

New Challenge on Suspension Design Using CAE Technology

-A Study on Concept Design Using CAP
(Computer Aided Principle)-

Qiang Yu (Yokohama National University)

Takanori Sakahara (Graduate School of Yokohama National University)

Keiichi Motoyama (Mechanical Dynamics Japan)



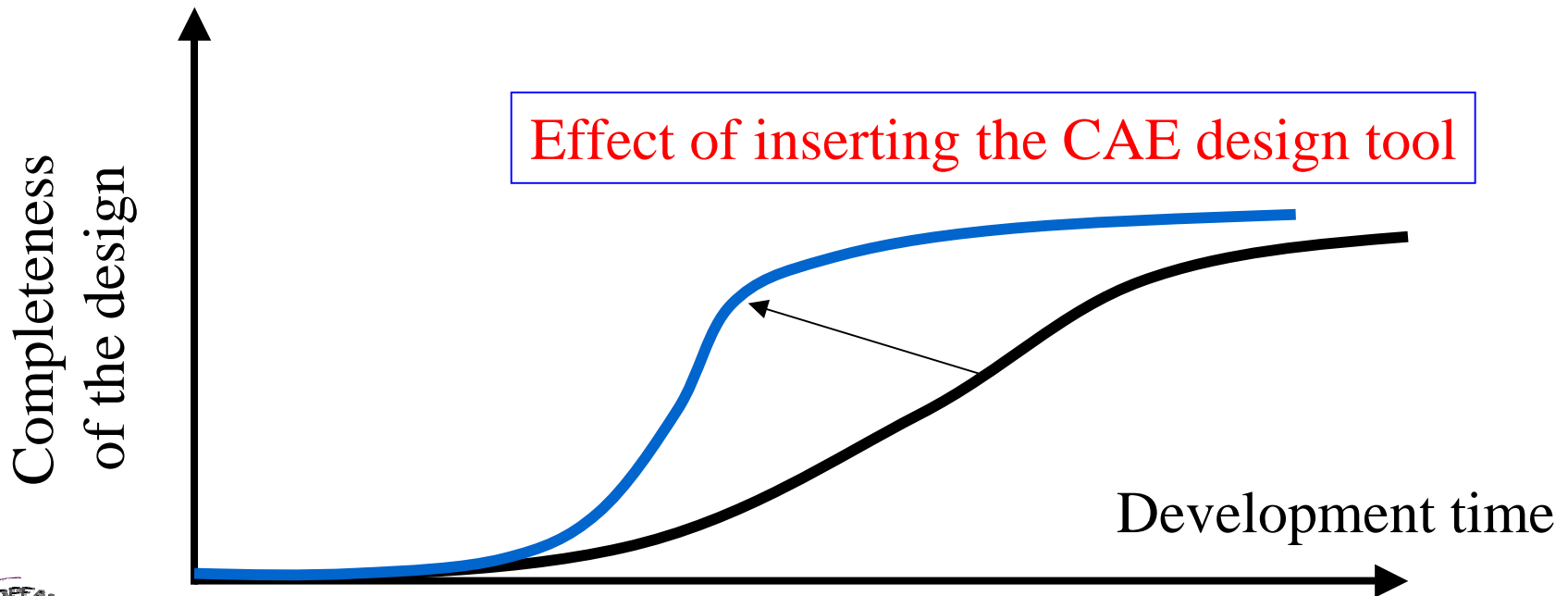
Software... Systems... Services...



Background Effect of the CAE technology

The development of the technology of the CAE was able to improve design efficiency of the large scale structure system like the automobile and realize the shortening in the design time .

Then, the CAE technology is already used as a general-purpose design tool in the detailed design processes of the product



Concept design

Detail design

Trial manufacture
Improvement

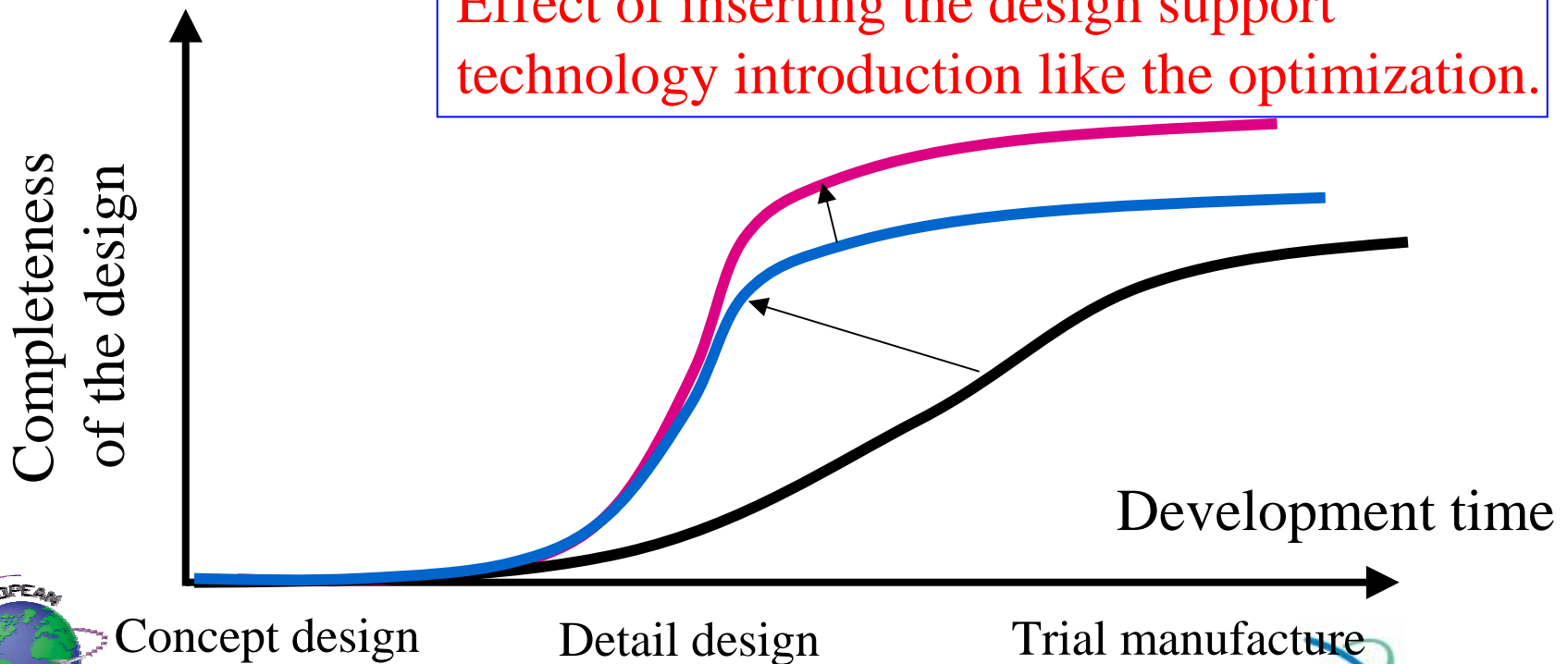
MSC SOFTWARE
SIMULATING REALITY

Background (Effect of the optimum design technology)

Furthermore, design support technologies for the optimization technology were introduced to realize the shortening in the design time and performance improvement

I-SIGHT, SDSS

Effect of inserting the design support technology introduction like the optimization.

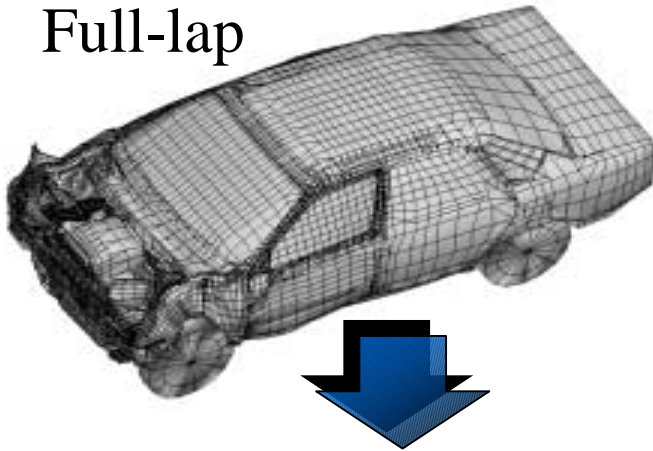


Trial manufacture
Improvement

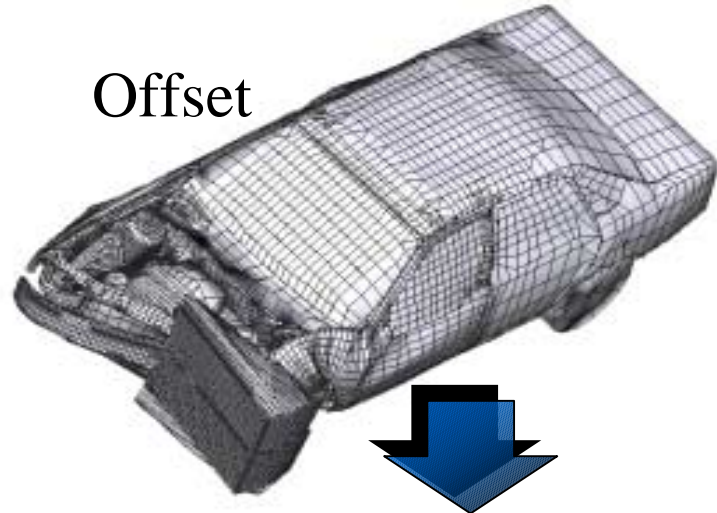
MSC SOFTWARE
SIMULATING REALITY

Multi-Objective Optimization

Full-lap



Offset



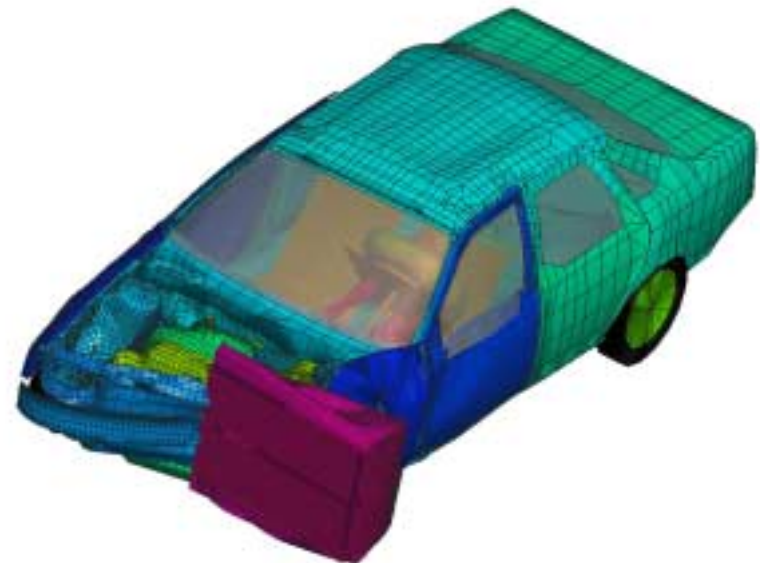
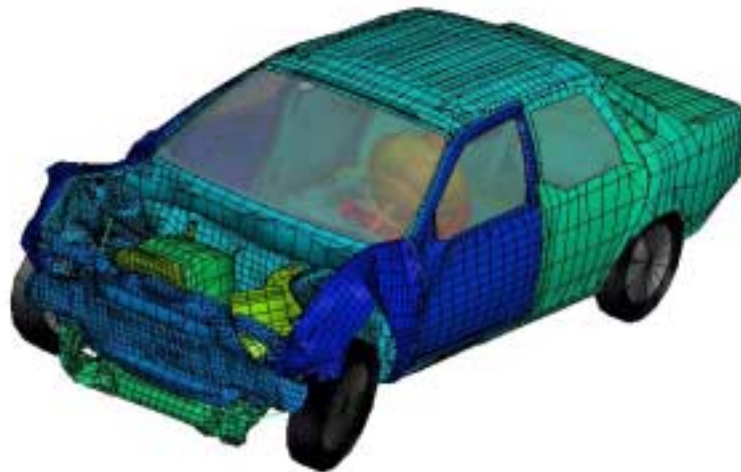
•Acceleration

- Weight
- A-C pillar Deformation
- Toe-Board Intrusion

Background Example of the optimum design-2

Result of the optimum design by SDSS

	Weight	A-C pillar	Toe-Board	Acceleration
Initial	46.0kg	0.0226m	0.0720m	13.9
Car body structure	30.60kg	0.0330m	0.0870m	14.86
Car body structure { Deceleration characteristics	30.89kg	0.0341m	0.0978m	11.87

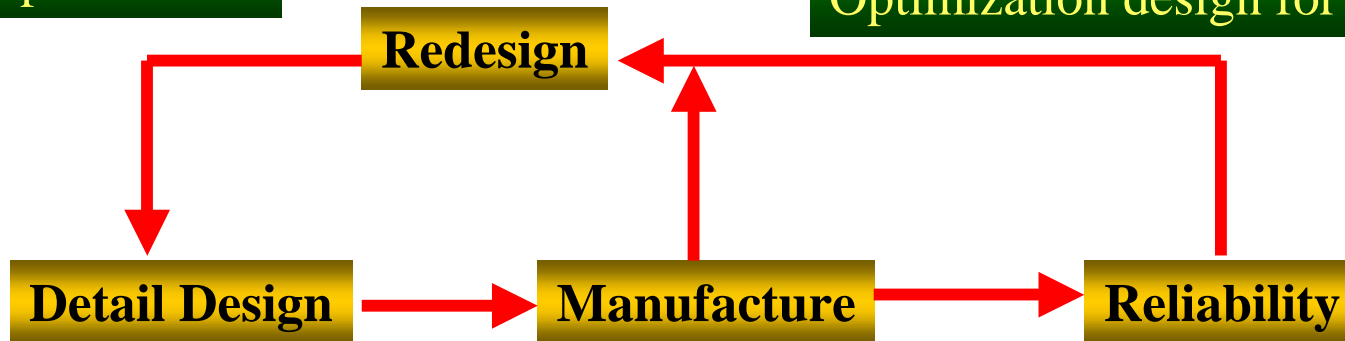


Background Completion of the technology of the detail design-3

Progress on the technology in the detailed design

FEA
Optimization

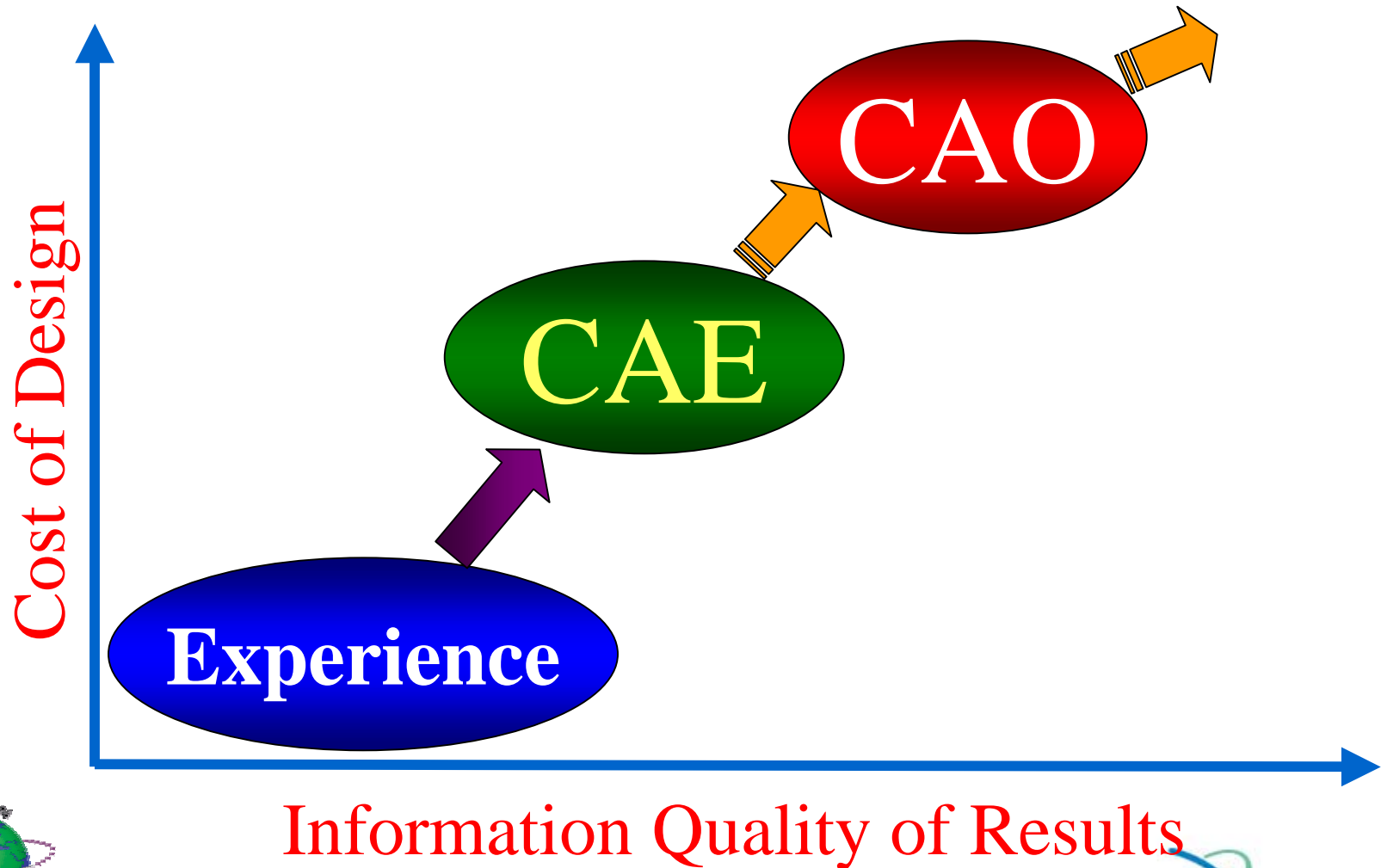
FEA
Reliability assessment and design
Optimization design for reliability



