

## TABLE OF CONTENT

TITLE	PAGE
Executive summary .....	i
Table of Content .....	viii
1. Background .....	1
2. Aim .....	1
3. Scope .....	1
<b>No. 1: PERFORMANCE TEST – KOMATSU MACHINE.....</b>	<b>2</b>
4. No 1: performance test .....	3
4.1. Performance test location .....	3
4.2. Test participants .....	6
4.2.1. Cambodian Mine Action Centre (CMAC) .....	6
4.2.2. Japan International Cooperation System (JICS) .....	8
4.2.3. KOMATSU Staff .....	8
4.2.4. KOMATSU machine .....	8
4.3. Test procedure .....	12
4.3.1. Resources: AP mine used in the test .....	13
4.3.2. Depth of AP mine .....	14
4.3.3. Time keeping .....	14
4.3.4. Test start time and end time of time keeping .....	14
4.3.5. The pattern & direction of mine clearance .....	14
4.3.6. Fuel consumption .....	15
4.3.7. Re-establish test land & landmine position .....	15
4.3.8. The classification of landmine after clearance .....	17
4.3.9. Mine evaluation technique .....	20
4.4. Test preparation .....	23
4.4.1. The preparation of dry condition test area .....	23
4.4.2. The preparation of light bush condition .....	28
4.4.3. The preparation of wet condition .....	33
4.5. Test schedule .....	36
4.5.1. Test schedule at dry condition .....	36
4.5.2. Test schedule at light bush condition .....	36
4.5.3. Test schedule at wet condition .....	36
4.6. Test no 1: performance test result .....	37
4.6.1. Potential pollution by mine clearance machine .....	37
4.6.2. Test result at dry condition .....	38
4.6.3. Test result at light blush condition .....	43
4.6.4. Test result at wet condition .....	48
<b>PERFORMANCE TEST RESULT ANALYSIS – KOMATSU MACHINE.....</b>	<b>51</b>
4.7. Performance test result analysis .....	52
4.7.1. Clearance productivity rate .....	52
4.7.2. Mine clearance quality .....	53
4.7.3. Fuel consumption rate .....	54
4.7.4. Clearance productivity – fuel ratio .....	55
4.7.5. Fragment position after clearance .....	56
4.7.6. Flying fragment cause by mine clearance machine .....	57
4.7.7. Potential to break one mine into pieces by demining machine .....	58
<b>No. 2: ACCEPTANCE TEST – KOMATSU MACHINE.....</b>	<b>59</b>
5. No. 2: acceptance test .....	60
5.1. Acceptance test location .....	60

5.1.1. Second test site selection .....	61
5.1.2. General geography .....	66
5.1.3. Historical contamination background .....	66
5.1.4. Safe access road in the minefield .....	67
5.1.5. Test lane.....	67
5.2. Test procedure .....	68
5.2.1. Safety distant.....	68
5.2.2. Productivity and true productivity .....	68
5.2.3. True productivity rate .....	68
5.2.4. Time keeping.....	68
5.2.5. Machine working duration .....	68
5.2.6. Daily maintenance.....	68
5.2.7. Fix or repair .....	68
5.2.8. The pattern & direction of mine clearance .....	68
5.2.9. Fuel consumption .....	69
5.2.10. Mine/UXO found.....	69
5.3. Test schedule.....	69
5.4. Test no. 3: acceptance test result.....	70
5.4.1. Productivity & productivity rate.....	70
5.4.2. Fuel consumption by demining machine KOMATSU.....	71
5.4.3. The repair of a demining machine KOMATSU.....	72
<b>ACCEPTANCE TEST RESULT ANALYSIS – KOMATSU MACHINE .....</b>	<b>73</b>
6. Acceptance test result analysis .....	74
6.1. Clearance duration.....	74
6.2. True clearance productivity rate.....	75
6.3. The comparison of productivity and true productivity .....	76
6.4. Clearance duration before next refuel time.....	77
6.5. Productivity – fuel ratio.....	78
6.6. The repair of a demining machine KOMATSU .....	79
6.7. Average productivity for one hour repair.....	80
6.8. Average clearance duration for one hour repair .....	81
7. Comparison between performance and acceptance test.....	82
7.1. A comparison of true productivity rate, m <sup>2</sup> /hour.....	82
7.2. A comparison of fuel consumption rate.....	83
7.3. A comparison of productivity – fuel ratio.....	84
<b>No. 3: SURVIVABILITY TEST – KOMATSU MACHINE.....</b>	<b>85</b>
8. Introduction .....	86
9. Test methods .....	86
9.1. Demining machines under test .....	86
9.2. Measurement system configuration .....	86
9.3. Test equipment .....	86
9.4. Explosive used.....	87
10. On – Test site.....	87
10.1. Test site.....	87
10.2. Test preparation.....	87
10.3. Test schedule.....	88
10.4. Measurement work detail.....	88
11. Experimental results .....	88
11.1. Measurement system installation.....	88
11.2. Test results.....	90
11.2.1. Sound pressure.....	90
11.2.2. Cabin pressure change.....	91
11.2.3. Floor acceleration.....	92
11.2.4. Seat acceleration.....	93
11.3. Verifying test results.....	94

