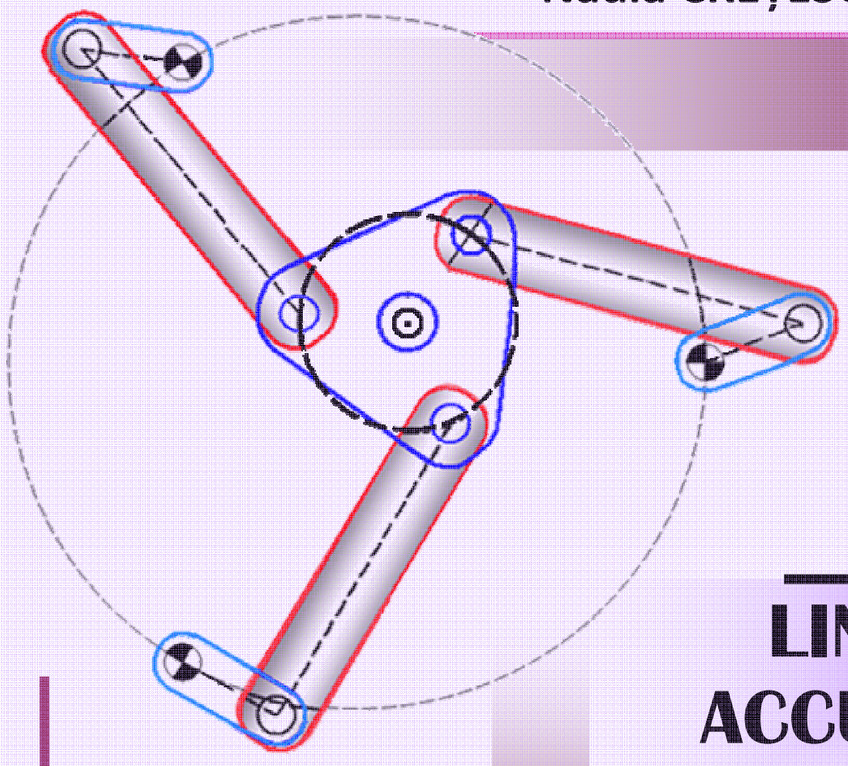
Mircea NEAGOE
Dorin DIACONESCU
Coduța JALIU
Olimpiu MUNTEANU
Radu SĂULESCU
Nadia CREȚESCU



LINKAGE ACCURACY MODELLING

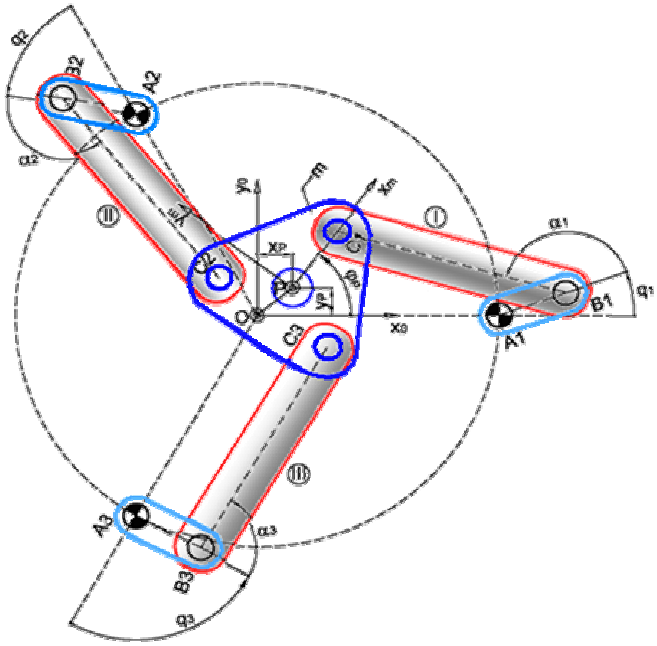
LINKAGE ACCURACY MODELLING

ISBN 978-973-635-921-7

EDITURA UNIVERSITĂŢII
TRANSILVANIA BRAŞOV

Prof.dr.ing. Mircea NEAGOE
Prof.dr.ing. Dorin DIACONESCU
Prof.dr.ing. Codruţa JALIU
Prof.dr.ing. Olimpiu MUNTEANU
Şef lucr.dr.ing. Radu SĂULESCU
Prep.ing. Nadia CREŢESCU