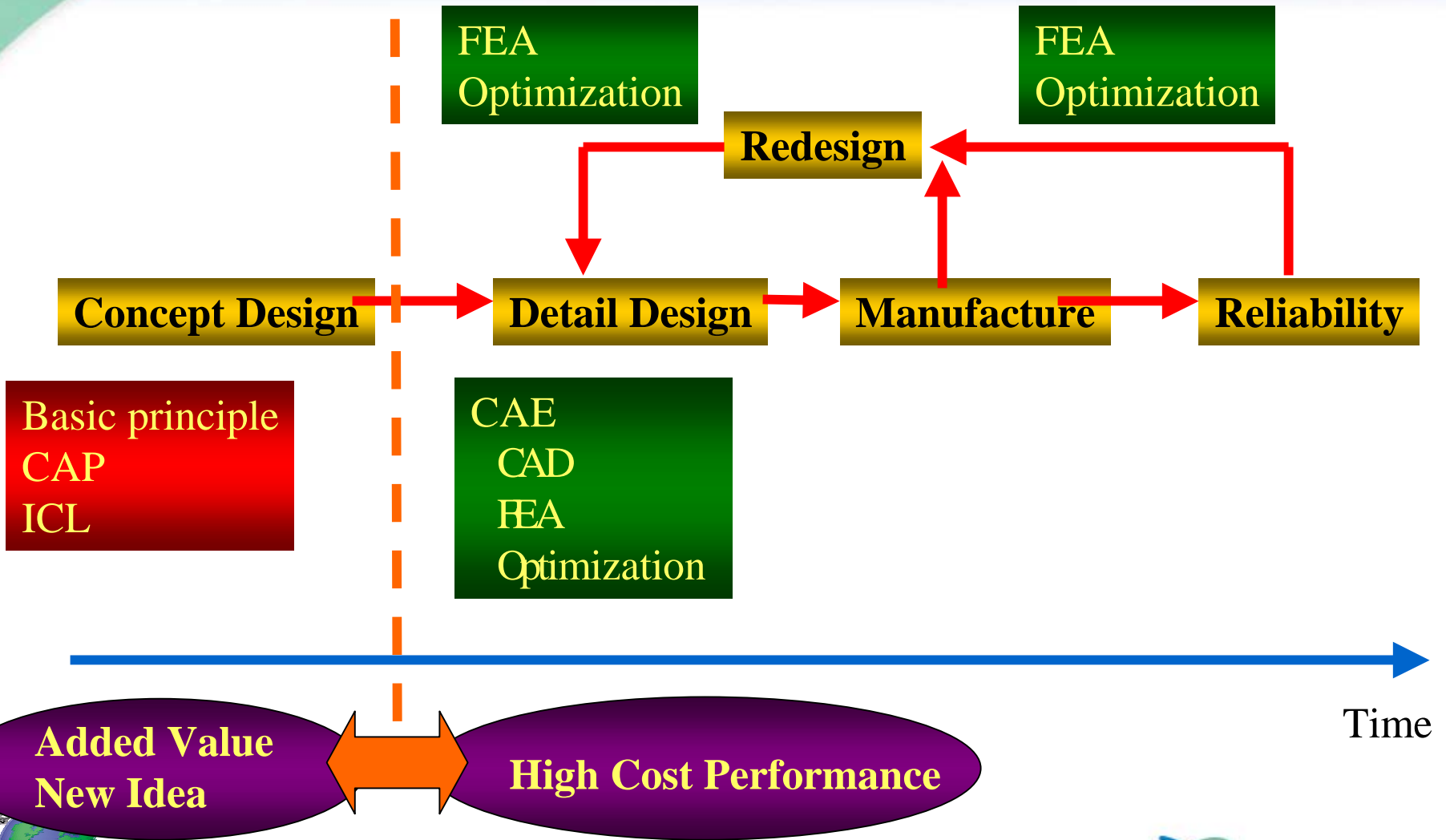
CAE
CAD
FEA
Optimization design methodology



Background What is the Next technology-4

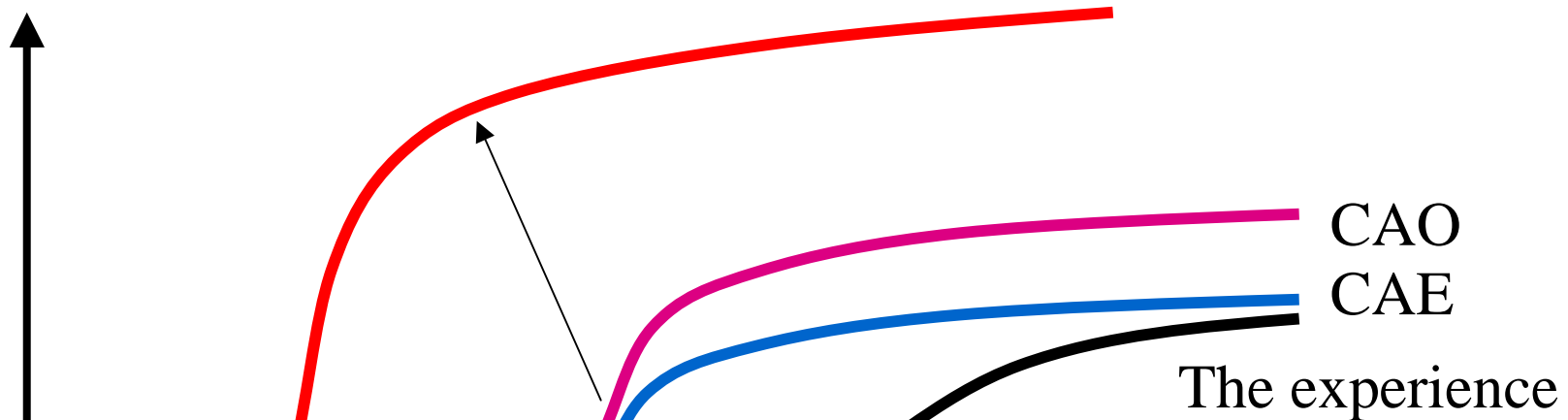


New CAE Technology for Concept Design

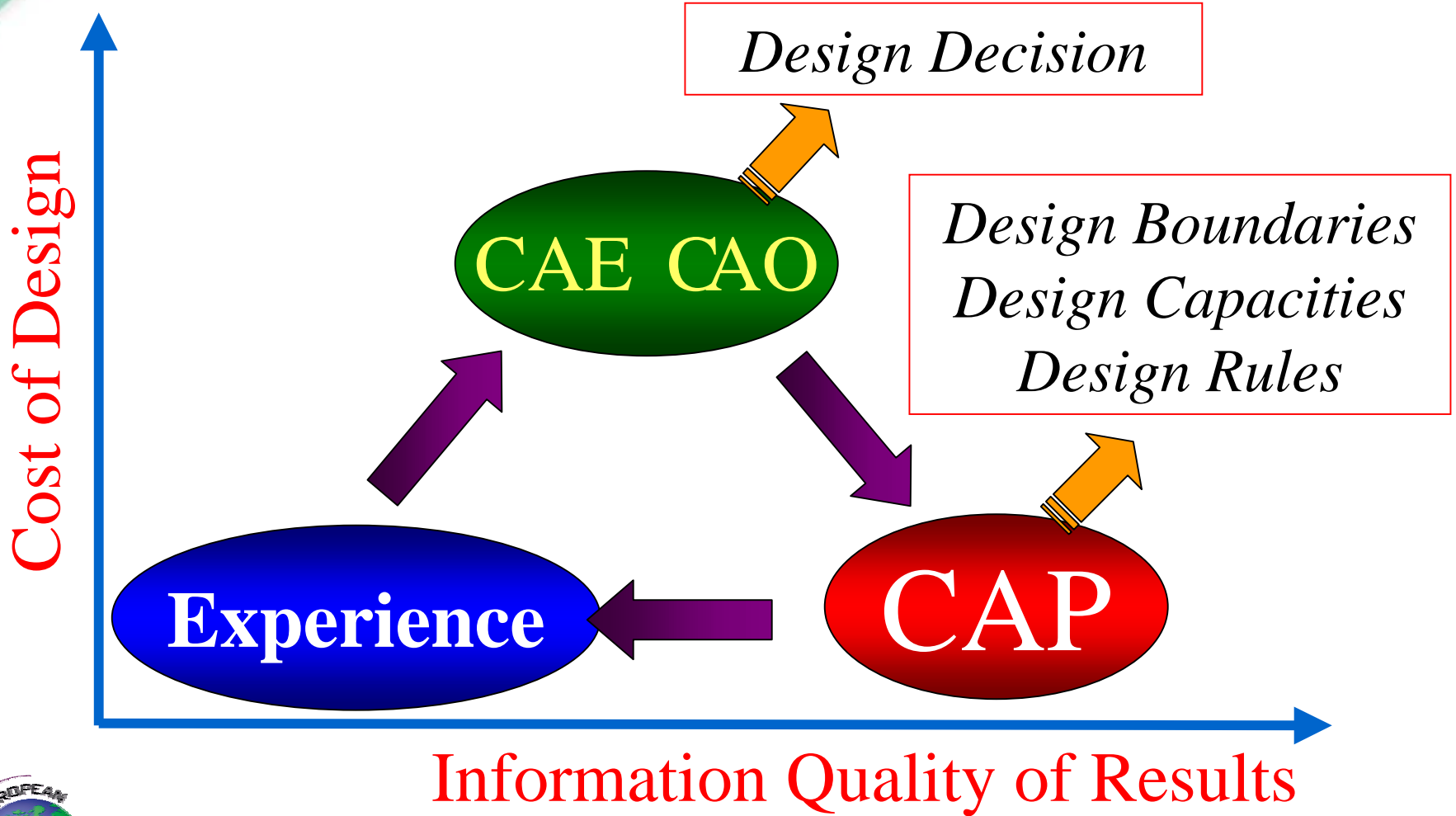


Background Needs for next technology-5

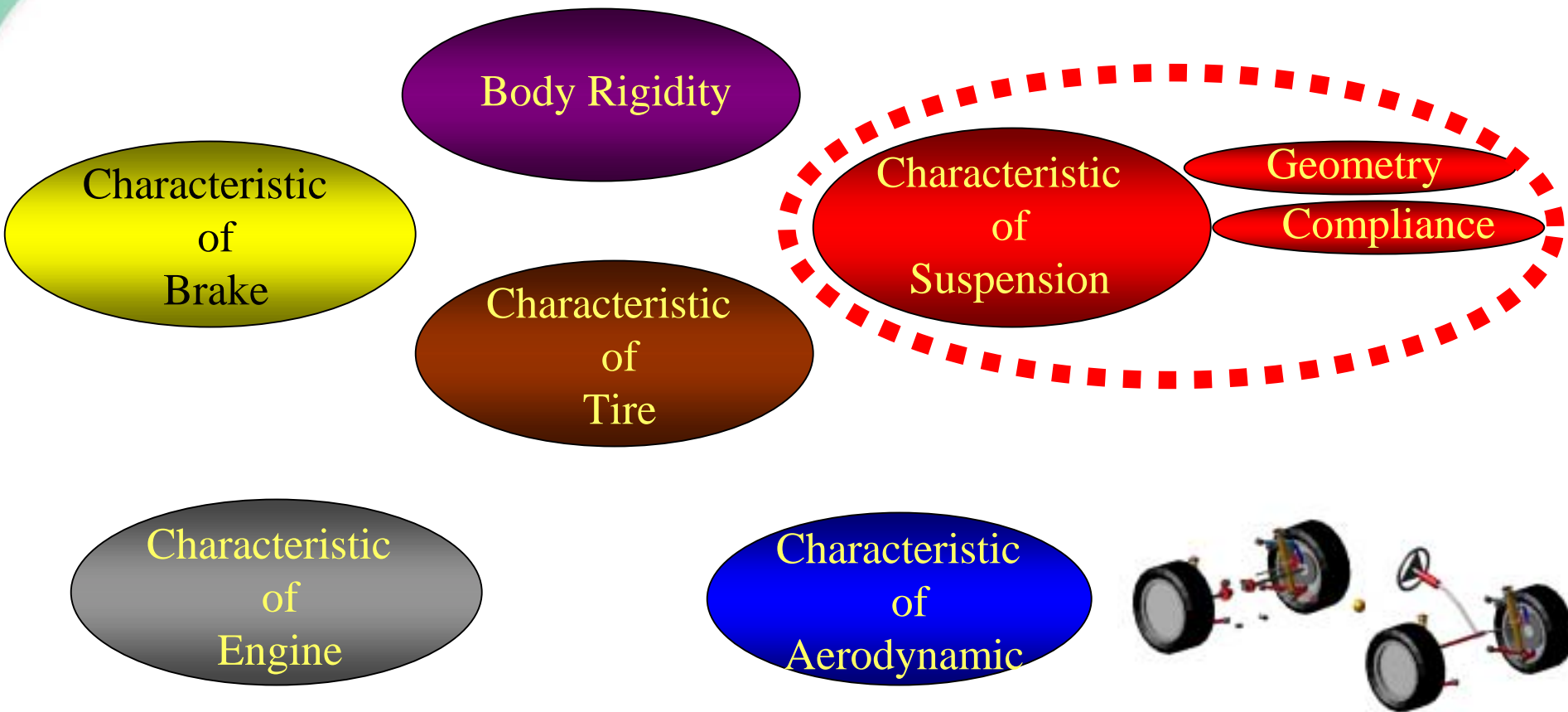
With the completion of CAE technology in the detail design, the efficiency improvement is attempted in the concept design process and The upgrading technology of concepts is required.