11.3.1. Cabin pressure change measurement.....	94
11.3.2. Corrupted data .....	95
12. Data Analysis .....	95
12.1. Analysis method.....	95
12.2. Ear injury .....	95
12.3. Foot and ankle injury.....	95
12.4. Spine injury .....	95
12.5. Data analysis on KOMATSU.....	96
12.5.1. Ear injury .....	96
12.5.2. Foot and ankle injury.....	96
12.5.3. Spine injury.....	97
<b>No. 4: REPAIR &amp; MAINTENANCE.....</b>	<b>99</b>
13. General maintenance work.....	100
13.1. Tools and Equipments .....	100
13.1.1. General equipment for the project.....	100
13.1.2. General tool for the project from workshop in Battambang .....	100
13.1.3. Assisted tools from CMAC .....	100
13.2. Performance and Acceptance tests .....	101
13.3. Survivability test .....	101
14. General repair work .....	101
14.1. Performance and Acceptance tests .....	101
14.2. Survivability test .....	101
14.2.1. General assessment .....	101
14.2.2. Damage to the attachment of the machine .....	101
<b>No. 5: TRANSPORTATION.....</b>	<b>103</b>
15. Transportation of the machine during test .....	104
15.1. Transport from Sihanoukville to Dam Dek Testing site in Siem Reap .....	104
15.2. Transport from the Mine Testing Site in Siem Reap to Battambang Workshop.....	105
15.3. Transport from CMAC Workshop to the mine field .....	105
15.4. Transport from the mine field to Battambang Workshop .....	106
15.5. Transport from Battambang CMAC Workshop to Siem Reap Regional Center.....	107
15.6. Transport from the CMAC Regional Center in Siem Reap to Sihanoukville.....	107
16. General Evaluation .....	108
16.1. Positive value of demining machine KOMATSU.....	108
16.2. Negative value of demining machine KOMATSU .....	108
17. General conclusion .....	111
17.1. Clearance productivity.....	111
17.2. Mine clearance quality.....	111
17.3. Fuel consumption .....	111
17.4. Maintenance/repair.....	111
17.5. Survivability of the machine .....	112
17.5.1. Ear injury risk.....	112
17.5.2. Foot and ankle injury risk .....	112
17.5.3. Spine injury risk.....	112
17.6. Transportation .....	112
18. Recommendation.....	113
Annex 1: Demining machine activities during test in pictures .....	114
Annex 2: The background of Cambodia.....	119
Annex 3: The history of mine/UXO contamination in Cambodia.....	124
Annex 4: General information about mine/UXO and minefield in Cambodia.....	128
Annex 5: General information about test site at Battambang .....	134
Annex 6: How to work in mine/UXO contaminated area.....	139
Annex 7: Frequently Asked Questions.....	141
Annex 8: Some useful information on-site rules and instructions .....	149
Annex 9: Demining machine test and evaluation procedures (valid for performance test only).....	150

---

Annex 10: Demining machine test and evaluation procedures (valid for survivability test only) .....	155
Annex 11: Demining machine test and evaluation procedures (valid for acceptance test only).....	162
Annex 12: Instruction for the team members .....	163
References: .....	164
Appendix:.....	165

