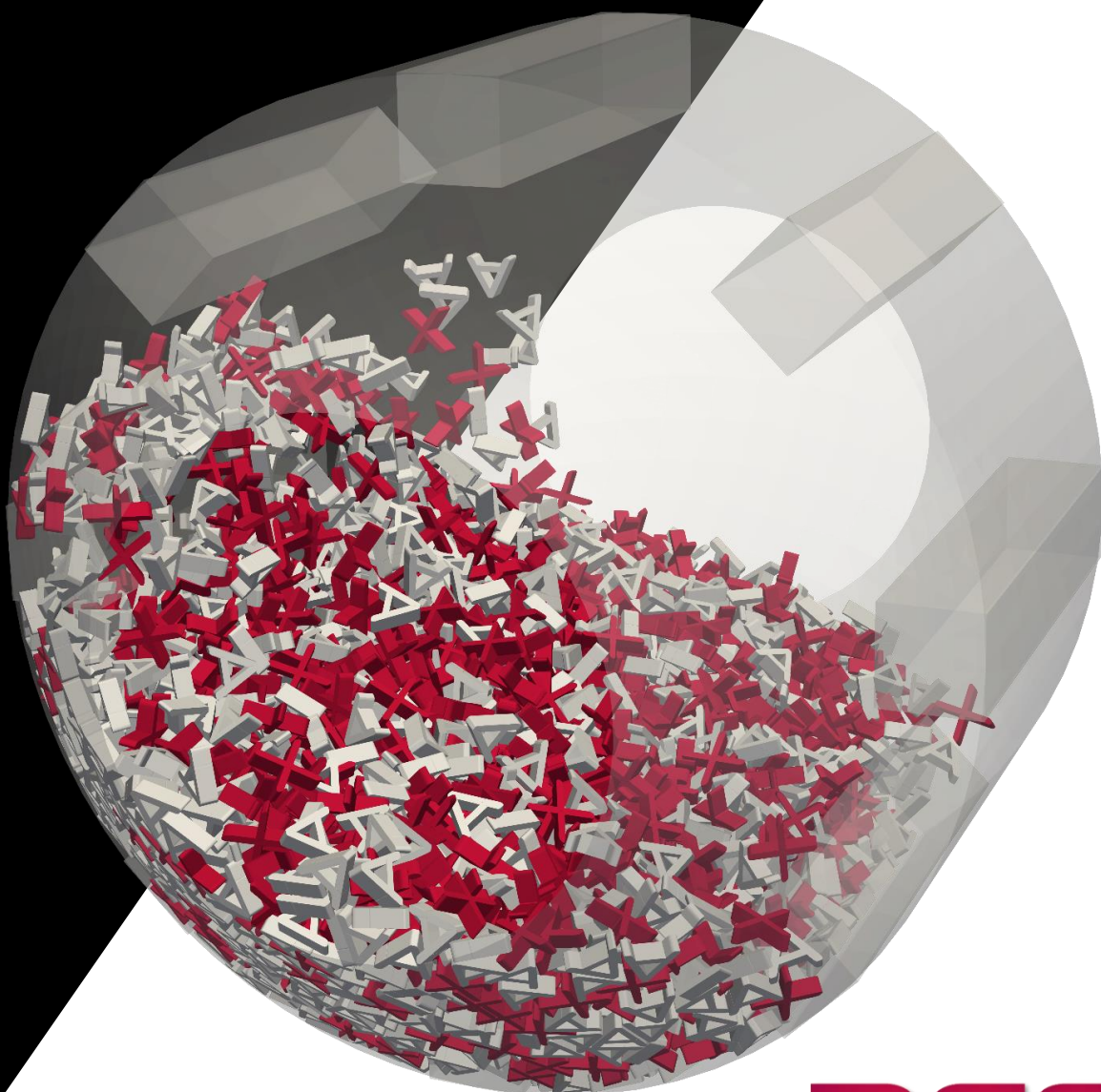




ASPHERIX

PRODUCT INFORMATION



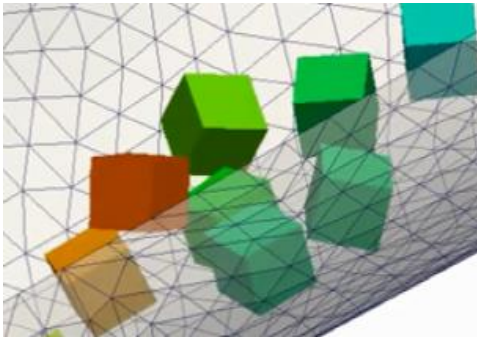
DCS
COMPUTING



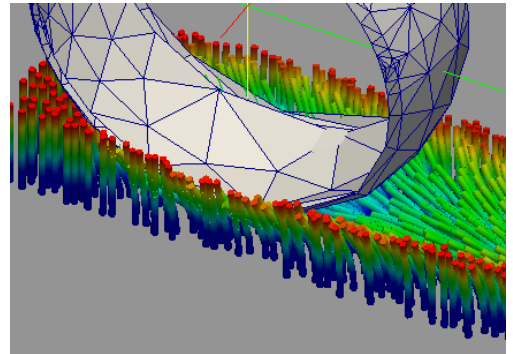
Aspherix® supports a large variety of particle shapes



Convex triangulated



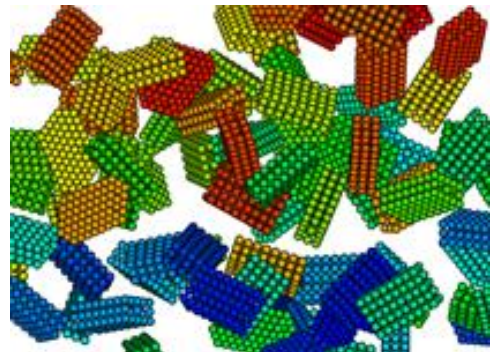
Fiber⁺ and bonded