Purpose CAP (Computer Aided Principle) Technology



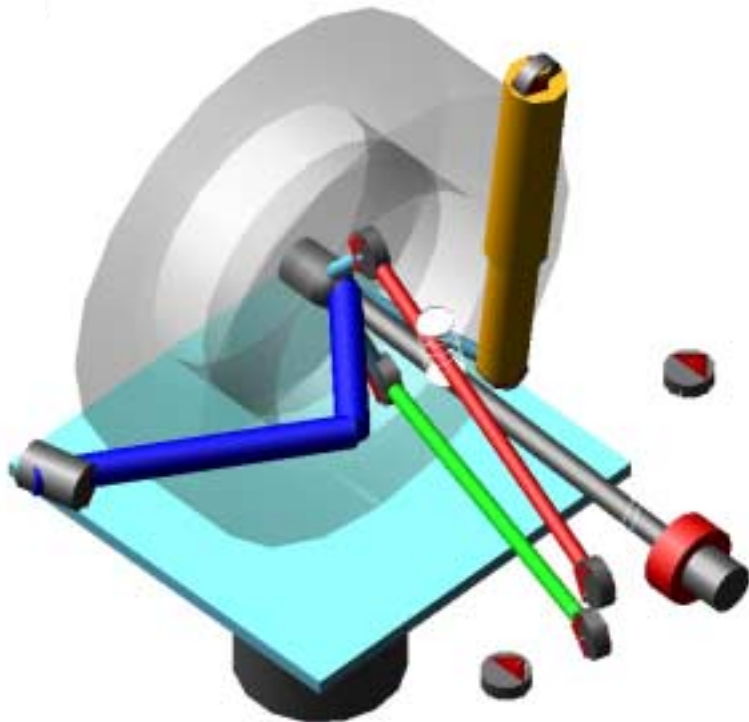
Example Study of the design concepts of the suspension by CAP
Stability Study of Vehicle Driving



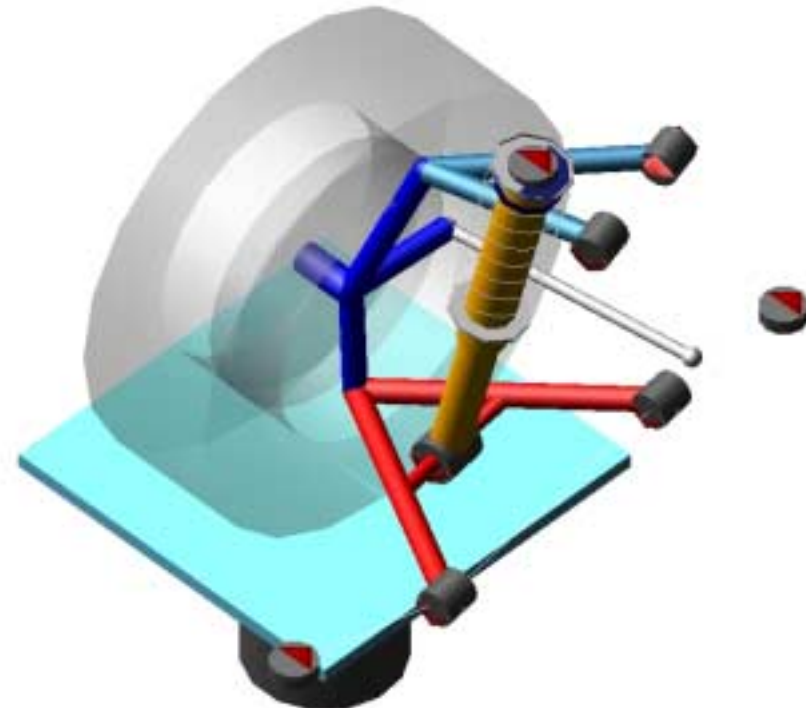
Used model

The purpose is drawing not only the good and bad of a system but also the knowledge about **WHY good**

ML(Multi-Link)



DWB(Double Wishbone)

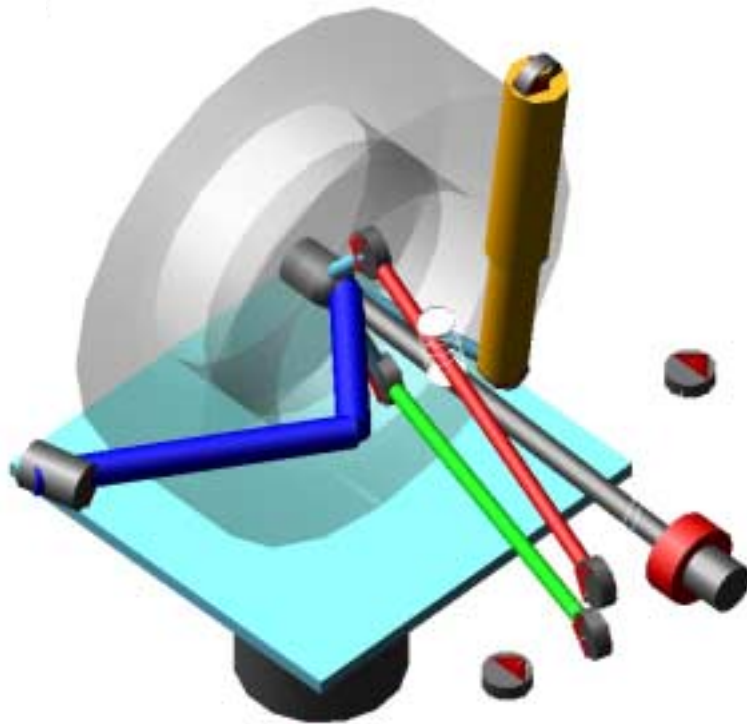


Evaluation factors Geometries of five Joints

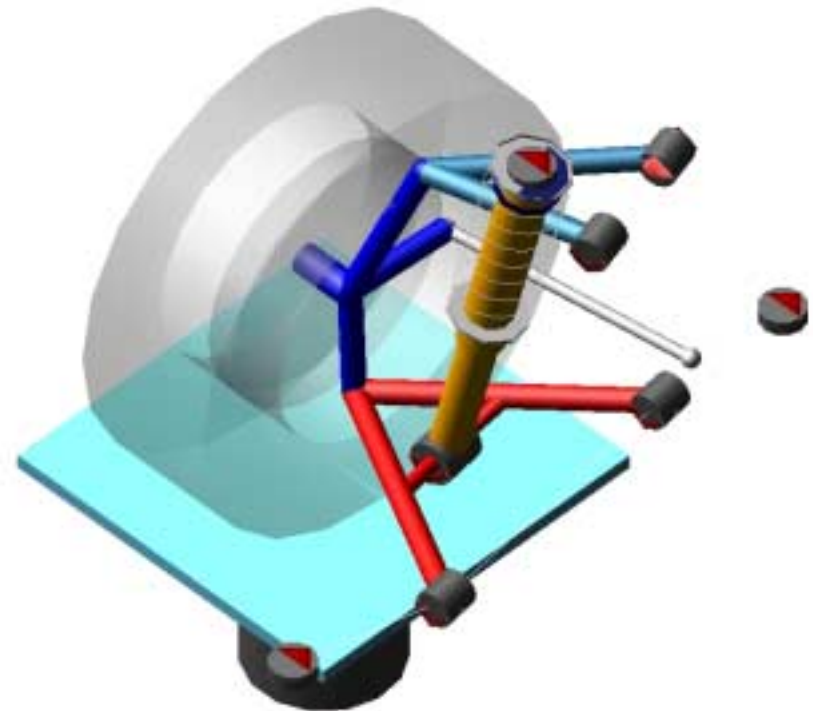
X: Original $\pm 50\text{mm}$, Y: Original $\pm 50\text{mm}$, Z: Original $\pm 50\text{mm}$

ML(Multi-Link)

DWB(Double Wishbone)



FRONT
↓



Analytical conditions and Objective functions-1

Suspension Static Characteristics Analysis

Analytical conditions

Factor

Level number level

Orthogonal table $L_{64}(4^{21})$

Analysis number

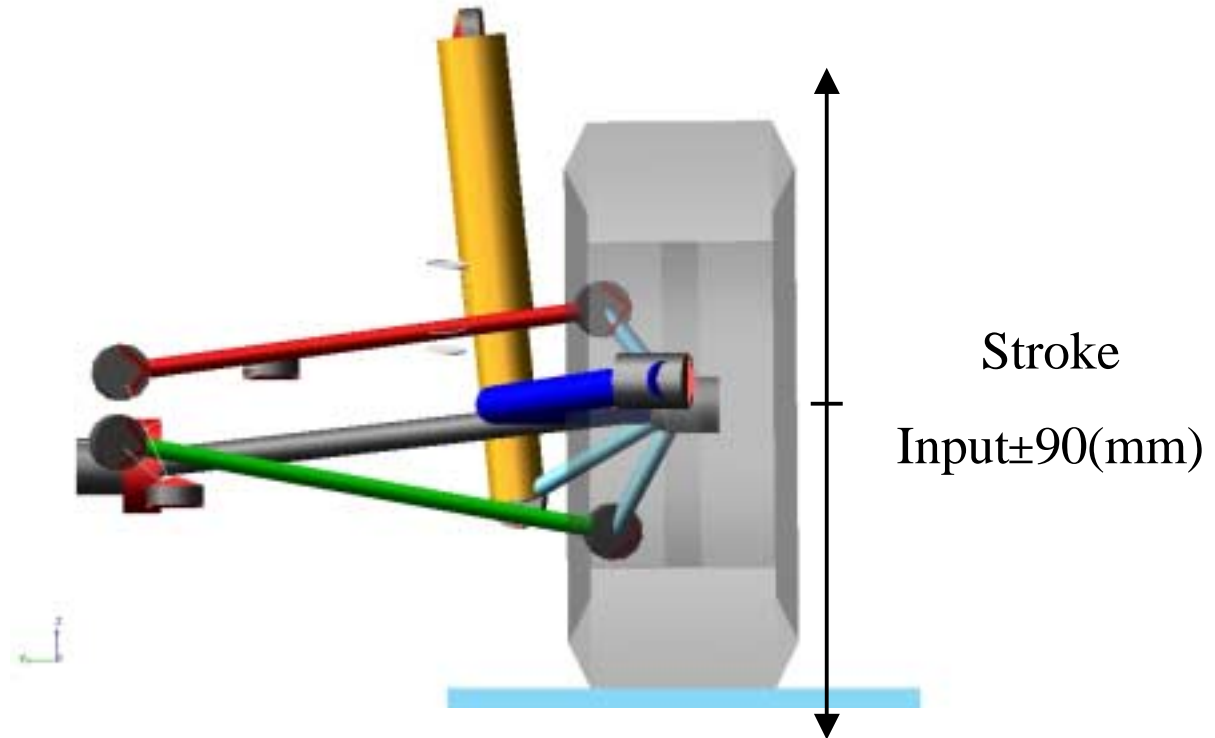
Objective functions

Toe Angle

Camber Angle

Wheel Center Base

Parallel Travel



Evaluation factor

Full Vehicle dynamic characteristic Analysis

Model

The model was developed by combining by the models used in the Suspension analysis

