



# **The Mechanics of Tractor-Implement Performance**

*Theory and Worked Examples*

A Textbook For Students And Engineers

**R.H. Macmillan**

Senior Fellow in Agricultural Engineering  
International Development Technologies Centre  
University of Melbourne



THE UNIVERSITY OF  
MELBOURNE

# CONTENTS

## CHAPTER 1

<b>THE AGRICULTURAL TRACTOR</b>	<b>1.1</b>
<b>1.1 INTRODUCTION</b>	<b>1.1</b>
1.1.1 General	1.1
1.1.2 Justification	1.1
1.1.3 Development	1.1
1.1.4 Classification of types	1.2
<b>1.2 FUNCTIONAL REQUIREMENTS AND LIMITATIONS</b>	<b>1.2</b>
1.2.1 Functional requirements	1.2
1.2.2 Performance limitations	1.2
<b>1.3 SYSTEMS AND POWER OUTLETS</b>	<b>1.4</b>
1.3.1 Engine	1.4
1.3.2 Transmission systems and outlets	1.6
1.3.3 Wheels	1.10
<b>1.4 STUDYING TRACTOR PERFORMANCE</b>	<b>1.10</b>
1.4.1 Need for the study	1.10
1.4.2 Approaches to the study	1.11
<b>1.5 PREVIEW</b>	<b>1.12</b>
<b>1.6 REFERENCES</b>	<b>1.12</b>

## CHAPTER 2

<b>TRACTOR MECHANICS</b>	<b>2.1</b>
<b>2.1 INTRODUCTION</b>	<b>2.1</b>
<b>2.2 IDEAL ANALYSIS (WITHOUT LOSSES)</b>	<b>2.1</b>
2.2.1 Speed analysis	2.1
2.2.2 Torque / force analysis	2.2
2.2.3 Power analysis	2.2
2.2.4 Ideal performance graphs	2.5
2.2.5 Performance envelopes	2.5
2.2.6 Conclusion	2.5
<b>2.3 ANALYSIS WITH LOSSES</b>	<b>2.7</b>
2.3.1 Speed analysis	2.7
2.3.2 Force analysis	2.7
2.3.3 Power analysis	2.7
<b>2.4 OTHER MEASURES OF PERFORMANCE</b>	<b>2.8</b>
2.4.1 Efficiency	2.8
2.4.2 Tractive coefficient	2.10
<b>2.5 SUMMARY</b>	<b>2.10</b>
<b>2.6 REFERENCES</b>	<b>2.10</b>

## CHAPTER 3

<b>TRACTOR PERFORMANCE ON A FIRM SURFACE</b>	<b>3.1</b>
<b>3.1 INTRODUCTION</b>	<b>3.1</b>
<b>3.2 ENGINE PERFORMANCE</b>	<b>3.3</b>
3.2.1 General	3.3
3.2.2 Output	3.3
3.2.3 Input	3.7
<b>3.3 TRACTOR DRAWBAR PERFORMANCE</b>	<b>3.11</b>
3.3.1 Output	3.11
3.3.2 Input	3.13
3.3.3 Other measures of performance	3.14
<b>3.4 REFERENCES</b>	<b>3.16</b>

## CHAPTER 4

<b>TRACTOR PERFORMANCE ON SOFT SOIL – THEORETICAL</b>	<b>4.1</b>
<b>4.1 INTRODUCTION</b>	<b>4.1</b>
4.1.1 General	4.1
4.1.2 Definitions	4.1
4.1.3 Operational states of a wheel	4.3
4.1.5 Wheel slip definition	4.4
4.1.6 Wheel slip measurement	4.4
<b>4.2 TRACTIVE PERFORMANCE</b>	<b>4.6</b>
4.2.1 Practical / experimental measurement	4.6
4.2.2 Theoretical prediction	4.6
4.2.3 Empirical prediction	4.6
<b>4.3 ROLLING RESISTANCE</b>	<b>4.8</b>
4.3.1 Wheel conditions	4.8
4.3.2 Theoretical prediction	4.8
4.3.3 Experimental measurement	4.14
4.3.4 Empirical prediction	4.14
<b>4.4 TRACTIVE FORCE</b>	<b>4.14</b>
4.4.1 Introduction	4.14
4.4.2 Shear stress - deformation characteristic for soil	4.14
4.4.3 Analysis of locked track	4.16
4.4.4 Analysis of track with slip	4.20
<b>4.5 DRAWBAR PULL</b>	<b>4.22</b>
<b>4.6 DRAWBAR POWER</b>	<b>4.24</b>
4.6.1 Wheel slip - drawbar power characteristic	4.24
4.6.2 Theoretical prediction of optimum wheel slip	4.26
<b>4.7 GENERAL PROBLEMS</b>	<b>4.30</b>
<b>4.8 REFERENCES</b>	<b>4.31</b>