LINKAGE ACCURACY MODELLING



Editura Universităţii *Transilvania* din Braşov
2010

© 2010 EDITURA UNIVERSITĂŢII *TRANSILVANIA* DIN BRAŞOV

Adresa: 500091 Braşov,
B-dul Iuliu Maniu 41A
Tel:0268 – 476050
Fax: 0268 476051
E-mail : editura@unitbv.ro

Tipărit la:
Tipografia Universităţii *Transilvania* din Braşov
B-dul Iuliu Maniu 41A
Tel: 0268 – 476050

Toate drepturile rezervate

Editură acreditată de CNCSIS
Adresa nr.1615 din 29 mai 2002

Referenţi ştiinţifici: Prof. univ. dr. ing., dr.h.c. Florea DUDIŢĂ
Prof. univ. dr. ing., dr.h.c. Ion VIŞA

Descrierea CIP a Bibliotecii Naţionale a României
Linkage accuracy modelling / Mircea Neagoe, Dorin Diaconescu, Codruţa Jaliu, ... - Braşov : Editura Universităţii "Transilvania", 2010
Bibliogr.
ISBN 978-973-635-921-7

I. Neagoe, Mircea
II. Diaconescu, Dorin
III. Jaliu, Codruţa

531

TABLE OF CONTENTS

1. On the kinematical calibration of a 2R planar serial robot-structure chain 9
1.1. Introduction 9
1.2. On the high order error–modelling 10
1.3. Third order modelling of the RR serial chain precision 12
1.4. High order kinematic error identification 15
1.5. Conclusions 17
REFERENCES 18

2. On the third degree error modelling of a serial chain 19
2.1. Introduction 19
2.2. On the high degree modelling of robot errors 19
2.3. Third degree positioning-error modelling of a RRR serial manipulator 22
2.4. Numerical example 25
2.5. Conclusions 25
REFERENCES 27

3. On the third degree kinematic calibration of a serial chain 28
3.1. Introduction 28
3.2. Third degree kinematic calibration of a RRR serial manipulator 29
3.3. Numerical example 31
3.4. Conclusions 34
REFERENCES 35

4. On the geometrical calibration of a 4R planar parallel linkage 36
4.1. Introduction 36
4.2. Geometric error modelling 37
4.3. Link error identification 40
4.4. Conclusions 43
REFERENCES 44

5. On the geometrical error modelling of a 5R planar parallel linkage 45
5.1. Introduction 45
5.2. The problem formulation 45
5.3. Modelling of the error jacobian J_L 46
5.4. Simulation results 51
5.5. Conclusions 52
REFERENCES 53

6. On the error modelling of a 9R planar parallel linkage 54
6.1. Introduction 54
6.2. The problem formulation 55
6.3. Modelling of the error jacobian J 57
6.4. The simulation results 60
6.5. Conclusions 63
REFERENCES 64

7. On the geometrical calibration of a 9R planar parallel linkage 65
7.1. Introduction 65
7.2. The linkage calibration: problem formulation 65
7.3. Geometrical error modelling 68
7.4. Identification of the geometrical errors 71
7.5. Conclusions 76
REFERENCES 76

8. On the structural deffects modelling in a technological linkage 78
8.1. Introduction 78
8.2. The problem formulation 80
8.3. Structural defects modelling 81
8.4. Conclusions 83
REFERENCES 83

9. Kinematical modelling of the errors influence from the 7R linkage 84
9.1. Introduction 84
9.2. Structural modelling of the 4-bar mechanism 86
9.3. Kinematical modelling 86
9.4. Conclusions 90
REFERENCES 91

10. Numerical analysis of the errors influence from the 7R linkage 92
10.1. Introduction 92
10.2. Structural modelling of the 4-bar mechanism 93
10.3. Numerical simulation 96
10.4. Conclusions 99
REFERENCES 99