Objective functions

Pitch Angle , Tire Force , Tire Slip Angle ,
Trailing Body Bush Force

Acceleration Analysis condition

Initial Velocity 0 (km/hr)
After 3 seconds → Full Throttle

Braking Analysis condition

Initial Velocity 100 (km/hr)
After 3 seconds. → Full Throttle

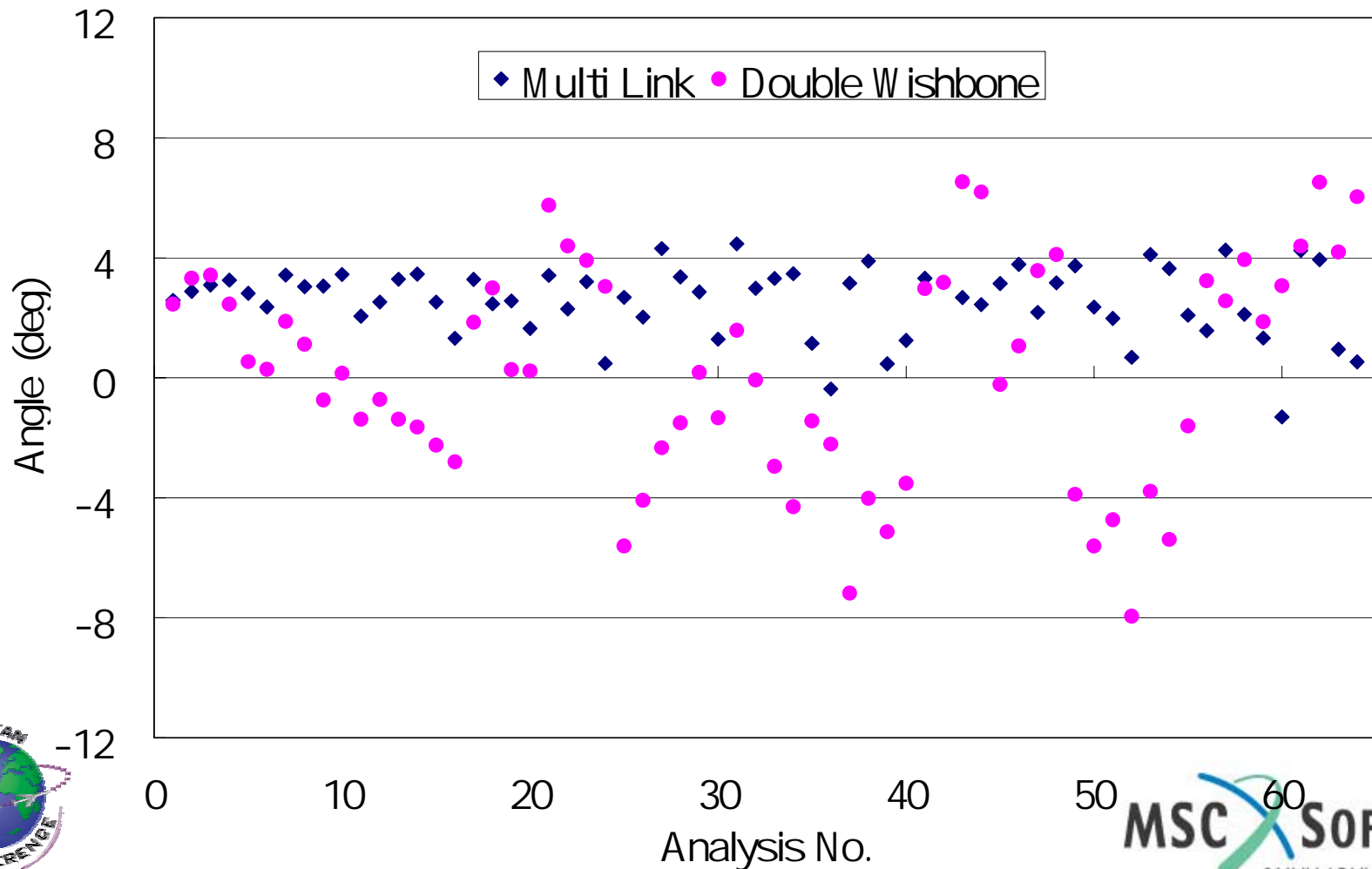
Analysis number Each 64



Analytical results Static Characteristics

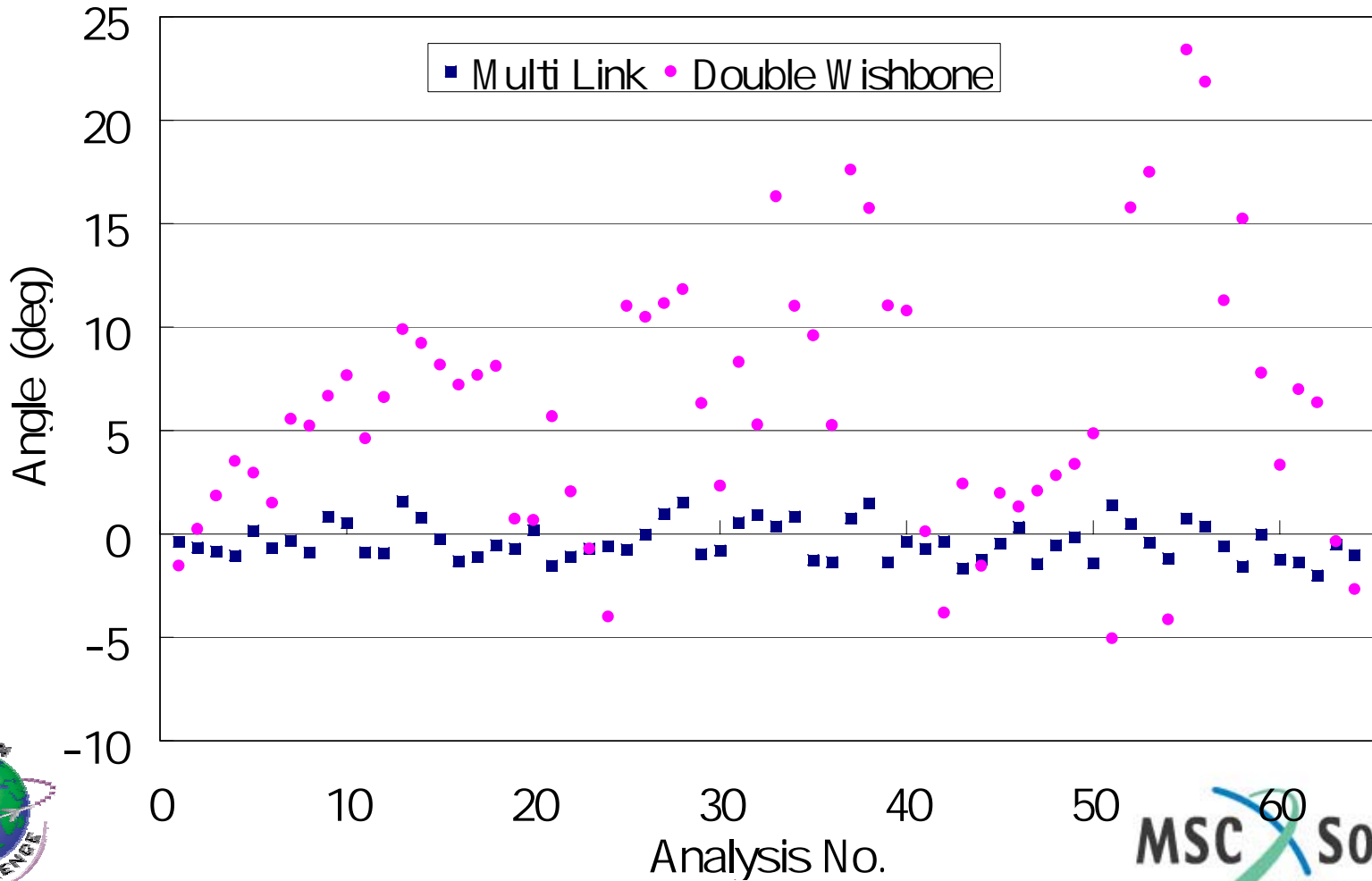
Camber Angle at Stroke=90mm

Camber Angle (stroke 90mm)



Analytical results Static Characteristics-2

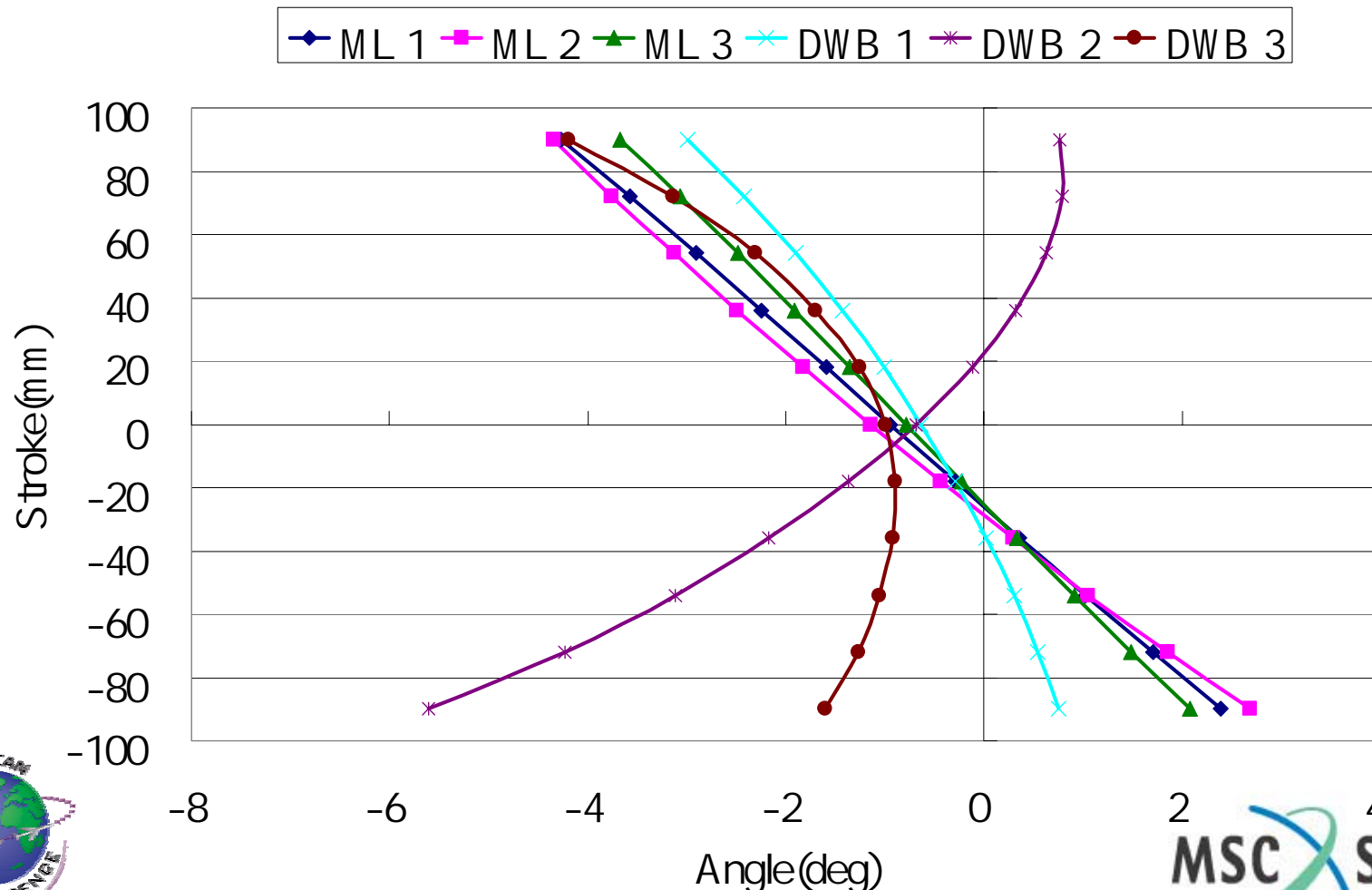
Toe Angle (stroke 90mm)



Analytical results Static Characteristics-3

Camber Angle of Multi Link(ML) and Double Wishbone(DWB)

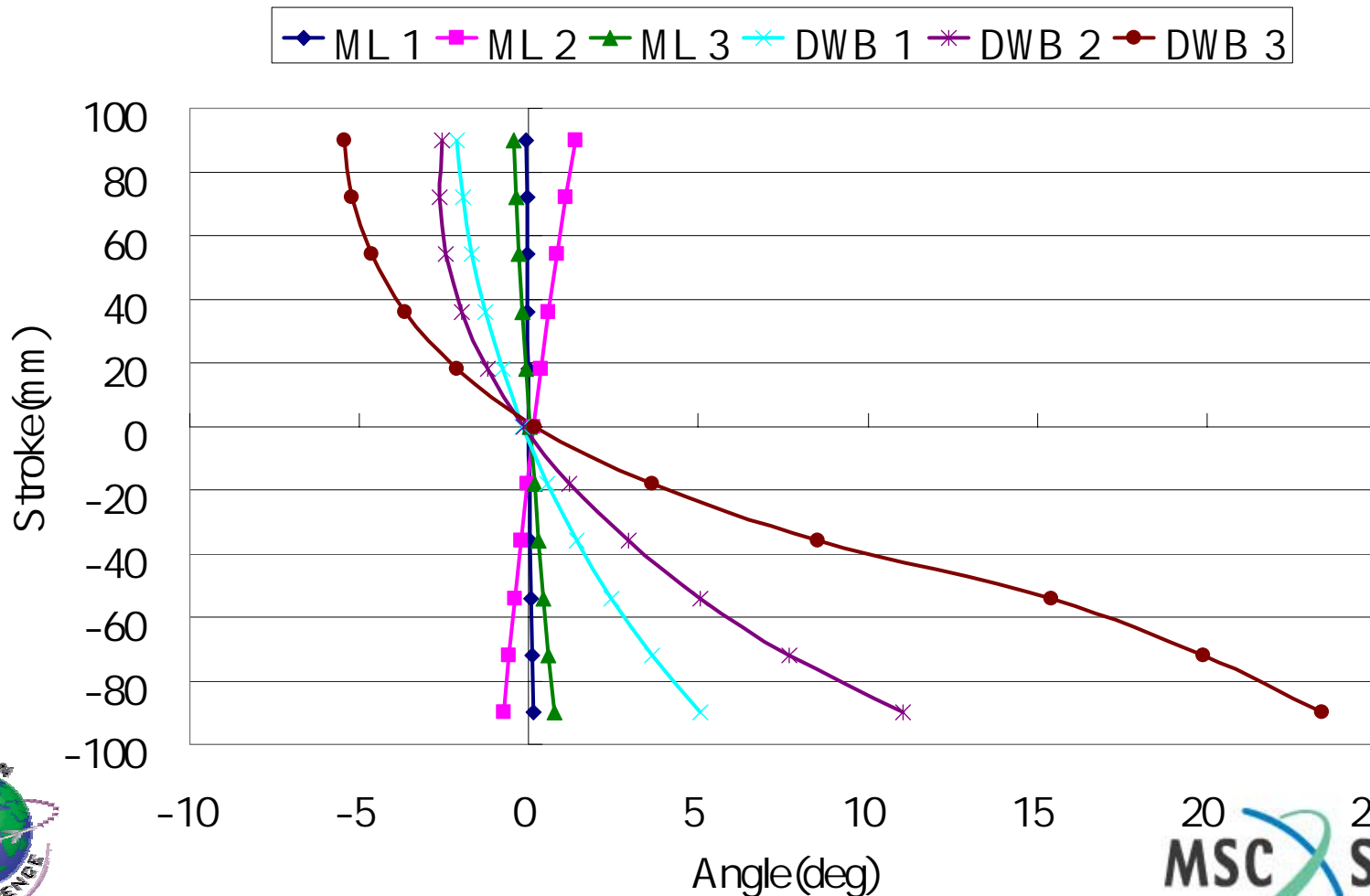
Camber Angle



Analytical results Static Characteristics-4

Toe Angle of Multi Link(ML) and Double Wishbone(DWB)

Toe Angle

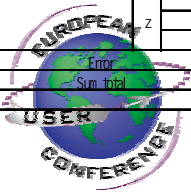


Results Static Characteristics

Results of dispersion analysis for the static characteristic in the ML model

Dispersion analysis table of ML CAMBER									
	Degree	Degree of freedom	F	Fluctuation S	Dispersion V	Variance ratio F0	Level of significance	Pure fluctuation S'	Contribution ratio %
trailing body	x	1	1	8.95758E+00	8.95758E+00	2.93122E+01	**	8.65198E+00	3.00%
		2	1	7.91066E+01	7.91066E+01	2.58863E+00		4.85474E+01	0.17%
		3	1	8.91517E+01	8.91517E+01	2.91734E+00		5.85925E+01	0.20%
	y	1	1	6.46036E+00	6.46036E+00	2.11405E+01	**	6.15477E+00	2.14%
		2	1	5.15950E+03	5.15950E+03	1.68836E+02		0.00000E+00	0.00%
		3	1	1.21963E+01	1.21963E+01	3.99104E+01		0.00000E+00	0.00%
z	1	1	3.24751E+00	3.24751E+00	1.06269E+01	**	2.94191E+00	1.02%	
	2	1	6.71532E+03	6.71532E+03	2.19748E+02		0.00000E+00	0.00%	
	3	1	3.45337E+01	3.45337E+01	1.13006E+00		3.97451E+02	0.01%	
lower link outer	x	1	1	1.78319E+01	1.78319E+01	5.83518E+01	**	1.75263E+01	6.08%
		2	1	9.92303E+03	9.92303E+03	3.24715E+02		0.00000E+00	0.00%
		3	1	1.66288E+01	1.66288E+01	5.44151E+01		0.00000E+00	0.00%
	y	1	1	6.70991E+01	6.70991E+01	2.19571E+00		3.65399E+01	0.13%
		2	1	6.96587E+03	6.96587E+03	2.27947E+02		0.00000E+00	0.00%
		3	1	3.71901E+01	3.71901E+01	1.21699E+00		6.63098E+02	0.02%
z	1	1	6.6898E+01	6.6898E+01	2.18820E+02	**	6.65642E+01	23.11%	
	2	1	5.95726E+01	5.95726E+01	1.94942E+00		2.90134E+01	0.10%	
	3	1	4.13673E+02	4.13673E+02	1.35368E+01		0.00000E+00	0.00%	
upper lower link inner	x	1	1	8.03017E+01	8.03017E+01	2.62774E+02	**	7.99961E+01	27.27%
		2	1	1.79561E+01	1.79561E+01	5.87584E+01		0.00000E+00	0.00%
		3	1	4.13368E+01	4.13368E+01	1.35268E+00		1.07776E+01	0.04%
	y	1	1	5.65192E+00	5.65192E+00	1.84950E+01	**	5.34632E+00	1.86%
		2	1	5.75637E+02	5.75637E+02	1.88368E+01		0.00000E+00	0.00%
		3	1	7.84400E+02	7.84400E+02	2.56682E+01		0.00000E+00	0.00%
z	1	1	3.92263E+00	3.92263E+00	1.28362E+01	**	3.61704E+00	1.26%	
	2	1	1.75505E+01	1.75505E+01	5.74312E+01		0.00000E+00	0.00%	
	3	1	2.90434E+02	2.90434E+02	9.50404E+02		0.00000E+00	0.00%	
upper link outer	x	1	1	3.21274E+00	3.21274E+00	1.05132E+01	**	2.90715E+00	1.01%
		2	1	1.08202E+01	1.08202E+01	3.54074E+01		0.00000E+00	0.00%
		3	1	7.15356E+02	7.15356E+02	2.34089E+01		0.00000E+00	0.00%
	y	1	1	6.65520E+00	6.65520E+00	2.17781E+01	**	6.34961E+00	2.20%
		2	1	2.72526E+01	2.72526E+01	8.91794E+01		0.00000E+00	0.00%
		3	1	2.02040E+03	2.02040E+03	6.61142E+03		0.00000E+00	0.00%
z	1	1	6.98779E+01	6.98779E+01	2.28664E+02	**	6.95723E+01	24.15%	
	2	1	1.56571E+00	1.56571E+00	5.12352E+00	*	1.26011E+00	0.44%	
	3	1	2.79503E+01	2.79503E+01	9.14629E+01		0.00000E+00	0.00%	
dam per lower	x	1	1	1.13099E+00	1.13099E+00	3.70099E+00		8.25400E+01	0.29%
		2	1	6.55902E+02	6.55902E+02	2.14633E+01		0.00000E+00	0.00%
		3	1	1.97920E+01	1.97920E+01	6.47660E+01		0.00000E+00	0.00%
	y	1	1	4.08334E+01	4.08334E+01	1.33621E+00		1.02742E+01	0.04%
		2	1	1.05424E+01	1.05424E+01	3.44983E+01		0.00000E+00	0.00%
		3	1	3.11320E+03	3.11320E+03	1.01875E+01		0.00000E+00	0.00%
z	1	1	1.40864E+03	1.40864E+03	4.60655E+03		0.00000E+00	0.00%	
	2	1	2.10769E+01	2.10769E+01	6.89709E+01		0.00000E+00	0.00%	
	3	1	1.77098E+01	1.77098E+01	5.79525E+01		0.00000E+00	0.00%	
Errnr	18	5.50066E+00	3.05592E-01	1.43197E+01	4.97%				
Sum total	63	2.88076E+02		2.88076E+02	100.00%				
				F(0.05) = 4.413872					F(0.01) = 8.285419

