clogging, turning at end of field, refilling seeds of fertilizer, unloading yield, waiting etc.
- Time lost is not counted when the machine is readied before beginning field works, servicing, or lost time due to major break-down.

- Only minor break-down in the field and lubrication apart from the daily required servicing. The total field time is the time lost in the field and the actual operating time.

- The time required to travel to and from the field is accounted for the total operational cost BUT it is not considered for calculating EFC or the Field Efficiency (FE) since Field Capacity, FC do not depend on the location of machinery owner.
Researchers have determined average FE of common implements:

<table>
<thead>
<tr>
<th>Operation</th>
<th>FE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most tillage operations (plowing, disking, cultivating)</td>
<td>75-90%</td>
</tr>
<tr>
<td>Seeding or fertilizing row crops or grain</td>
<td>60-80</td>
</tr>
<tr>
<td>Seeding AND fertilizing row crops or grain</td>
<td>45-65</td>
</tr>
<tr>
<td>Combine harvesting</td>
<td>65-80</td>
</tr>
<tr>
<td>Field chopping of grass for animal feed</td>
<td>50-75</td>
</tr>
<tr>
<td>Spraying</td>
<td>55-65</td>
</tr>
</tbody>
</table>
Time lost during turning

- Turns at ends or corners of a field represent a loss of time that is often of considerable importance, especially for short fields.
- Regardless of whether a field is worked back and forth or worked by traveling around the perimeter, the total number of turns per unit area with a given width of implements is inversely proportional to the length of the field.
For a perfect square field, the total trip around the field is the same for any method of field works; be it turning around the perimeter, middle cut or linearly forward and back. Forward and back requires two 180° for each round trip. The first method require four 90° turns for each trip around the field.

If only Field Efficiency is required it can be estimated by taking the total time in the field for an extended period (a day), the average speed while the implement is working, the total area covered and the width of the implement. The average rate covered can be related to TFC in order to determine FE.
Field Machinery Index (FMI)

“ratio of productive field time to productive plus turn time”

Field Machine Index (FMI)

\[ FMI = \frac{Total \ field \ time - total \ stop \ time/reverse - total \ turning \ time}{total \ field \ time - total \ stop \ time/reverse} \times 100 \]
Increase in the FMI index as in reduction of the turning time

Figure 6. Relationship of field machine index with turning time of citrus canopy shaker (Oxbo 3220).
Estimation of speed and FC

- The estimated value is sometimes useful in the field or the lab. The estimation can be made by walking at the pace with the implement and counting the steps within 20 seconds. The total steps divided by 10 will give the speeds in mph when the average step is 2.94 ft. wide.
FE at 82.5% is normal for tillage operations. This may be used in

$$EFC = \frac{S \times W \times FE}{10}$$

If the speed and implement width is known.

**Improving the FE.**

Presently field machinery becomes more complex and more expensive. It is important to gain maximum output from the machines. Reduction of time lost is one of the methods to increase the FE.
The development of implements that are more efficient and the system for material management within the body of a combine harvester may have the potential of increasing the FE.

Seeds, fertilizer, weedicides must be transported into the field and loaded into the field machinery. Harvested materials must be unloaded and transported to storage areas.

Handling of materials in bags may consume 25% of the total time in the field during planting operation. Handling dried fertilizer in bulk or liquid fertilizer by pump from storage tanks to the machine may reduce the handling time effectively.
Summary

**Theoretical Field Capacity (TFC)**

$$TFC = \frac{V \left( \frac{km}{hr} \right) \times w(m)}{10}$$

**Effective Field Capacity (EFC)**

$$EFC = \frac{V \left( \frac{km}{hr} \right) \times w(m) \times F.E}{10}$$

**Field Efficiency (EF)**

$$EF = \frac{EFC}{TFC} \times 100$$

**Field Machine Index (FMI)**

$$FMI = \frac{\text{Total field time} - \text{total stop time/reverse} - \text{total turning time}}{\text{total field time} - \text{total stop time/reverse}} \times 100$$
Exercise #1

A combine having 2 m cutter bar is operated at a speed of 4.5 km/hr to harvest wheat crop. If 20% time is lost in turning, loading and unloading, calculate the harvested area in 8 hours.
Solution Exercise #1

Prob. 1: A combine having 2 m cutter bar is operated at a speed of 4.5 km/hr to harvest wheat crop. If 20 % time is lost in turning, loading and unloading, calculate the harvested area in 8 hours.

Solution

The theoretical field capacity of combine can be calculated by following equation,

Theoretical field capacity = \( \frac{\text{Speed (km/hr) \times Width of implement (m)}}{10} \)

\[ = \frac{4.5 \times 2}{10} = 0.9 \text{ ha/hr} \]

But, 20 % time is lost in turning, loading and unloading, field efficiency

= 100 - 20 = 80 %

Actual field capacity = Theoretical field capacity \( \times \) Field efficiency

= 0.9 \( \times \) 0.80 = 0.72 ha/hr

\( \therefore \) Total harvested area in 8 hours = 0.72 \( \times \) 8 = 5.76 hectares.
Exercise #2

Calculate theoretical field capacity, effective field capacity and field efficiency of a 4.5 m grain combine operating at a forward speed of 5.0 km/hr. The average width of cut is 3.5 m and time required for emptying the grain tank is averaged to 9.0 minutes per hectare. Turning, adjusting and other miscellaneous time requirement is amounted to 15% of the effective operating time.
Solution Exercise #2

Theoretical field capacity = \frac{\text{Speed (km/hr)} \times \text{Width of implement (m)}}{10}

= \frac{4.5 \times 5}{10} = 2.25 \text{ ha/hr}

Time required for emptying tank = 9 \times 2.25 = 20 \text{ min}

\therefore \text{ Effective operating time} = 60 + 20 = 80 \text{ min}

Time for turning, adjustment and other miscellaneous
= 0.15 \times 80 = 12 \text{ min}

\therefore \text{ Total operating time} = 80 + 12 = 92 \text{ min}

Effective field capacity = \frac{\text{Speed (km/hr)} \times \text{Effective Width (m)} \times \text{Total operating time}}{10}

= \frac{5 \times 3.5 \times 60}{10} \times \frac{92}{92} = 1.41 \text{ ha/hr}

Field efficiency = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100

= \frac{1.41}{2.25} \times 100 = 63 \%
Exercise #3

Calculate the field machine index if the total operation time during harvesting was 60 minutes and 5% of the total operation time contributed to the reverse motion and 20% of the total operation time contributed to the turning.

Field Machine Index (FMI)

\[
FMI = \frac{\text{Total field time} - \text{total stop time/reverse} - \text{total turning time}}{\text{total field time} - \text{total stop time/reverse}} \times 100
\]
Solution Exercise #3

Given

Total operation time = 60 min or 1 hr
Total time for reverse = 0.05 x 60 min = 3 min
Total time for turning = 0.2 x 60 min = 12 min

Field Machine Index (FMI)

\[
FMI = \frac{\text{Total field time} - \text{total stop time/reverse} - \text{total turning time}}{\text{total field time} - \text{total stop time/reverse}} \times 100
\]

\[
= \frac{60 - 3 - 12}{60 - 3} \times 100
\]

\[
= 45/57
\]

\[
= 79\%
\]
Assignment #1
>> On PutraBlast
Thank you.