## LIST OF FIGURES

TITLE	PAGE
Fig. 1: Performance test location in Cambodia .....	3
Fig. 2: General view of light bush test area (performance & survivability test area).....	5
Fig. 3: Structure of the project.....	6
Fig. 4: KOMATSU machine .....	8
Fig. 5: AP PMN-2 mine.....	12
Fig. 6: AP T-72A mine .....	12
Fig. 7: AP T-72A is dismantled.....	12
Fig. 8: Mine depth is properly measured before the burial.....	13
Fig. 9: One time keeper for one test machine equipped with two chronometers.....	13
Fig. 10: Clearance direction of the machine.....	14
Fig. 11: Fuel is transported close to the test site.....	14
Fig. 12: Re-establish test lane.....	15
Fig. 13: CMAC deminer is using metal detector to re-establish the test lane boundary after the area is cleared by the machine .....	15
Fig. 14: CMAC deminer is re-establish the test lane boundary.....	15
Fig. 15: Mine in good shape is marked with yellow stick with red note.....	16
Fig. 16: Fragment of mine is marked with yellow stick and yellow note (safe) .....	16
Fig. 17: CMAC deminer is detecting mine fragment nearby the test lane (in light bush).....	16
Fig. 18: Round Yellow Stick indicates existing mine position .....	17
Fig. 19: Mine is destroyed by the machine. In this category, mine is classified to be destroyed by the machine. ....	18
Fig. 20: Mine had been hit by the machine. This mine is subjected for checking.....	18
Fig. 21: Mine is hit and moved from its original location but still in good condition. This mine is in category three and is subjected for evaluation .....	19
Fig. 22: Mine had been hit by the machine but the machine does not have the sufficient digging depth. This mine is subjected for checking.....	19
Fig. 23: Machine did not touch mine due to insufficient digging depth. Mine still dangerous. Round stick painted in yellow indicate previous mine position. ....	20
Fig. 24: CMAC deminer with PPE and visor walking to mine evaluation spot.....	20
Fig. 25: Mine is neutralized before analyzing.....	21
Fig. 26: Some evidents of damaged mine [1/2].....	21
Fig. 27: Some evident of damaged mine [2/2] .....	22
Fig. 28: The change of mine status from live mine to damaged mine .....	22
Fig. 29: Dry condition test area & test lane arrangement.....	23
Fig. 30: All top vegetation is removed by machine (bulldozer) .....	24
Fig. 31: Metallic object is removed from the test site .....	24
Fig. 32: CMAC deminer is marking test lane.....	25
Fig. 33: Landmine is color before laid in the ground .....	25
Fig. 34: The pattern of laid mine in the test lane.....	26
Fig. 35: Drill hole according to its designated position and depth to laid landmine .....	26
Fig. 36: The location, depth, type and quantity of landmine .....	27
Fig. 37: Light Bush test area & test lane arrangement.....	28
Fig. 38: Buffer zone of 8m is being bulldozed .....	29
Fig. 39: Tree top is being trimmed by CMAC deminer .....	29
Fig. 40: Large tree (>20cm) is being removed .....	29
Fig. 41: Termite hill is subjected to be identified and leveled.....	29
Fig. 42: CMAC deminer is setting up metal detector MINELAB F1A4 to be used to remove metallic object from light bush test area.....	30
Fig. 43: Landmine is color before laid in the ground.....	30
Fig. 44: Landmine with its designated color will be laid according to the above pattern .....	31
Fig. 45: After identifying the location, the hole is drilled up to the specified depth. ....	31
Fig. 46: The location, depth, type and quantity of landmine .....	32
Fig. 47: Wet condition test area & test lane arrangement.....	33
Fig. 48: CMAC deminer is marking test lane at wet condition area .....	34
Fig. 49: Landmine pattern at wet condition .....	35