Dispersion analysis table of ML Toe									
	Degree	Degree of freedom	F	Fluctuation S	Dispersion V	Variance ratio F0	Level of significance	Pure fluctuation S'	Contribution ratio %
trailing body	x	1	1	7.84105E+02	7.84105E+02	1.30960E+01		0.00000E+00	0.00%
		2	1	5.16686E+02	5.16686E+02	8.62958E+02		0.00000E+00	0.00%
		3	1	2.66683E+05	2.66683E+05	4.45409E+05		0.00000E+00	0.00%
	y	1	1	8.79633E+03	8.79633E+03	1.46915E+02		0.00000E+00	0.00%
		2	1	1.52448E+01	1.52448E+01	2.56416E+01		0.00000E+00	0.00%
		3	1	8.30984E+02	8.30984E+02	1.38789E+01		0.00000E+00	0.00%
z	1	1	1.65318E+00	1.65318E+00	2.76111E+00		1.05444E+00	1.86%	
	2	1	2.85006E+00	2.85006E+00	4.76011E+00	*	2.25132E+00	3.97%	
	3	1	2.76279E+01	2.76279E+01	4.61435E+01		0.00000E+00	0.00%	
lower link outer	x	1	1	7.87845E+02	7.87845E+02	1.31584E+01		0.00000E+00	0.00%
		2	1	5.57019E+02	5.57019E+02	9.30323E+02		0.00000E+00	0.00%
		3	1	8.56717E+02	8.56717E+02	1.43087E+01		0.00000E+00	0.00%
	y	1	1	6.73250E+01	6.73250E+01	1.12445E+00		7.45122E+02	0.13%
		2	1	1.25271E+02	1.25271E+02	2.09226E+02		0.00000E+00	0.00%
		3	1	1.59736E+01	1.59736E+01	2.66789E+01		0.00000E+00	0.00%
z	1	1	5.00164E+01	5.00164E+01	8.35368E+01		0.00000E+00	0.00%	
	2	1	1.24349E+01	1.24349E+01	2.07686E+01		0.00000E+00	0.00%	
	3	1	2.08334E+02	2.08334E+02	3.47955E+02		0.00000E+00	0.00%	
upper lower link inner	x	1	1	3.63953E+01	3.63953E+01	6.07867E+01		0.00000E+00	0.00%
		2	1	7.15617E+02	7.15617E+02	1.19521E+01		0.00000E+00	0.00%
		3	1	2.20829E+01	2.20829E+01	3.68824E+01		0.00000E+00	0.00%
	y	1	1	5.48264E+01	5.48264E+01	9.15701E+01		0.00000E+00	0.00%
		2	1	2.07185E+03	2.07185E+03	3.46037E+03		0.00000E+00	0.00%
		3	1	1.57135E+01	1.57135E+01	2.62444E+01		0.00000E+00	0.00%
z	1	1	1.38259E+01	1.38259E+01	2.30917E+01	**	1.32271E+01	23.30%	
	2	1	7.61621E+00	7.61621E+00	1.27204E+01	**	7.01747E+00	12.36%	
	3	1	1.30946E+01	1.30946E+01	2.18704E+01		0.00000E+00	0.00%	
upper link outer	x	1	1	1.79769E+01	1.79769E+01	3.00247E+01		0.00000E+00	0.00%
		2	1	1.33454E+01	1.33454E+01	2.22893E+01		0.00000E+00	0.00%
		3	1	9.96240E+02	9.96240E+02	1.66390E+01		0.00000E+00	0.00%
	y	1	1	1.55937E+03	1.55937E+03	2.60443E+03		0.00000E+00	0.00%
		2	1	9.13072E+03	9.13072E+03	15.2500E+02		0.00000E+00	0.00%
		3	1	3.40314E+03	3.40314E+03	5.68387E+03		0.00000E+00	0.00%
z	1	1	7.45486E+00	7.45486E+00	1.24510E+01	**	6.85612E+00	12.08%	
	2	1	6.65509E+01	6.65509E+01	1.11152E+00		6.67713E+02	0.12%	
	3	1	2.61789E+00	2.61789E+00	4.37234E+00		2.01915E+00	3.56%	
dam per lower	x	1	1	7.89255E+04	7.89255E+04	1.31820E+03		0.00000E+00	0.00%
		2	1	1.80148E+02	1.80148E+02	3.00879E+02		0.00000E+00	0.00%
		3	1	4.43777E+02	4.43777E+02	7.41188E+02		0.00000E+00	0.00%
	y	1	1	2.59945E+02	2.59945E+02	4.34156E+02		0.00000E+00	0.00%
		2	1	4.04129E+02	4.04129E+02	6.74969E+02		0.00000E+00	0.00%
		3	1	3.28625E+01	3.28625E+01	5.48863E+01		0.00000E+00	0.00%
z	1	1	1.09119E+01	1.09119E+01	1.82248E+01		0.00000E+00	0.00%	
	2	1	8.21822E+01	8.21822E+01	1.37259E+00		2.23084E+01	0.39%	
	3	1	3.63320E+01	3.63320E+01	6.06810E+00	*	3.03446E+00	5.35%	
Errnr	18	1.07773E+01	5.98737E-01	1.43197E+01	4.97%				
Sum total	63	5.67666E+01		5.67666E+01	100.00%				
				F(0.05) = 4.413872					F(0.01) = 8.285419



Results Static Characteristics-6

Results of dispersion analysis for the static characteristic in the DWB model

Dispersion analysis table ofDWB CAMBER

	Degree	Degree of freedom	F	Fluctuation S	Dispersion V	Variance ratio F(0)	Level of significance	Pure fluctuation S'	Contribution ratio %
upper_control_iam_front	x	1	1	1.57319E+02	1.57319E+02	4.75049E+01	**	1.54007E+02	13.45%
		2	1	5.10855E+00	5.10855E+00	1.54261E+00		1.79691E+00	0.16%
		3	1	3.88700E+00	3.88700E+00	1.17374E+00		5.75362E-01	0.05%
	y	1	1	9.15291E+01	9.15291E+01	2.76384E+01	**	8.82174E+01	7.71%
		2	1	1.66929E+00	1.66929E+00	5.04278E-01		0.00000E+00	0.00%
		3	1	4.72303E+00	4.72303E+00	1.42619E+00		1.41139E+00	0.12%
	z	1	1	2.78893E+02	2.78893E+02	8.42161E+01	**	2.75582E+02	24.08%
		2	1	2.05434E+02	2.05434E+02	6.20345E+01	**	2.02124E+02	17.66%
		3	1	5.50031E+00	5.50031E+00	1.64090E+00		2.18869E+00	0.19%
upper_control_iam_rear	x	1	1	2.70281E+01	2.70281E+01	8.16155E+00	*	2.37165E+01	2.07%
		2	1	4.87469E+00	4.87469E+00	1.47199E+00		1.56306E+00	0.14%
		3	1	2.01947E+00	2.01947E+00	6.09809E-01		0.00000E+00	0.00%
	y	1	1	2.58160E+01	2.58160E+01	7.79555E+00	*	2.25044E+01	1.97%
		2	1	1.54758E+00	1.54758E+00	4.67315E-01		0.00000E+00	0.00%
		3	1	1.16825E+01	1.16825E+01	3.52772E+00		8.37089E+00	0.73%
	z	1	1	9.63382E+00	9.63382E+00	2.93089E+00		6.32218E+00	0.55%
		2	1	6.86089E-01	6.86089E-01	2.07175E-01		0.00000E+00	0.00%
		3	1	1.60697E+00	1.60697E+00	4.85251E-01		0.00000E+00	0.00%
lower_control_iam_front	x	1	1	4.48570E+00	4.48570E+00	1.35453E+00		1.17404E+00	0.10%
		2	1	1.59405E+00	1.59405E+00	4.81345E-01		0.00000E+00	0.00%
		3	1	2.64924E-04	2.64924E-04	7.99978E-05		0.00000E+00	0.00%
	y	1	1	1.62651E+00	1.62651E+00	4.91149E-01		0.00000E+00	0.00%
		2	1	1.35460E+00	1.35460E+00	4.09042E-01		0.00000E+00	0.00%
		3	1	4.63155E+00	4.63155E+00	1.39857E+00		1.31991E+00	0.12%
	z	1	1	6.63212E+01	6.63212E+01	2.00267E+01	**	6.30095E+01	5.50%
		2	1	1.39857E+00	1.39857E+00	4.22319E-01		0.00000E+00	0.00%
		3	1	4.27574E-02	4.27574E-02	1.29112E-02		0.00000E+00	0.00%
lower_control_iam_rea	x	1	1	1.67769E+01	1.67769E+01	5.06604E+00	*	1.34653E+01	1.18%
		2	1	7.90558E+00	7.90558E+00	2.38721E+00		4.59394E+00	0.40%
		3	1	4.61672E+00	4.61672E+00	1.39409E+00		1.30508E+00	0.11%
	y	1	1	4.30680E+01	4.30680E+01	1.30050E+01	**	3.97563E+01	3.47%
		2	1	3.50201E+00	3.50201E+00	1.05749E+00		1.90377E-01	0.02%
		3	1	4.21177E-01	4.21177E-01	1.27181E-01		0.00000E+00	0.00%
	z	1	1	4.99481E+01	4.99481E+01	1.50826E+01	**	4.66265E+01	4.07%
		2	1	3.70727E+00	3.70727E+00	1.11947E+00		3.95633E-01	0.03%
		3	1	3.11220E-02	3.11220E-02	9.39776E-03		0.00000E+00	0.00%
lower_strutmount	x	1	1	1.28420E+01	1.28420E+01	3.87785E+00		9.53041E+00	0.83%
		2	1	3.06393E+00	3.06393E+00	9.25200E-01		0.00000E+00	0.00%
		3	1	6.61655E-01	6.61655E-01	1.99797E-01		0.00000E+00	0.00%
	y	1	1	4.26345E-06	4.26345E-06	1.28742E-06		0.00000E+00	0.00%
		2	1	8.04275E+00	8.04275E+00	2.42863E+00		4.73112E+00	0.41%
		3	1	2.91418E+00	2.91418E+00	8.79982E-01		0.00000E+00	0.00%
	z	1	1	2.94042E-01	2.94042E-01	8.87906E-02		0.00000E+00	0.00%
		2	1	4.60305E+00	4.60305E+00	1.39177E+00		1.29741E+00	0.11%
		3	1	2.19888E+00	2.19888E+00	6.63984E+00		0.00000E+00	0.00%
Error	18		5.96095E+01	3.31164E+00			1.68844E+02	14.75%	
Sum total	63		1.14463E+03				1.14463E+03	100.00%	

F(0,05) = 4.413872

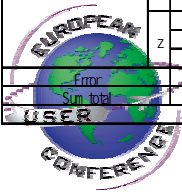
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Dispersion analysis table ofDWB TOE

	Degree	Degree of freedom	F	Fluctuation S	Dispersion V	Variance ratio F(0)	Level of significance	Pure fluctuation S'	Contribution ratio %
upper_control_iam_front	x	1	1	1.62066E+02	1.62066E+02	9.15255E+00	**	1.44359E+02	5.32%
		2	1	1.30612E+01	1.30612E+01	7.37619E-01		0.00000E+00	0.00%
		3	1	1.44537E+00	1.44537E+00	8.16261E-02		0.00000E+00	0.00%
	y	1	1	2.41208E+01	2.41208E+01	1.36220E+00		6.41361E+00	0.24%
		2	1	1.39202E+02	1.39202E+02	7.86132E+00	*	1.21495E+02	4.48%
		3	1	4.54907E+01	4.54907E+01	2.56905E+00		2.77835E+01	1.02%
	z	1	1	8.75810E+02	8.75810E+02	4.94607E+01	**	8.58102E+02	31.64%
		2	1	5.31606E+01	5.31606E+01	3.00220E+00		0.00000E+00	0.00%
		3	1	6.58769E+01	6.58769E+01	3.72035E+00		4.81697E+01	1.78%
upper_control_iam_rear	x	1	1	1.79289E+00	1.79289E+00	1.01252E-01		0.00000E+00	0.00%
		2	1	7.65304E+01	7.65304E+01	4.32000E+00		5.88232E+01	2.17%
		3	1	7.08162E+01	7.08162E+01	3.99929E+00		5.31090E+01	1.96%
	y	1	1	1.44166E+00	1.44166E+00	8.14166E-02		0.00000E+00	0.00%
		2	1	7.90844E+01	7.90844E+01	4.46623E+00	*	6.13772E+01	2.26%
		3	1	6.13007E+01	6.13007E+01	3.46191E+00		4.35935E+01	1.61%
	z	1	1	4.60863E+00	4.60863E+00	2.60269E-01		0.00000E+00	0.00%
		2	1	1.95787E+01	1.95787E+01	1.10669E+00		1.87150E+00	0.07%
		3	1	8.77127E-01	8.77127E-01	4.95351E-02		0.00000E+00	0.00%
lower_control_iam_front	x	1	1	3.77695E+00	3.77695E+00	2.13300E-01		0.00000E+00	0.00%
		2	1	4.43314E+00	4.43314E+00	2.50358E-01		0.00000E+00	0.00%
		3	1	7.44399E-01	7.44399E-01	4.20393E-02		0.00000E+00	0.00%
	y	1	1	1.27262E+01	1.27262E+01	7.18700E-01		0.00000E+00	0.00%
		2	1	1.00644E+01	1.00644E+01	5.68381E-01		0.00000E+00	0.00%
		3	1	3.45048E-02	3.45048E-02	1.94863E-03		0.00000E+00	0.00%
	z	1	1	8.45244E-02	8.45244E-02	4.77345E-03		0.00000E+00	0.00%
		2	1	1.72823E+00	1.72823E+00	9.76003E-02		0.00000E+00	0.00%
		3	1	1.45455E+01	1.45455E+01	8.21444E-01		0.00000E+00	0.00%
lower_control_iam_rea	x	1	1	3.88487E+01	3.88487E+01	2.19395E+00		2.11415E+01	0.78%
		2	1	1.78607E+00	1.78607E+00	1.00867E-01		0.00000E+00	0.00%
		3	1	1.00836E+01	1.00836E+01	5.69846E-01		0.00000E+00	0.00%
	y	1	1	1.12793E+02	1.12793E+02	6.36992E+00	*	9.50862E+01	3.51%
		2	1	2.68795E+00	2.68795E+00	1.51800E-01		0.00000E+00	0.00%
		3	1	3.51293E+00	3.51293E+00	1.98390E-01		0.00000E+00	0.00%
	z	1	1	2.55494E+02	2.55494E+02	1.44289E+01	**	2.37789E+02	8.77%
		2	1	5.34513E+00	5.34513E+00	3.01862E-01		0.00000E+00	0.00%
		3	1	6.93247E+01	6.93247E+01	3.91506E+00		5.16175E+01	1.90%
lower_strutmount	x	1	1	3.99637E+01	3.99637E+01	2.25669E+00		2.22565E+01	0.82%
		2	1	9.72307E+00	9.72307E+00	5.49103E-01		0.00000E+00	0.00%
		3	1	6.65834E+01	6.65834E+01	3.76025E+00		4.88762E+01	1.80%
	y	1	1	2.14961E+01	2.14961E+01	1.21397E+00		3.78889E+00	0.14%
		2	1	2.13978E+01	2.13978E+01	1.20843E+00		3.69064E+00	0.14%
		3	1	2.95363E+00	2.95363E+00	1.66804E-01		0.00000E+00	0.00%
	z	1	1	3.40468E+01	3.40468E+01	1.92277E+00		1.63394E+01	0.60%
		2	1	1.73346E+00	1.73346E+00	9.78956E-02		0.00000E+00	0.00%
		3	1	4.11588E+00	4.11588E+00	2.32441E-01		0.00000E+00	0.00%
Error	18		3.18730E+02	1.77072E+01			7.86711E+02	29.00%	
Sum total	63		2.71239E+03				2.71239E+03	100.00%	