## CHAPTER 5

<b>TRACTOR PERFORMANCE ON SOFT SOIL – EMPIRICAL</b>	<b>5.1</b>
<b>5.1 INTRODUCTION</b>	<b>5.1</b>
5.1.1 General	5.1
5.1.2 Empirical method	5.1
<b>5.2 ENGINE PERFORMANCE MODELING</b>	<b>5.1</b>
<b>5.3 TRACTIVE PERFORMANCE MODELING</b>	<b>5.2</b>
5.3.1 Parameters	5.2
5.3.2 Prediction of performance measures	5.6
<b>5.4 TRACTOR DRAWBAR PERFORMANCE</b>	<b>5.12</b>
5.4.1 Performance in various gears	5.12
5.4.2 Distribution of power components	5.14
5.4.3 Effect of surface and weight	5.16
<b>5.5 CONCLUSION</b>	<b>5.17</b>
<b>5.6 REFERENCES</b>	<b>5.17</b>

## CHAPTER 6

<b>HITCHING AND MECHANICS OF THE TRACTOR CHASSIS</b>	<b>6.1</b>
<b>6.1 INTRODUCTION</b>	<b>6.1</b>
<b>6.2 IMPLEMENT HITCHING</b>	<b>6.1</b>
6.2.1 Introduction	6.1
6.2.2 Hitching systems	6.3
<b>6.3 TRACTOR CHASSIS MECHANICS</b>	<b>6.3</b>
6.3.1 Centre of gravity	6.3
6.3.2 Issues	6.8
6.3.3 Analysis and assumptions	6.9
<b>6.4 WEIGHT TRANSFER</b>	<b>6.11</b>
6.4.1 Four wheel tractor	6.11
6.4.2 Weight transfer with rolling resistance	6.15
6.4.3 Weight transfer with hitching systems	6.21
6.4.4 Other examples	6.28
<b>6.5 IMPENDING INSTABILITY</b>	<b>6.36</b>
<b>6.6 REFERENCES</b>	<b>6.40</b>

## **CHAPTER 7**

<b>TRACTOR - IMPLEMENT MATCHING AND OPERATION</b>	<b>7.1</b>
<b>7.1 INTRODUCTION</b>	<b>7.1</b>
<b>7.2 IMPLEMENT PERFORMANCE</b>	<b>7.1</b>
7.2.1 Implement draught	7.1
7.2.2 Implement draught - speed characteristic	7.3
7.2.3 Implement power	7.3
7.2.4 PTO driven and towed implements	7.3
<b>7.3 TRACTOR - IMPLEMENT PERFORMANCE</b>	<b>7.5</b>
7.3.1 Operating conditions	7.5
7.3.2 Optimum performance criteria	7.5
7.3.3 Matching wheels and engine	7.9
<b>7.4 MATCHING TRACTOR AND IMPLEMENT</b>	<b>7.10</b>
7.4.1 Variables available	7.10
7.4.2 Optimising performance	7.10
7.4.3 Setting up tractor and implement	7.12
<b>7.5 OPERATING THE TRACTOR</b>	<b>7.14</b>
<b>7.6 REFERENCES</b>	<b>7.15</b>

## **CHAPTER 8**

<b>GENERAL PROBLEMS</b>	<b>8.1</b>
-------------------------	------------

## **APPENDICES**

<b>LIST OF SYMBOLS</b>	<b>I</b>
------------------------	----------

<b>DIMENSIONAL DATA FOR FARMLAND TRACTOR</b>	<b>II</b>
--	-----------