11. On the dynamic behaviour of a 3-DOF planar linkage variant with flexi-blocks 101
11.1. Introduction 101
11.2. Structural modelling 101
11.3. Kinematical modelling 103
11.4. Modelling of the aggregate's dynamic response 104
11.5. Conclusions 108
REFERENCES 109

12. On the dynamic behaviour of a 5-DOF planar linkage with flexi-blocks 110
12.1. Introduction 110
12.2. Structural modelling of the isolated mechanisms 110
12.3. The kinematical modelling of the isolated mechanisms 111
12.4. The dynamic response modelling 113
12.5. Conclusions 119
REFERENCES 120

13. On the heterokinematism expression in cardan transmissions 121
13.1. Introduction 121

13.2. The kinematic modelling of the elementary cardan mechanism 121
13.3. Limits of the classical expression and a proposal for a generalized solution of expressing the heterokinetism 123
13.4. Conclusions 126
REFERENCES 126

14. New aspects concerning the homokinetical modelling of tricardanic transmissions 127
14.1. Introduction 127
14.2. Notations 127
14.3. The modelling of homokinetics using the differences Δij and Ψ 128
14.4. Conclusions 133
REFERENCES 133

15. Kinematic analysis and synthesis of cardan transmission 134
15.1. Introduction 134
15.2. Solution 137
15.3. Conclusion 141
REFERENCES 141

16. About the kinematic optimisation of the mechanisms with general configuration 141
16.1. Introduction 142
16.2. The main applied HOM method variants in the kinematics analysis of the 3D mechanisms 144
16.3. The kinematics analysis optimisation by the combined application of HOM and GBM methods. 145
16.4. Conclusions 147
REFERENCES 148

17. On the accuracy modelling of cardan linkage 149
17.1. Introduction 149
17.2. Kinematic analysis of RRRC/S configuration 149
17.3. Modelling of the classical cardan mechanism precision on the basis of RCCC configuration 151
17.4. Precision modelling of classical cardan mechanism on the basis of RRRC/S configuration 154
17.5. Conclusions 158
REFERENCES 158

18. The representative modules usable in the dynamic modelling of n-cardan transmissions 159
18.1. Introduction 159
18.2. Notations and prerequisites 160
18.3. Modelling of the forces from the cross–fork connection 161
18.3. The module of the correlations between a cardanic cross forces 162
18.4. The module of the correlations between the cardanic fork forces 162
18.5. The module of the correlations between the forces of mediate shafts 164
18.6. The module of the correlations between the forces of the extremal shafts 165

18.7. Conclusions....167
REFERENCES....167

19. On the dynamic analysis of a 3-cardan transmission....168
19.1. Introduction....168
19.2. General algorithm for the modelling of the forces and torques....168
19.3. Numerical simulations....169
19.4. Conclusions....174
REFERENCES....175

20. Modelling of cardan transmissions with elastic secondary shafts....176
20.1. Introduction....176
20.2. Notations and conditions....177
20.3. Adaptation of the kinematic correlations to the condition of elastic shafts....177
20.4. Adaptation of the general algorithm to the condition of elastic secondary shafts....178
20.5. Numerical simulations and conclusions....180
REFERENCES....183

21. A systhematic approach for accuracy modelling of complex parallel linkages....184
21.1. Introduction....184
21.2. The problem formulation....185
21.3. Algorithm A for modelling the error Jacobians....188
21.4. Algorithm B for modelling the error Jacobians....191
21.5. Algorithm C for modelling the error Jacobians....195
21.6. Conclusions....202
REFERENCES....202

22. The geometrical errors of a Stewart platform, identified by accuracy experimental testing....204
22.1. Introduction....204
22.2. Stewart platform: brief presentation and parameterisation....204
22.3. Geometrical error modelling....206
22.4. Accuracy measurements....209
22.5. Identification of the geometrical errors....210
22.6. Conclusions....212
REFERENCES....212

23. On the calibration of a Stewart platform....214
23.1. Introduction....214
23.2. Stewart platform: description and parameterization....215
23.3. Kinematical error model....215
23.4. Joint level calibration of the Stewart platform....220
23.5. Conclusions....224
REFERENCES....224