F(0,05) = 4.413872

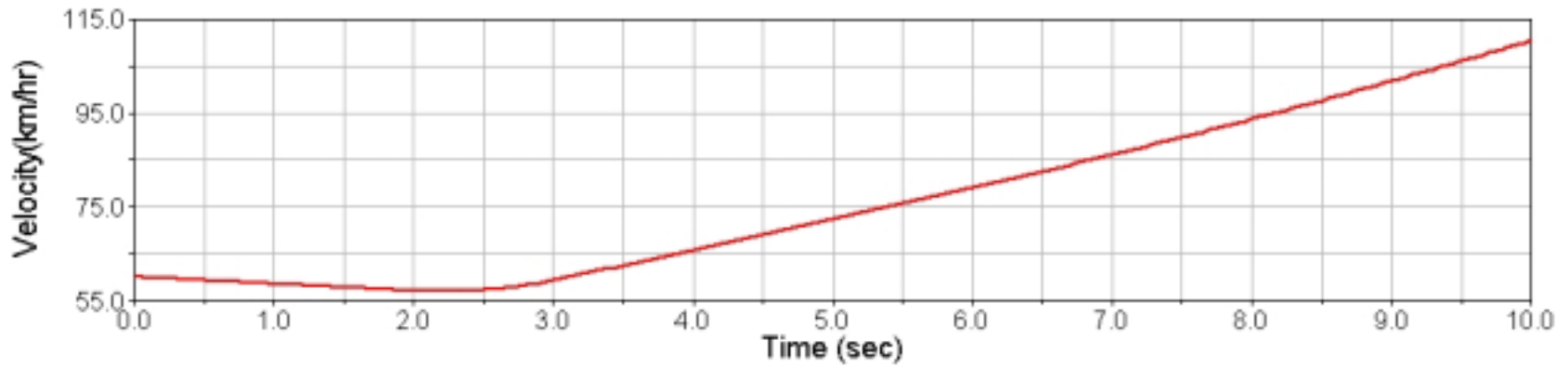
F(0,01) = 8.985419



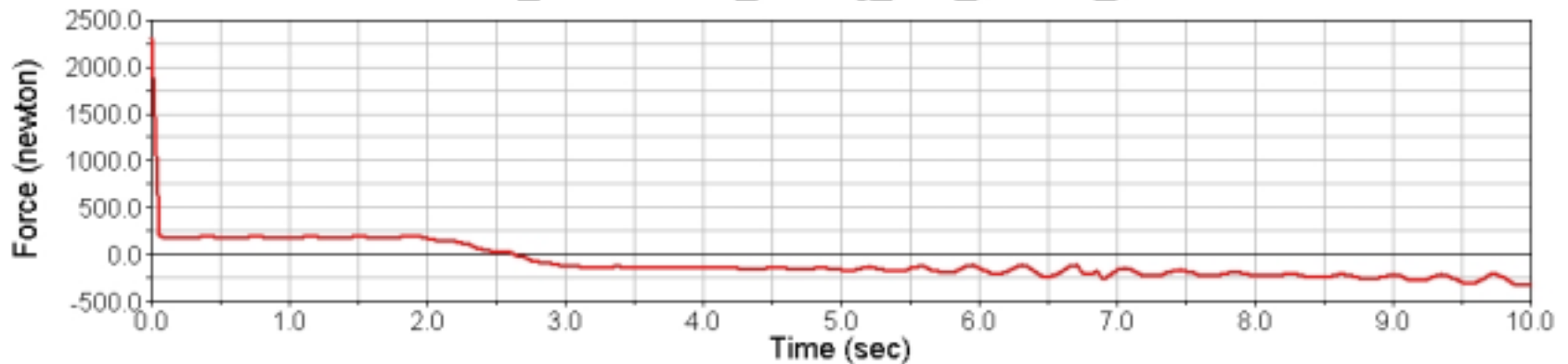
Results Static Characteristics-7

Result of Acceleration analysis of Multi Link

ML_Acceleration_Chassis_Velocity

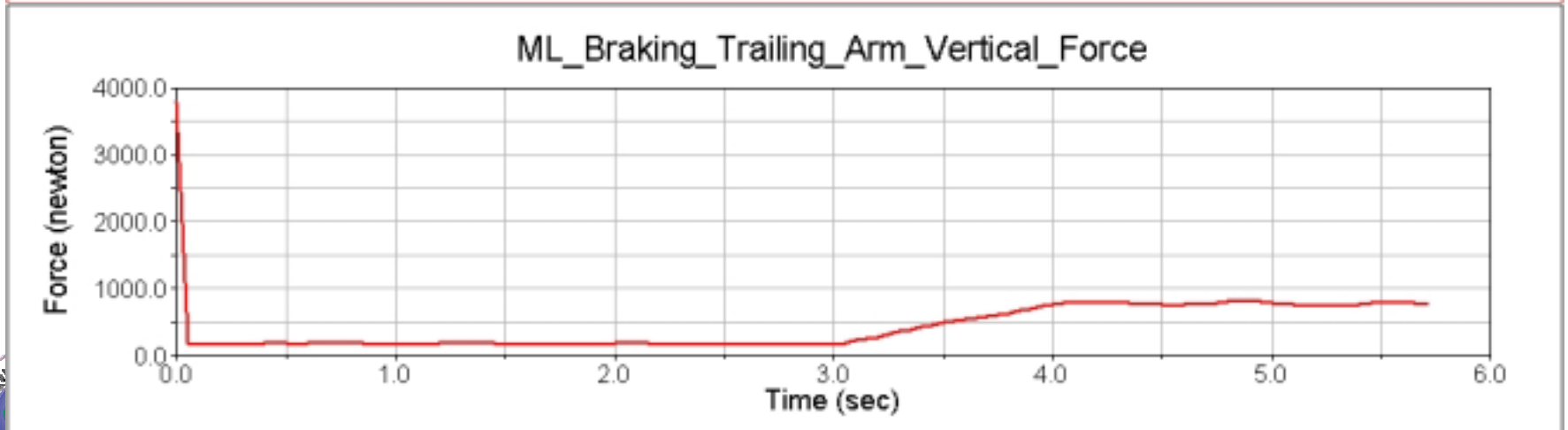
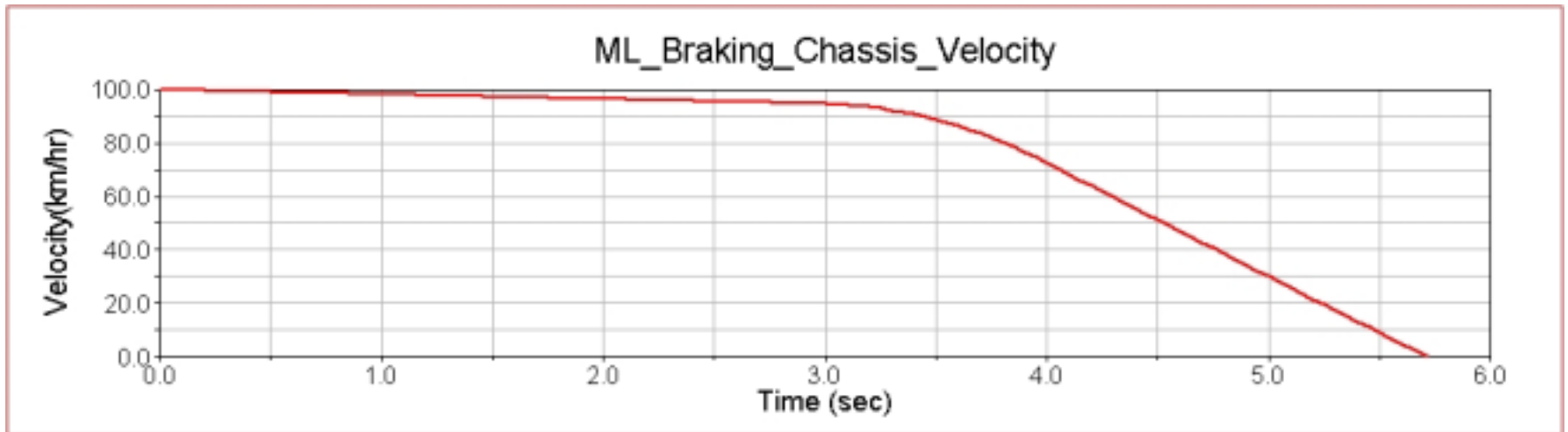


ML_Acceleration_Trailing_Arm_Vertical_Force



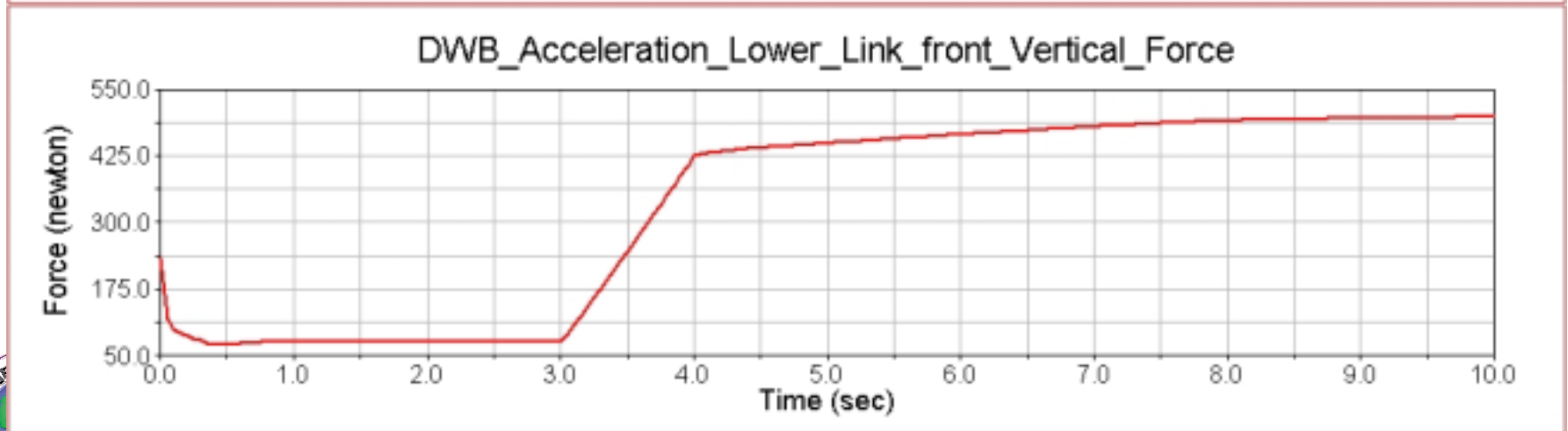
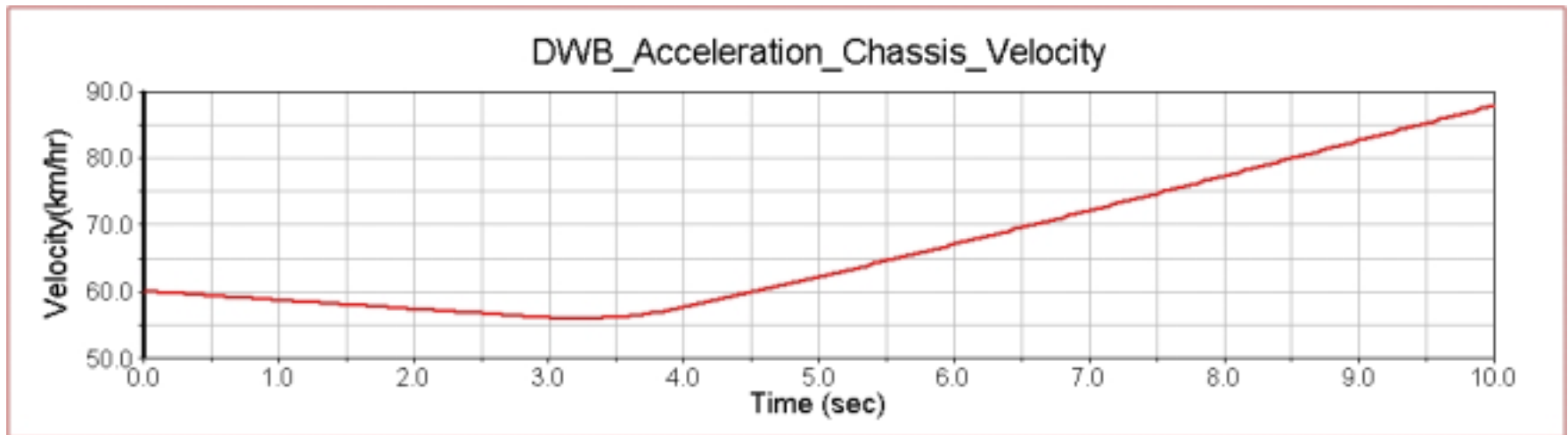
Results Static Characteristics-8