Fig. 50: Potential polluted area after clearance.....	37
Fig. 51: Nearby earth and object is crushed underneath the drum.....	37
Fig. 52: Front part of KOMATSU machine is covered by iron chain to keep the dirt or gragment.....	37
Fig. 53: Clearance productivity rate.....	52
Fig. 54: Clearance quality of AP mine.....	53
Fig. 55: Fuel consumption rate.....	54
Fig. 56: Clearance size – fuel ratio.....	55
Fig. 57: Fragment in test lane.....	56
Fig. 58: Fragment out of test lane.....	56
Fig. 59: Fragment position in and out of test lane.....	56
Fig. 60: distant of flying fragment.....	57
Fig. 61: Potential to break AP mine by the machine.....	58
Fig. 62: Acceptance test location in Cambodia.....	60
Fig. 63: Map of O dounpov test site.....	62
Fig. 64: Activities at O dounpov test site.....	63
Fig. 65: Map of Pich Chongwa test site.....	64
Fig. 66: Activities at Pich Chongwa test site.....	65
Fig. 67: There are many trees in this test site.....	66
Fig. 68: Landmine is easily found at Pich Chongwa test site.....	66
Fig. 69: Preparation for the acceptance test.....	67
Fig. 70: Clearance duration at acceptance test.....	74
Fig. 71: True productivity rate of the machine at acceptance test.....	75
Fig. 72: the comparison of true clearance productivity.....	76
Fig. 73: Fuel consumption rate.....	77
Fig. 74: Productivity – fuel ratio.....	78
Fig. 75: Repair activities of the machine.....	79
Fig. 76: Average repair time of the machine.....	79
Fig. 77: The relationship between productivity and repair.....	80
Fig. 78: Average clearance duration.....	81
Fig. 79: the comparison of productivity rate.....	82
Fig. 80: A comparison of productivity – fuel ratio at performance & acceptance tests (sq.m/l).....	84
Fig. 81: A comparison of productivity – fuel ratio at performance & acceptance tests (%)......	84
Fig. 82: Measurement System Configuration.....	86
Fig. 83: a combination of Anti-tank and C4 to be exploded under the attachment.....	87
Fig. 84: Survivability test spot of the machine.....	87
Fig. 85: Equipment Installation in the Machine [1/4].....	88
Fig. 86: Equipment Installation in the Machine [2/4].....	89
Fig. 87: Equipment Installation in the Machine [3/4].....	89
Fig. 88: Equipment Installation in the Machine [4/4].....	89
Fig. 89: Sound Pressure in machine # 3 (KOMATSU) - Anti-personnel landmine [1/2].....	90
Fig. 90: Sound Pressure in machine # 3 (KOMATSU) - Anti-personnel landmine [2/2].....	90
Fig. 91: Sound Pressure in machine # 3 (KOMATSU) - Anti-tank mine [1/2].....	91
Fig. 92: Sound Pressure in machine # 3 (KOMATSU) - Anti-tank mine [2/2].....	91
Fig. 93: Cabin Pressure in machine # 3 (KOMATSU) - Anti-personnel Mine.....	91
Fig. 94: Cabin Pressure in machine # 3 (KOMATSU) - Anti-tank Mine.....	92
Fig. 95: Floor Acceleration in machine # 3 (KOMATSU) - Anti-personnel Mine [1/2].....	92
Fig. 96: Floor Acceleration in machine # 3 (KOMATSU) - Anti-personnel Mine [2/2].....	92
Fig. 97: Floor Acceleration in machine # 3 (KOMATSU) - Anti-tank Mine [1/2].....	93
Fig. 98: Floor Acceleration in machine # 3 (KOMATSU) - Anti-tank Mine [2/2].....	93
Fig. 99: Seat Acceleration in machine # 3 (KOMATSU) - Anti-Personnel Mine [1/2].....	93
Fig. 100: Seat Acceleration in machine # 3 (KOMATSU) - Anti-Personnel Mine [2/2].....	94
Fig. 101: Seat Acceleration in machine # 3 (KOMATSU) - Anti-tank Mine [1/2].....	94
Fig. 102: Seat Acceleration in machine # 3 (KOMATSU) - Anti-tank Mine [2/2].....	94
Fig. 103: B-duration of Sound Pressure in KOMATSU - Anti-tank Mine.....	96
Fig. 104: Floor Velocity-Time Chart for KOMATSU - Anti-personnel Mine.....	96
Fig. 105: Floor Velocity-Time Chart for KOMATSU - Anti-tank Mine.....	97
Fig. 106: Seat Velocity-Time Chart for Machine #3 (KOMATSU) - Anti-personnel Mine.....	97
Fig. 107: Simulated Human Body Displacement in Machine #3 (KOMATSU) - Anti-personnel Mine.....	98

Fig. 108: Seat Velocity-Time Chart for Machine #3 (KOMATSU) - Anti-tank Mine.....	98
Fig. 109: Machine #3 (KOMATSU) Displacement of Human Body on the Operator Seat - Anti-Tank Mine .....	98
Fig. 110: General view of the Komatsu machine after explosion.....	102
Fig. 111: Hydraulic holders are dislocated .....	102
Fig. 112: Broken pit and a hollow drum.....	102
Fig. 113: Komatsu counter weight is built from separated pieces of metal.....	108
Fig. 114: Komatsu run over a tree underneath the tree is an un-cleared area .....	108
Fig. 115: Poor visibility from Komatsu operator room to the front of the machine .....	109
Fig. 116: Operator's view inside-out from the cabin.....	109
Fig. 117: Spotter direct/command the machine behind this shield .....	109
Fig. 118: Fuel is leak from its tank.....	109
Fig. 119: Komatsu flash light mounted on top of the roof of the machine.....	109
Fig. 120: Front host has no protection from tree branch .....	110

