ISO 13232-5:2005-12 (E)

Motorcycles - Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles - Part 5: Injury indices and risk/benefit analysis

Contents

Page

Foreword vii

Introduction viii

1 Scope 1

2 Normative references 2

3 Definitions and abbreviations 2

4 Requirements 3
4.1 Injury variables 3
4.2 Lower extremity injuries 4
4.3 Injury severity probabilities 4
4.4 Injury indices 5
4.5 Risk/benefit analysis 5

5 Procedures 5
5.1 Injury variables 5
5.2 Frangible component damage 10
5.3 Injury severity probabilities 10
5.4 Probability of discrete AIS injury severity level 15
5.5 Injury costs 17
5.6 Probability of fatality 18
5.7 Probable AIS 21
5.8 Normalized injury costs 22
5.9 Risk/benefit analysis 23

6 Documentation 27

Annex A (normative) Injury costs 28

Annex B (normative) Mortality rate 30

Annex C (informative) ICM Variable and subscript definitions 31

Annex D (informative) Example computer code of the injury cost model 34

Annex E (informative) Comparison of results to reference risk and benefit values 56

Annex F (informative) Example probable injury cost data 57

Annex G (informative) Probability distribution curves 69

Annex H (informative) Example cumulative distribution function plots 73

Annex I (informative) Example computer code for calculations of head contacts 74

Annex J (informative) AO/C1/C2 upper neck injury probabilities and injury cost 97

Annex K (informative) Estimated distribution of neck AO/C1/C2 injury severities in the LA/Hannover database 120

Annex L (informative) Distribution of maximum neck forces and moments from computer simulations of 498 LA/Hannover cases and 67 fatal USC cases 122

Annex M (informative) Injury criteria coefficient search algorithm used for neck injury criteria identification 124

Annex N (informative) Dummy neck computer simulation validation 131

Figures Figure 1 -- Chest potentiometer geometry shown for the upper sternum 8

Figure 2 -- Risk of life threatening brain injury for HIC for t2 - t1 0,015 s 21

Figure D.1 -- Flow diagram of the injury cost model 55

Figure G.1 -- Probability distribution of head injuries as a function of Gmax (Kramer & Appel, 1990) 70

Figure G.2 -- Probability distribution of thoracic injury as a function of maximum resultant upper (or lower) sternum compression (Kroell, et al., 1974) 70

Figure G.3 -- Probability distribution of thoracic injuries as a function of maximum resultant upper (or lower) sternum velocity-compression (Lowne & Janssen, 1990) 71

Figure G.4 -- Probability distribution of human abdominal injuries as a function of maximum human abdominal penetration (Rouhana, et al., 1990) 71

Figure G.5 -- Probability distribution of neck injury as a function of NIImax 72

Figure H.1 -- Example of a continuous cumulative distribution function graph for change in an injury assessment variable 73

Figure H.2 -- Example of a discrete cumulative distribution function graph for change in an injury index 73

Figure J.1 -- Forces and moments at tmax from computer simulations of 67 USC fatal cases and the best step- wise fit envelopes of constant NIImax, providing the basis for the envelope shape 108

Figure J.2 -- Forces and moments at tmax from computer simulations of 498 LA and Hannover cases and envelopes of constant NIImax, providing the basis for the NIImax vs 50% injury probability 110

Figure J.3 -- Critical tension force vs the coefficient, providing the basis for the =3.1 111

Figure J.4 -- Neck AO/C1/C2 injury risk curves for the new MATD neck 112

Figure J.5 -- Distribution of observed and predicted computer simulations 113

Figure J.6 -- Comparison of the general shape and axes of the injury criteria for the new MATD neck to the allowable limits proposed by NHTSA for the HIII 50 PAM neck (recognizing that the necks have very different stiffnesses) 116

Figure J.7 -- Neck AIS 3 + injury risk vs tension for the Hybrid III P50 male neck (Mertz & Prasad 2000) 117

Figure J.8 -- Neck AIS 3 + injury risk vs combined tension and extension for the Hybrid III P50 male neck (Mertz & Prasad 2000) 118

Figure L.1 -- Maximum neck force and moment distributions for the new MATD neck (498 LA/Hannover cases and 67 USC fatal cases) 123

Figure M.1 -- Convergence of the global search algorithm 129

Figure M.2 -- Convergence of the local search algorithm 130

Figure N.1 -- Laboratory test and computer simulation of forward neck flexion at 0,1 s 133

Figure N.2 -- Forward neck flexion response of laboratory test and computer simulation 134

Figure N.3 -- Laboratory test and computer simulation of rearward neck extension at 0,1 s 135

Figure N.4 -- Rearward neck extension response of laboratory test and computer simulation 136

Figure N.5 -- Laboratory test and computer simulation of lateral neck flexion at 0,1 s 137

Figure N.6 -- Lateral neck flexion response of laboratory test and computer simulation 138

Figure N.7 -- Computer simulation of neck torsion test at 0,1 s 139

Figure N.8 -- Neck torsion response of laboratory test and computer simulation 140

Figure N.9 -- Neck axial force response of laboratory impact test and computer simulation 141

Figure N.10 -- Full scale test and computer simulation of impact configuration 413-0/30 0,1 s after initial contact 142

Figure N.11 -- Full scale test and computer simulation of 413-0/30 with new MATD neck 143

Tables Table 1a -- Closed head injury severity probability as a function of Gmax 12

Table 1b -- Closed head injury severity probability as a function of HIC 12

Table 2 -- Thoracic compression injury severity probability as a function of Cus,max and Cls,max ..13

Table 3 -- Thoracic injury velocity-compression severity probability as a function of VCus,max and VCls,max 13

Table 4 -- Intra-abdominal penetration injury severity probability as a function of PA,max 14

Table 5 -- Neck combined loading injury severity probability as a function of NII 14

Table 6 -- AIS injury severity level for frangible component damage 15

Table 7 -- Example PIE,j determination 16

Table 8 -- Permanent partial incapacity determination 16

Table 9 -- Injury probability and probable AIS 19

Table 10 -- Injury assessment variables, change in head injury potential, and injury indices to be calculated for each impact configuration 24

Table 11 -- Example table used to calculate the weighted cumulative distribution of change in maximum head acceleration due to a protective device 26

Table A.1 -- Medical costs 28

Table A.2 -- Ancillary costs 29

Table B.1 -- Mortality rates for all AIS combinations 30

Table C.1 -- Variable definitions 31

Table C.2 -- Body region subscript definition 32

Table C.3 -- Other subscripts 32

Table F.1 -- Legend for Table F.2 57

Table F.2 -- Example probable injury cost input/output results 58

Table J.1 -- Summary of Accident Databases 99

Table J.2 -- Distribution of neck AO/C1/C2 injuries in the USC fatal motorcycle accident database 103

Table J.3 -- Distribution of neck AO/C1/C2 injuries in the LA/Hannover database 105

Table J.4 -- Number of cases with observed and predicted injuries 105

Table J.5 -- Force and moment normalizing coefficients for the new MATD neck 106

Table J.6 -- Injury threshold coefficients for the 67 USC fatal cases with the new MATD neck 106

Table J.7 -- Comparison of number of observed and predicted injuries by injury severity and direction 107

Table J.8 -- Injury severity risk coefficients for the new MATD neck 109

Table J.9 -- Comparison of neck injury criteria for a 50th percentile male 115

Table K.1 -- Distribution of neck AO/C1/C2 injury severities in the LA/Hannover and USC Fatal Accident Databases 121