Result of Braking Analysis of Multi Link



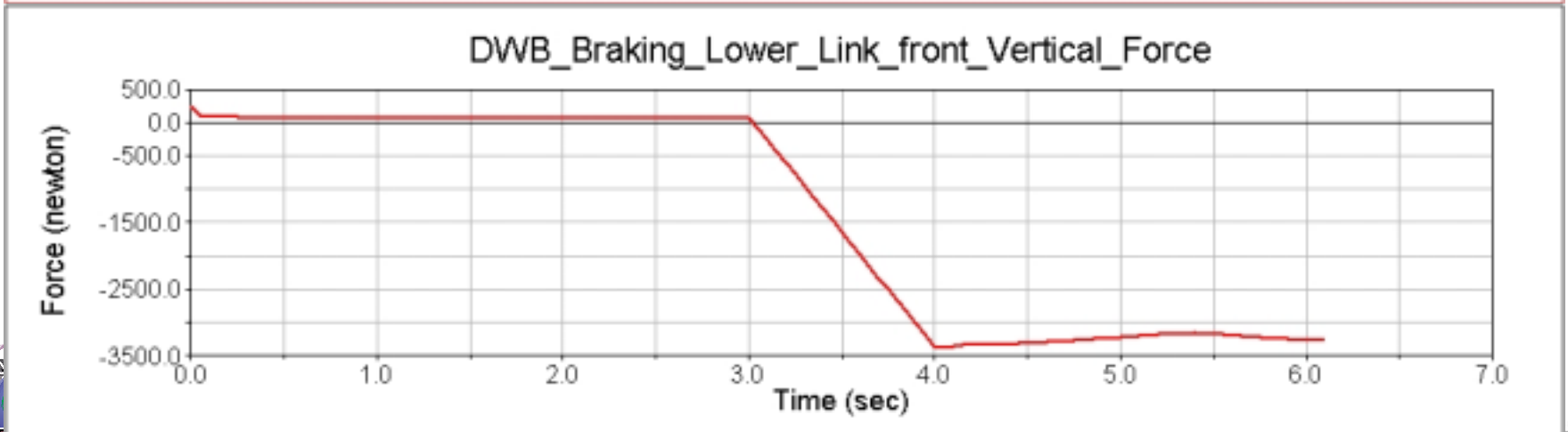
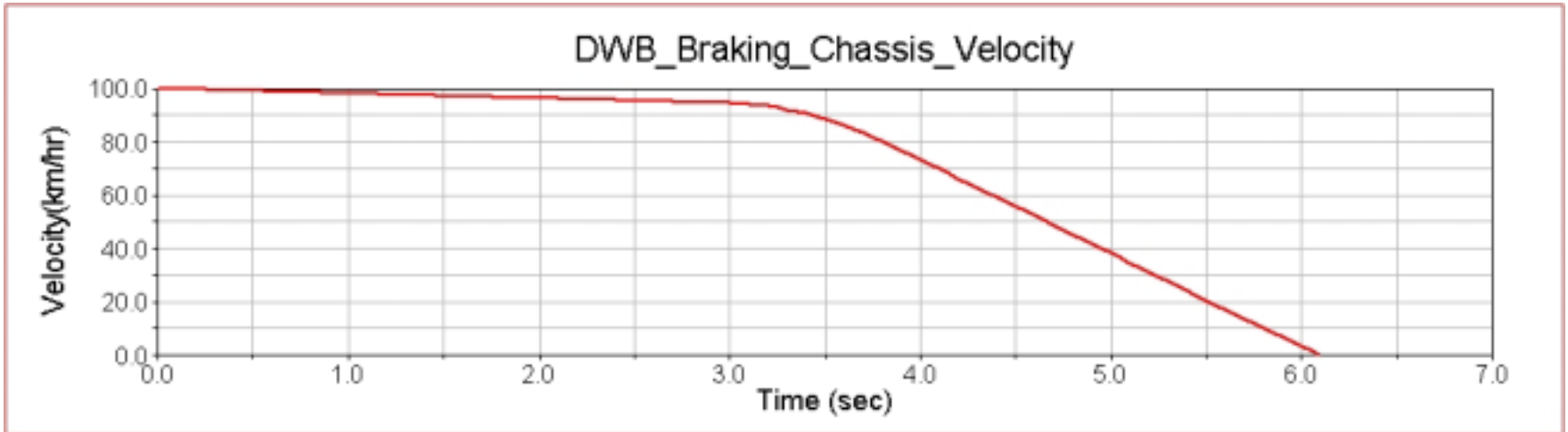
Results Static Characteristics-9

Result of Acceleration Analysis of Double Wishbone



Results Static Characteristics-10

Result of Braking Analysis of Double Wishbone

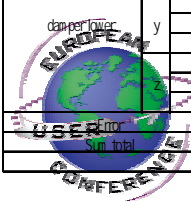


Results Dynamic characteristic -1

Result of dispersion analysis for the dynamic characteristic in the ML model

Dispersion analysis table of ML (ACCELERATION) TRAILING ARM Fz								
	Degree	Degree of freedom f	Fluctuation S	Dispersion V	Variance ratio F0	Level of significance	Pure fluctuation S'	Contribution ratio ρ
trailing_body	x	1	6.82148E-04	6.82148E+04	1.10864E+01	**	6.20618E-04	3.75%
		2	1.44853E-03	1.44853E+03	2.35418E-01		0.00000E-00	0.00%
		3	2.99781E-04	2.99781E+04	4.87208E+00	*	2.38250E-04	1.44%
	y	1	8.75993E-05	8.75993E-05	1.42368E-02	**	8.69940E-05	52.54%
		2	1.18507E-04	1.18507E+04	3.00758E+00		1.23527E-04	0.75%
		3	5.82904E-03	5.82904E+03	9.47344E-01		0.00000E-00	0.00%
	z	1	7.46087E-04	7.46087E+04	1.21255E+01	**	6.84556E-04	4.13%
		2	2.94696E-04	2.94696E+04	4.78944E+00	*	2.33166E-04	1.41%
		3	6.25801E-04	6.25801E+04	1.01706E+01	**	5.64271E-04	3.41%
lower_link_outer	x	1	9.70581E-03	9.70581E+03	1.57740E+00		3.55278E-03	0.21%
		2	2.94696E-04	2.94696E+04	4.78944E+00	*	2.33166E-04	1.41%
		3	2.52400E-04	2.52400E+04	4.10204E+00		1.90870E-04	1.15%
	y	1	9.10157E-02	9.10157E+02	1.47920E-01		0.00000E-00	0.00%
		2	9.79378E-04	9.79378E+04	1.59170E+01	**	9.17847E-04	5.54%
		3	9.70280E-03	9.70280E+03	1.57691E+00		3.54977E-03	0.21%
	z	1	9.98459E-02	9.98459E+02	1.62271E-01		0.00000E-00	0.00%
		2	3.25524E-04	3.25524E+04	5.29046E+00	*	2.63993E-04	1.59%
		3	1.90977E-03	1.90977E+03	3.10378E-01		0.00000E-00	0.00%
upper_lower_link_inner	x	1	2.18980E-03	2.18980E+03	3.55889E-01		0.00000E-00	0.00%
		2	1.08171E-03	1.08171E+03	1.75801E-01		0.00000E-00	0.00%
		3	5.18465E-03	5.18465E+03	8.42618E-01		0.00000E-00	0.00%
	y	1	1.60428E-03	1.60428E+03	2.60730E-01		0.00000E-00	0.00%
		2	1.08171E-03	1.08171E+03	1.75801E-01		0.00000E-00	0.00%
		3	6.07752E-03	6.07752E+03	9.87727E-01		0.00000E-00	0.00%
	z	1	6.83414E-03	6.83414E+03	1.11070E+00		6.81113E-02	0.04%
		2	2.31516E-03	2.31516E+03	3.76263E-01		0.00000E-00	0.00%
		3	5.28889E-01	5.28889E+01	8.59559E-03		0.00000E-00	0.00%
upper_link_outer	x	1	3.08104E-03	3.08104E+03	5.00735E-01		0.00000E-00	0.00%
		2	1.84755E-03	1.84755E+03	3.00266E-01		0.00000E-00	0.00%
		3	6.74287E-01	6.74287E+01	1.09586E-02		0.00000E-00	0.00%
	y	1	1.46689E-04	1.46689E+04	2.38401E-00		8.51583E-03	0.51%
		2	1.49043E-03	1.49043E+03	2.42227E-01		0.00000E-00	0.00%
		3	1.18257E-04	1.18257E+04	1.92193E+00		5.67266E-03	0.34%
	z	1	6.91954E-02	6.91954E+02	1.12457E-01		0.00000E-00	0.00%
		2	1.49043E-03	1.49043E+03	2.42227E-01		0.00000E-00	0.00%
		3	5.12281E-04	5.12281E+04	8.32569E+00	**	4.50751E-04	2.72%
damper_lower	x	1	1.71228E-04	1.71228E+04	2.78282E+00		1.09697E-04	0.66%
		2	3.27248E-03	3.27248E+03	5.31849E-01		0.00000E-00	0.00%
		3	2.97166E-02	2.97166E+02	4.82959E-02		0.00000E-00	0.00%
	y	1	2.46107E-03	2.46107E+03	3.99977E-01		0.00000E-00	0.00%
		2	2.47545E-02	2.47545E+02	4.02314E-02		0.00000E-00	0.00%
		3	6.86688E-02	6.86688E+02	1.11602E-01		0.00000E-00	0.00%
	z	1	2.18111E-04	2.18111E+04	3.54477E+00		1.56580E-04	0.95%
		2	2.98069E-01	2.98069E+01	4.84427E-03		0.00000E-00	0.00%
		3	1.10840E-04	1.10840E+04	1.80139E+00		4.93096E-03	0.30%
Sum total	18	1.10755E-05	6.15303E+03			2.80162E-05	16.92%	
Sum total	63	1.65564E-06	1.65564E+06			1.65564E-06	100.00%	
					F(0.05) = 4.413872		F(0.01) = 8.285419	

Dispersion analysis table of ML (BRAKE) TRAILING ARM Fz								
	Degree	Degree of freedom f	Fluctuation S	Dispersion V	Variance ratio F0	Level of significance	Pure fluctuation S'	Contribution ratio ρ
trailing_body	x	1	4.65135E+02	4.65135E+02	4.30076E-03		0.00000E+00	0.00%
		2	8.95072E+03	8.95072E+03	8.27607E-02		0.00000E+00	0.00%
		3	1.35859E+04	1.35859E+04	1.25619E-01		0.00000E+00	0.00%
	y	1	3.87033E+06	3.87033E+06	3.57861E+01	**	3.76218E+06	36.25%
		2	1.69038E+05	1.69038E+05	1.56297E+00		6.08857E+04	0.59%
		3	5.56390E+04	5.56390E+04	5.14453E-01		0.00000E+00	0.00%
	z	1	3.76436E+05	3.76436E+05	3.48026E+00		2.68284E+05	2.59%
		2	9.37381E+04	9.37381E+04	8.66727E-01		0.00000E+00	0.00%
		3	3.70847E+04	3.70847E+04	3.42895E-01		0.00000E+00	0.00%
lower_link_outer	x	1	1.37448E+05	1.37448E+05	1.27088E+00		2.92965E+04	0.28%
		2	9.37381E+04	9.37381E+04	8.66727E-01		0.00000E+00	0.00%
		3	1.18503E+04	1.18503E+04	1.09571E-01		0.00000E+00	0.00%
	y	1	8.92382E+04	8.92382E+04	8.25120E-01		0.00000E+00	0.00%
		2	3.53973E+04	3.53973E+04	3.27293E-01		0.00000E+00	0.00%
		3	1.23664E+03	1.23664E+03	1.14343E-02		0.00000E+00	0.00%
	z	1	4.65127E+04	4.65127E+04	4.30069E-01		0.00000E+00	0.00%
		2	5.36687E+04	5.36687E+04	4.96235E-01		0.00000E+00	0.00%
		3	2.97028E+05	2.97028E+05	2.74640E+00		1.88876E+05	1.82%
upper_lower_link_inner	x	1	1.97539E+04	1.97539E+04	1.82650E-01		0.00000E+00	0.00%
		2	1.41481E+05	1.41481E+05	1.30817E+00		3.33295E+04	0.32%
		3	1.14347E+03	1.14347E+03	1.05729E-02		0.00000E+00	0.00%
	y	1	7.24772E-02	7.24772E-02	6.70143E-03		0.00000E+00	0.00%
		2	1.41481E+05	1.41481E+05	1.30817E+00		3.33295E+04	0.32%
		3	2.22473E+05	2.22473E+05	2.05705E+00		1.14322E+05	1.10%
	z	1	3.30202E+04	3.30202E+04	3.05314E-01		0.00000E+00	0.00%
		2	8.96146E+03	8.96146E+03	8.28600E-02		0.00000E+00	0.00%
		3	2.95917E+03	2.95917E+03	2.73613E-02		0.00000E+00	0.00%
upper_link_outer	x	1	1.23575E+05	1.23575E+05	1.14261E+00		1.54236E+04	0.15%
		2	3.72100E-01	3.72100E-01	3.44053E-06		0.00000E+00	0.00%
		3	1.38507E+05	1.38507E+05	1.28068E+00		3.03557E+04	0.29%
	y	1	3.30609E+04	3.30609E+04	3.05690E-01		0.00000E+00	0.00%
		2	2.55111E+05	2.55111E+05	2.35882E+00		1.46959E+05	1.42%
		3	2.82960E+04	2.82960E+04	2.61635E-01		0.00000E+00	0.00%
	z	1	4.94021E+04	4.94021E+04	4.56785E-01		0.00000E+00	0.00%
		2	2.55111E+05	2.55111E+05	2.35882E+00		1.46959E+05	1.42%
		3	1.29552E+05	1.29552E+05	1.19789E+00		2.14009E+04	0.21%
damper_lower	x	1	8.51904E+00	8.51904E+00	7.87693E-05		0.00000E+00	0.00%
		2	1.29319E+05	1.29319E+05	1.19527E+00		2.21167E+04	0.20%
		3	6.20318E+03	6.20318E+03	5.73567E-02		0.00000E+00	0.00%
	y	1	1.51059E+04	1.51059E+04	1.39673E-01		0.00000E+00	0.00%
		2	4.63557E+03	4.63557E+03	4.28617E-02		0.00000E+00	0.00%
		3	6.23672E+05	6.23672E+05	5.76664E+00	*	5.15520E+05	4.97%
	z	1	6.65162E+04	6.65162E+04	6.15027E-01		0.00000E+00	0.00%
		2	5.03546E+05	5.03546E+05	4.65692E+00	*	3.95395E+05	3.81%
		3	1.06270E+05	1.06270E+05	9.82079E-01		0.00000E+00	0.00%
Sum total	18	1.94673E+06	1.08152E+07			4.59433E+06	44.27%	
Sum total	63	1.03780E+07	1.03780E+07			1.03780E+07	99.00%	
					F(0.05) = 4.413872		F(0.01) = 8.285419	