## LIST OF TABLES

TITLE	PAGE
Table 1: Project Management team .....	6
Table 2: Member for demining machine number 1 .....	6
Table 3: Member for demining machine number 2 .....	7
Table 4: Member for demining machine number 3 .....	7
Table 5: Member for demining machine number 4 .....	7
Table 6: Demining machine KOMATSU .....	8
Table 7: The classification of landmine damaged by the machine .....	17
Table 8: Deployment pattern of landmine PMN-2 and T-72A at dry condition lane 1, 2 and 3 .....	27
Table 9: Deployment pattern of landmine PMN-2 and T-72A at dry condition lane 4.....	27
Table 10: summary of landmine at dry condition test lane 1, 2, 3 and lane 4.....	27
Table 11: Deployment pattern of landmine PMN-2 and T-72A at light bush condition lane 1, 2 and 3 ...	32
Table 12: Deployment pattern of landmine PMN-2 and T-72A at light bush condition lane 4 .....	32
Table 13: summary of landmine at light bush condition test lane 1, 2, 3 and lane 4 .....	32
Table 14: Deployment pattern of landmine PMN-2 and T-72A at Wet condition lane 1, 2 .....	35
Table 15: summary of landmine at wet condition test lane 1 and test lane 2 .....	35
Table 16: Test schedule of swing demining machine in dry condition .....	36
Table 17: Test schedule of swing demining machine in Light Bush condition .....	36
Table 18: Test schedule of swing demining machine in wet condition .....	36
Table 19: Summary Test result at Dry condition .....	38
Table 20: Distant of flying fragment from original location in Dry condition .....	38
Table 21: Potential mine to be broken up by KOMATSU MACHINE during performance test.....	38
Table 22: Fragment position in dry condition area after the performance test by KOMATSU MACHINE .....	38
Table 23: mine fragment scattered at dry condition, test lane 1 .....	39
Table 24: mine fragment scattered at dry condition, test lane 2 .....	40
Table 25: mine fragment scattered at dry condition, test lane 3 .....	41
Table 26: mine fragment scattered at dry condition, test lane 4 .....	42
Table 27: Summary Test result at light bush condition .....	43
Table 28: Distant of flying fragment from original location in Light Bush condition.....	43
Table 29: Potential mine to be broken up by KOMATSU MACHINE during performance test.....	43
Table 30: Fragment position in Light Bush condition area after the performance test by KOMATSU MACHINE .....	43
Table 31: mine fragment scattered at light bush condition, test lane 1 .....	44
Table 32: mine fragment scattered at light bush condition, test lane 2.....	45
Table 33: mine fragment scattered at light bush condition, test lane 3.....	46
Table 34: mine fragment scattered at light bush condition, test lane 4.....	47
Table 35: Summary Test result at Wet condition .....	48
Table 36: Distant of flying fragment from original location in Wet condition .....	48
Table 37: Potential mine to be broken up by KOMATSU MACHINE during performance test.....	48
Table 38: Fragment position in Wet condition area after the performance test by KOMATSU MACHINE .....	48
Table 39: mine fragment scattered at wet condition, test lane 1.....	49
Table 40: mine fragment scattered at wet condition, test lane 2.....	50
Table 41: Summary of performance test data .....	52
Table 42: Selected sites for acceptance test .....	61
Table 43: Test schedule of acceptance test.....	69
Table 44: Productivity and productivity rate of the machine .....	70
Table 45: Fuel consumption by the machine .....	71
Table 46: The repair of a demining machine.....	72
Table 47: the comparison of clearance and true clearance productivity.....	76
Table 48: fuel consumption used by demining swing machine at acceptance test .....	77
Table 49: Productivity of the machine and fuel consumption .....	78
Table 50: Repair activities .....	79
Table 51: True productivity rate at performance & acceptance tests.....	82
Table 52: A comparison of fuel consumption rate at performance & acceptance tests.....	84



---

Table 53: Test Schedule .....	88
Table 54: Measurement Work Details .....	88
Table 55: General equipment for the project.....	100
Table 56: General tool from CMAC workshop in Battambang .....	100
Table 57: Assisted tool from CMAC .....	100
Table 58: Safety Evaluation on Machine # 3 (KOMATSU) .....	112