PERMAS

Contact Analysis - Fast and Accurate

Exact contact conditions

by Lagrange multipliers

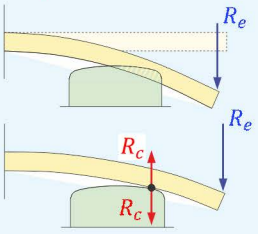
Hertz-Signorini-Moreau Conditions

(gap width δ and contact force R_c)

$\delta \geq 0$ bodies must not penetrate each other

$R_c \geq 0$ contact cannot transmit tensile forces

$\delta * R_c = 0$ contact forces only in case of a closed gap



$K r_0 = R_e$

$K r = R_e + R_c$

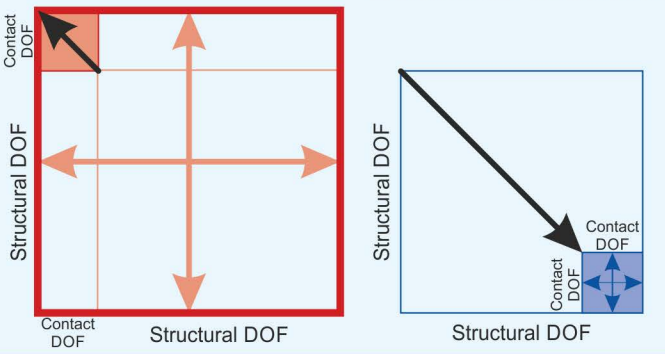
$r = r_0 + r_c$

Reducing problem size

by condensation

Additional Langrangian Multipliers

Condensation to Lagrangian Contact Conditions



Getting contact forces directly

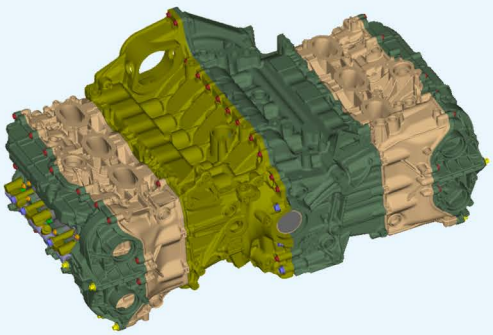
by flexibility method

Static Analysis	Contact Analysis
$K r = R$	$F_c R_c = r_c$
Unknowns are Displacements	Unknowns are Contact Forces

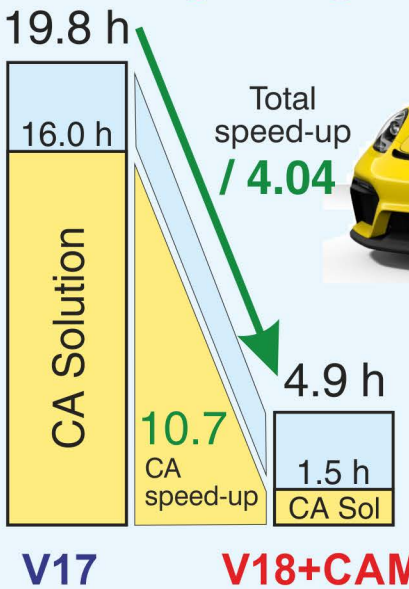
A Flexibility Method is the adequate approach for contact analysis

Condensed Lagrange Flexibility (CLF) Solver

Analysis of Large Engine Model



Model:
19 Million nodes,
13 Million elements,
56 Million DOF,
145,000 contacts,
gasket, bolt pretension,
two temperature states



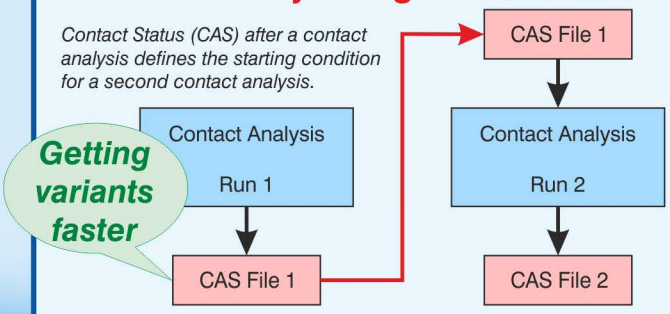
Contact Multi-Grid

2 Xeon 6146 + GPU
(24 cores + P100/16GB)

Analysis:
Static analysis,
37 time steps with
various loads,
with contact status files.

Acceleration by Using Contact Status Files

Contact Status (CAS) after a contact analysis defines the starting condition for a second contact analysis.



Engine with Assembly and 360° Crank Shaft Revolution

Nodes	2,605,313
Elements	1,603,484
Unknowns	7,363,408

CA DOF	44,387
- normal	29,815
- frictional	14,572

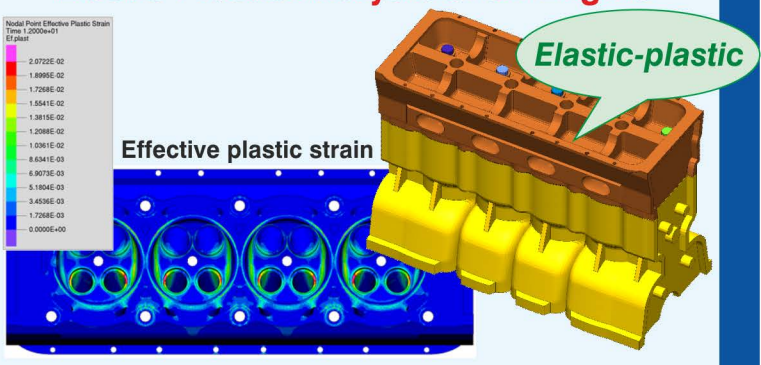
Linear static analysis for 70 load steps:

1. analysis (no CAS files): **7h23m**
2. analysis (with CAS files): **47m** → **Factor 9.8**

*112 cores (4*Intel-Platinum-8180) @ 2.5 GHz, 768 GiB*

High run time reduction when used in optimization runs

Elastic-Plastic Analysis of an Engine



Model:	
Nodes	13,384,000
Elements	10,160,500
Unknowns	39,850,000
Contact	95,000

Analysis:
12 steps with various loads (bolt pretension, temperature, pressure), gasket, elastic-plastic with contact

Run time: 5h 31m

*2*24 cores Intel(R) Xeon(R) Platinum 8260L*

Hertzian Contact

Accurate contact results

For two spheres with Radius R_1 and R_2, the maximum contact pressure is given as:

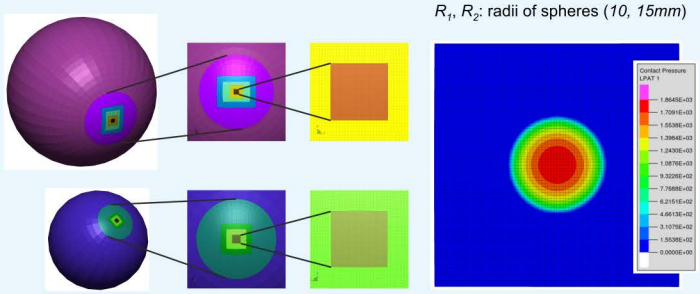
$$p_0 = \frac{3F}{2\pi a^2} = \frac{1}{\pi}\left(\frac{6FE^{*2}}{R^2}\right)^{1/3}$$

with

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}, \quad \frac{1}{E^*} = \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}$$

and

F: applied point load (*100 N*)
E_1, E_2: Young's moduli (*200 GPa*)
ν_1, ν_2: Poisson's ratios (*0.3*)
R_1, R_2: radii of spheres (*10, 15mm*)

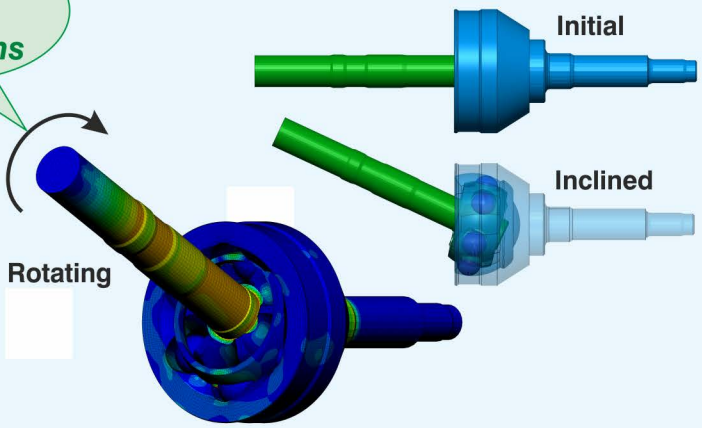


Hertz: p_0= 1865.40 Mpa
Permas: p_0= 1864.52 Mpa
Δ = **0.05%**

Model: 1.5 MDOF, 40k contacts
Run time: **85 sec**
Computer: 4*28 Intel(R) Xeon(R) Platinum 8180 @ 2.5 /754.57 GB

Stress Analysis of a CVJoint during Inclination and Rotation

With large rotations



Model:	
Nodes	627,000
Elements	523,000
Unknowns	1,747,000
Contact	15,000

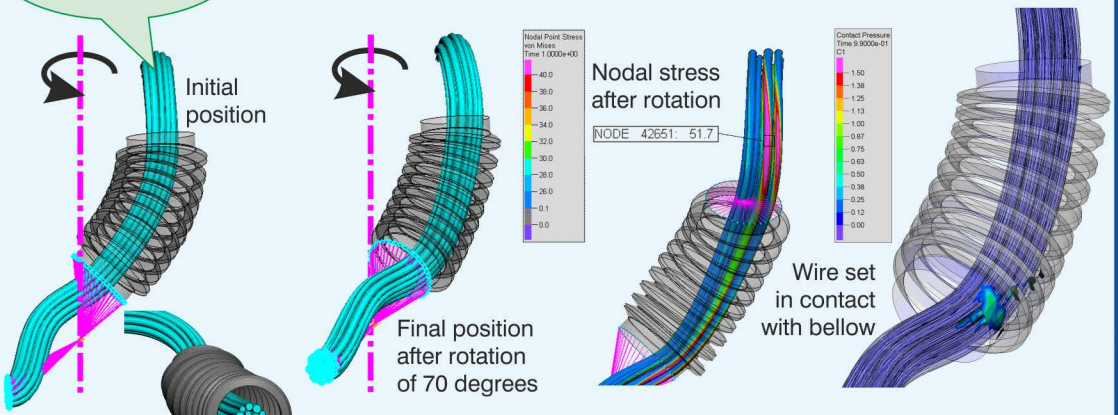
Analysis:
Nonlinear static analysis,
Inclination 50 steps,
Torque,
Rotation 360° in 72 steps

Run time: 11h 2m → **~5m per load step**

*1*18 cores Intel(R) Xeon(R) CPU E5-2697 v4 @ 2.30GH / 110 GiByte*

Contact in a Wire Harness

With self-contact



Model:	
Nodes	34,100
Elements	25,130
Unknowns	107,600
Contacts	10,200

Analysis:
Nonlinear static with contact,
Prescribed rotation,
100 time steps,
CAS file.

Run time: 29m 53s

18 core,Intel(R) Xeon(R) CPU E5-2697 v4 @ 2.30GH, 110 GiByte Memory

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