Results Dynamic characteristic -2

Result of Dispersion analysis for the dynamic characteristic in the DWB model

Dispersion analysis table ofDWB (ACCELERATION)LOWER CONTROL ARM Fz

	Degree	Degree of freedom	F fluctuation S	Dispersion V	Variance ratio F0	Level of significance	Pure fluctuation S'	Contribution ratio c
upper_control_arm_front	x	1	9.22847E+04	9.22847E+04	7.99254E+00	*	8.07383E+04	5.699
		2	1.27115E+04	1.27115E+04	1.10091E+00		1.16514E+03	0.088
		3	1.19638E+04	1.19638E+04	1.03615E+00		4.17435E+02	0.039
	y	1	1.10265E+05	1.10265E+05	9.54973E+00	**	9.87183E+04	6.958
		2	1.88599E+04	1.88599E+04	1.63341E+00		7.31357E+03	0.524
		3	3.54101E+03	3.54101E+03	3.06678E+01		0.00000E+00	0.009
	z	1	4.83430E+03	4.83430E+03	4.18689E+00		3.67967E+04	2.599
		2	9.67306E+03	9.67306E+03	8.37759E+01		0.00000E+00	0.009
		3	9.68050E+03	9.68050E+03	8.38403E+01		0.00000E+00	0.009
upper_control_arm_rear	x	1	3.83097E+04	3.83097E+04	3.31791E+00		2.67634E+04	1.899
		2	1.38009E+03	1.38009E+03	1.19526E+01		0.00000E+00	0.009
		3	8.23295E+03	8.23295E+03	7.13035E+01		0.00000E+00	0.009
	y	1	1.58803E+05	1.58803E+05	1.37535E+01	**	1.47256E+05	10.379
		2	7.05995E+01	7.05995E+01	6.11444E+03		0.00000E+00	0.009
		3	1.44999E+04	1.44999E+04	1.25580E+00		2.95359E+03	0.219
	z	1	8.97354E+03	8.97354E+03	7.77177E+01		0.00000E+00	0.009
		2	2.09392E+03	2.09392E+03	1.81349E+01		0.00000E+00	0.009
		3	2.61748E+01	2.61748E+01	2.26693E+03		0.00000E+00	0.009
lower_control_arm_front	x	1	2.72105E+04	2.72105E+04	2.35663E+00		1.56642E+04	1.108
		2	1.63544E+04	1.63544E+04	1.41641E+00		4.80801E+03	0.349
		3	1.82788E+04	1.82788E+04	1.58308E+00		6.73242E+03	0.478
	y	1	2.06652E+03	2.06652E+03	1.78976E+01		0.00000E+00	0.009
		2	1.80537E+03	1.80537E+03	1.56359E+01		0.00000E+00	0.009
		3	2.84461E+04	2.84461E+04	2.48095E+01		1.70997E+04	1.208
	z	1	3.00810E+03	3.00810E+03	2.60524E+01		0.00000E+00	0.009
		2	4.74455E+04	4.74455E+04	4.10913E+00		3.58991E+04	2.539
		3	7.70925E+04	7.70925E+04	6.67678E+00	*	6.55461E+04	4.628
lower_control_arm_rea	x	1	1.32460E+04	1.32460E+04	1.14720E+00		1.69961E+03	0.128
		2	2.59048E+03	2.59048E+03	2.24354E+01		0.00000E+00	0.009
		3	3.56709E+02	3.56709E+02	3.08936E+02		0.00000E+00	0.009
	y	1	1.53597E+05	1.53597E+05	1.33026E+01	**	1.42050E+05	10.019
		2	5.27708E+04	5.27708E+04	4.57034E+00		4.12244E+04	2.908
		3	4.08761E+03	4.08761E+03	3.54017E+01		0.00000E+00	0.009
	z	1	3.24881E+04	3.24881E+04	2.81371E+00		2.09417E+04	1.488
		2	1.41126E+03	1.41126E+03	1.22225E+01		0.00000E+00	0.009
		3	7.38691E+04	7.38691E+04	6.39761E+01	*	6.23228E+04	4.399
lower_strutmount	x	1	2.02009E+04	2.02009E+04	1.74955E+00		8.65456E+03	0.619
		2	1.74665E+04	1.74665E+04	1.51273E+00		5.92018E+03	0.428
		3	1.92512E+04	1.92512E+04	1.66730E+00		7.70489E+03	0.549
	y	1	1.06632E+04	1.06632E+04	9.23515E+01		0.00000E+00	0.009
		2	1.20516E+04	1.20516E+04	1.04376E+00		5.05242E+02	0.049
		3	6.62257E+03	6.62257E+03	5.73564E+01		0.00000E+00	0.009
	z	1	1.02839E+02	1.02839E+02	8.90658E+03		0.00000E+00	0.009
		2	1.92865E+04	1.92865E+04	1.67036E+00		7.74017E+03	0.559
		3	2.10825E+02	2.10825E+02	1.82590E+02		0.00000E+00	0.009
Errr	18	2.07834E+05	1.15464E+04	5.17309E+05		40.379		
Sum total	63	1.41973E+06		1.41973E+06		100.008		

F(0,05) = 4.413872

F(0,01) = 8.285419

Dispersion analysis table ofDWB (BRAKE)LOWER CONTROL ARM Fz

	Degree	Degree of freedom	F fluctuation S	Dispersion V	Variance ratio F0	Level of significance	Pure fluctuation S'	Contribution ratio c
upper_control_arm_front	x	1	2.83814E+06	2.83814E+06	5.54951E+00	*	2.32672E+06	3.659
		2	1.19756E+06	1.19756E+06	2.34162E+00		6.86134E+05	1.088
		3	3.61075E+05	3.61075E+05	7.06021E+01		0.00000E+00	0.009
	y	1	8.37456E+06	8.37456E+06	1.63751E+01	**	7.86314E+06	12.328
		2	9.37635E+04	9.37635E+04	1.83339E+01		0.00000E+00	0.009
		3	1.35731E+06	1.35731E+06	2.65399E+00		8.45889E+05	1.338
	z	1	3.60932E+04	3.60932E+04	7.05743E+01	*	3.09790E+04	4.868
		2	4.09823E+04	4.09823E+04	8.01341E+02		0.00000E+00	0.009
		3	8.76265E+05	8.76265E+05	1.71339E+00		3.64884E+05	0.578
upper_control_arm_rear	x	1	1.12751E+06	1.12751E+06	2.20467E+00		6.16092E+05	0.978
		2	3.10250E+04	3.10250E+04	6.06643E+01	*	2.59108E+04	4.068
		3	2.97280E+04	2.97280E+04	5.81281E+02		0.00000E+00	0.009
	y	1	2.28348E+06	2.28348E+06	4.46497E+01	*	1.77206E+06	2.788
		2	8.45692E+03	8.45692E+03	1.65361E+02		0.00000E+00	0.009
		3	4.29555E+05	4.29555E+05	8.39923E+01		0.00000E+00	0.009
	z	1	1.03056E+06	1.03056E+06	2.01508E+00		5.19136E+05	0.819
		2	6.66071E+04	6.66071E+04	1.30239E+01		0.00000E+00	0.009
		3	2.58645E+06	2.58645E+06	5.05737E+01	*	2.07503E+06	3.258
lower_control_arm_front	x	1	2.84178E+06	2.84178E+06	5.55663E+00	*	2.33036E+06	3.658
		2	1.19969E+04	1.19969E+04	2.34579E+02		0.00000E+00	0.009
		3	5.95823E+04	5.95823E+04	1.16503E+01		0.00000E+00	0.009
	y	1	7.05860E+05	7.05860E+05	1.80191E+00		1.94438E+05	0.308
		2	1.65957E+04	1.65957E+04	3.24501E+00		1.14815E+04	1.808
		3	1.88958E+04	1.88958E+04	3.69476E+00		1.37816E+04	2.168
	z	1	8.91103E+04	8.91103E+04	1.74240E+01		0.00000E+00	0.009
		2	1.50795E+05	1.50795E+05	2.94854E+01		0.00000E+00	0.009
		3	1.03574E+04	1.03574E+04	2.02522E+00		5.24318E+03	0.828
lower_control_arm_rea	x	1	2.40380E+06	2.40380E+06	4.70023E+01	*	1.89238E+06	2.978
		2	5.98270E+05	5.98270E+05	1.16982E+01		8.68480E+04	0.148
		3	3.49542E+05	3.49542E+05	6.83470E+01		0.00000E+00	0.009
	y	1	1.28261E+06	1.28261E+06	2.50792E+00		7.71184E+05	1.218
		2	7.34794E+05	7.34794E+05	1.43677E+00		2.23374E+05	0.358
		3	3.90735E+04	3.90735E+04	7.64017E+01	*	3.39593E+04	5.328
	z	1	1.87959E+04	1.87959E+04	3.67522E+00		1.36817E+04	2.148
		2	5.25383E+05	5.25383E+05	1.02730E+00		1.39610E+04	0.028
		3	1.40380E+06	1.40380E+06	2.74489E+00		8.92374E+05	1.408
lower_strutmount	x	1	9.15039E+03	9.15039E+03	1.78920E+02		0.00000E+00	0.009
		2	4.52161E+05	4.52161E+05	8.84126E+01		0.00000E+00	0.009
		3	8.72760E+04	8.72760E+04	1.70654E+01		0.00000E+00	0.009
	y	1	1.35796E+06	1.35796E+06	2.65527E+00		8.46540E+05	1.338
		2	4.67308E+05	4.67308E+05	9.13743E+01		0.00000E+00	0.009
		3	1.33287E+05	1.33287E+05	2.60620E+01		0.00000E+00	0.009
	z	1	2.21157E+05	2.21157E+05	4.32436E+01		0.00000E+00	0.009
		2	7.25808E+05	7.25808E+05	1.41920E+01		2.14836E+05	0.348
		3	1.95866E+05	1.95866E+05	3.82984E+01		0.00000E+00	0.009
Errr	18	9.20559E+06	5.11422E+05			40.388		
Sum total	63	6.37985E+07		6.37985E+07		100.008		

F(0,05) = 4.413872

F(0,01) = 8.985419



Discussion: Correlation between Geometry and suspension characteristics

ML

Relation between geometry and objective function

		Camber	Toe	Anti-Dive	Anti-Squat
trailing_body	x				
	y				
	z				
upper_link_outer	x				
	y				
	z				
lower_link_outer	x				
	y				
	z				
upper_lower_link_inner	x				
	y				
	z				
damper_lower	x				
	y				
	z				

DWB

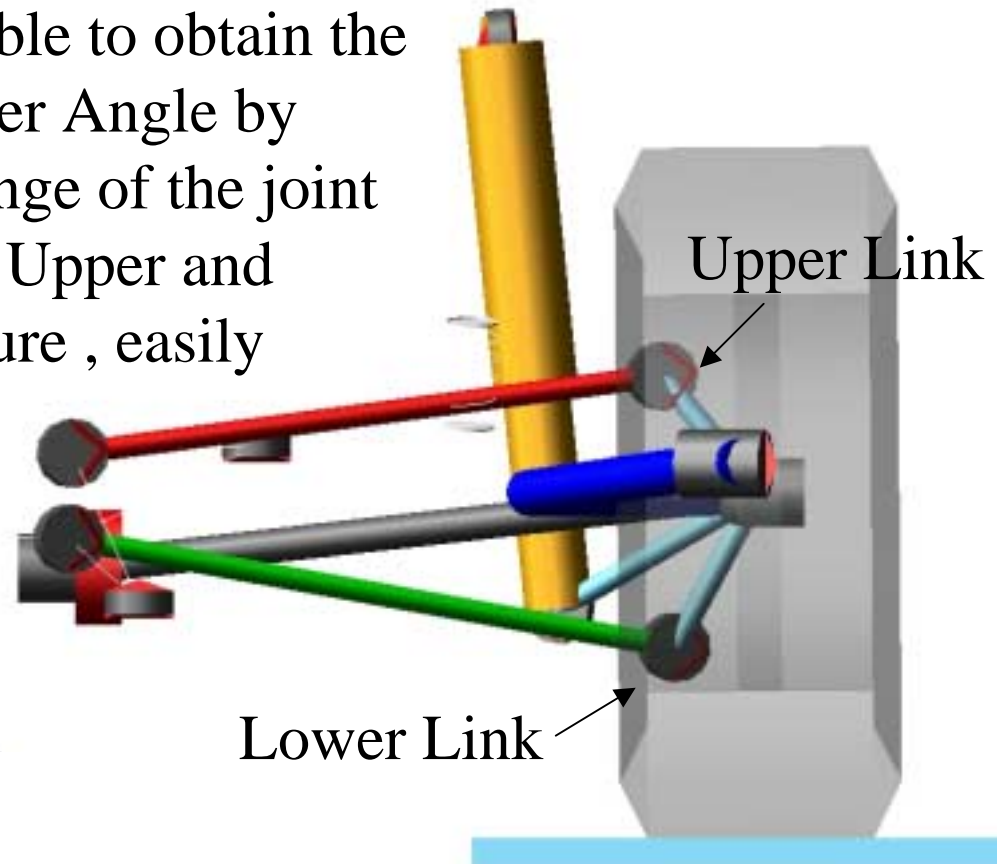
Relation between geometry and objective function

		Camber	Toe	Anti-Dive	Anti-Squat
upper_control_arm_front	x				
	y				
	z				
upper_control_arm_rear	x				
	y				
	z				
lower_control_arm_front	x				
	y				
	z				
lower_control_arm_rear	x				
	y				
	z				
lower_strut_mount	x				
	y				
	z				

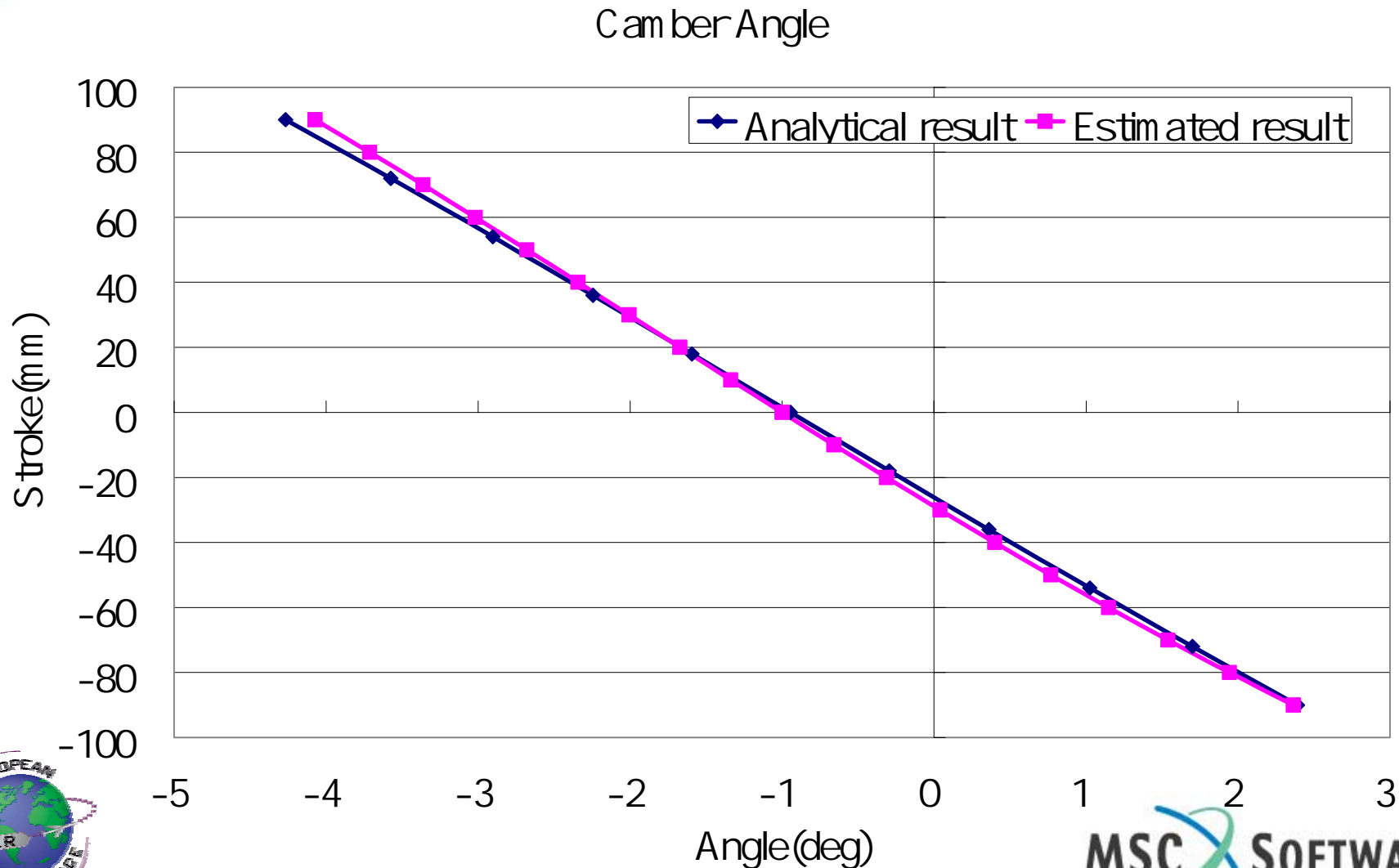


Discussion

As a conclusion, it is possible to obtain the estimated formula of Camber Angle by considering y direction change of the joint points of the ML system of Upper and Lower Link of the right figure, easily



Comparison of analytic value and estimated formula of Camber Angle in Multi Link



Summary

- A new basic concept of CAP (Computer Aided Principle) was proposed for improving the effect of first design stage of the suspension systems.
- Being different from the traditional design support method, this concept was proposed to evaluate the capacity or design space of a basic design concept, not to give the final design decisions.
- By the results of case studies for Multi Link and Double Wishbone suspension systems, it was found that separating the design space for each objective function (as the ML system) can give larger design capacity and better robustness for each objective functions.