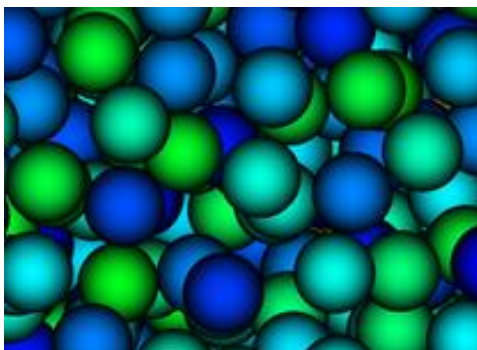
Concave triangulated



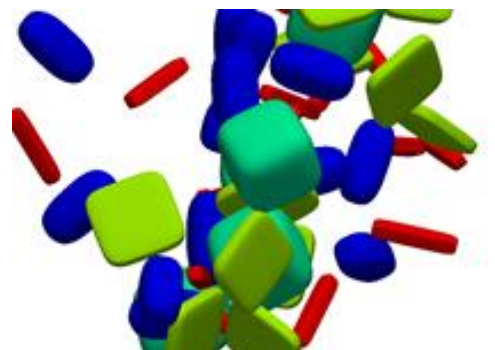
Multisphere



Sphere



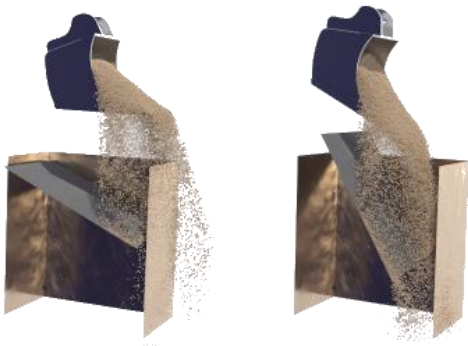
Box, cylinder, ellipsoid



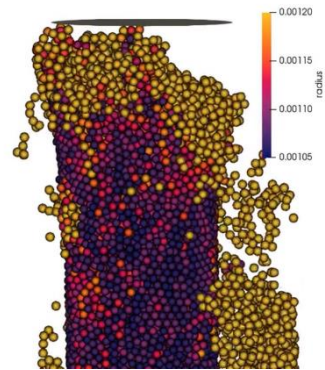


Aspherix® has numerous cutting-edge physics models and great options for integration. Here are some highlights:

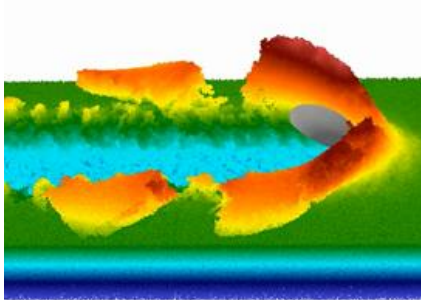
6 degree of freedom solver



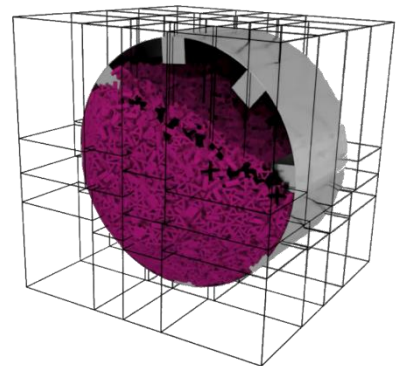
Powder compaction⁺



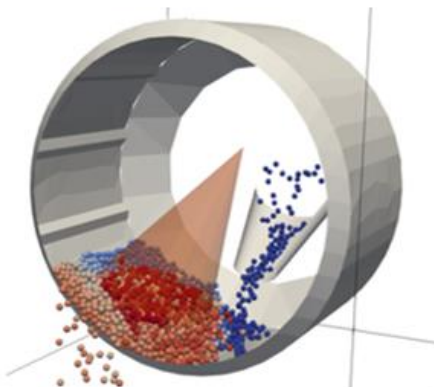
Cohesion models



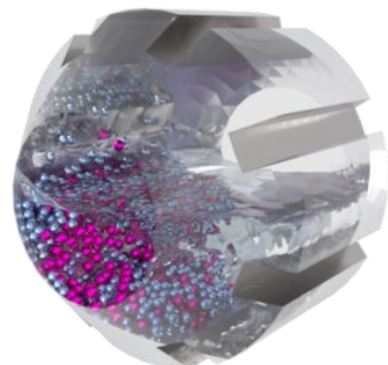
Loadbalancing



Spray coating



Coupling interface⁺



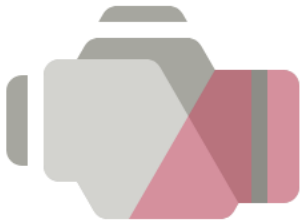
^S functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic



COMPONENTS AND OPTIONS

Aspherix® consists of the following components:

Strong
simulation
engine for DEM



Easy to use GUI
for DEM



GUI workflow for
coupled CFD-
DEM simulations



Aspherix® runs on:

Desktop machines



Clusters



Clouds



ASPHERIX® is available for Linux and Windows



SYSTEM REQUIREMENTS

Aspherix® Solver - MPI

Windows

- Delivered with installer

Linux

- MPI is required
- has to support MPI 3 standard (e.g. min OpenMPI 1.8, or MPICH 3.0)

Aspherix® GUI

- OpenGL library (version 3.2 or higher)

Aspherix® Solver - API

Linux

- cmake is required (min cmake 3.9)

Aspherix® Calibration – for Python Support

- Python is required (min Python 3.8)

System requirements - Operating systems

- Windows 10, 11
- Ubuntu 18.04, 20.04, 22.04
- Centos Stream 9
- Red Hat 9
- Suse Enterprise 12,15; Open Suse tumbleweed
- GUI requires glibc 2.17 or higher

Operating Systems – Special cases

- Centos Stream 8 (Aspherix® Solver ONLY, GUI support not guaranteed)
- Windows Server 2019, 2022 (Aspherix® GUI needs OpenGL 3.2)



SYSTEM REQUIREMENTS

Prerequisites for coupling interfaces only

CFDEMcoupling:

- cmake 3.10
- OpenFOAM 10*
- Linux only (systems as specified on previous page), Windows subsystem for Linux allows for usage on Windows
- System prerequisites of specified OpenFOAM version apply

Palabos:

- Palabos 2.1
- Linux only (systems as specified on previous page)
- System prerequisites of specified Palabos version apply

Additional remark

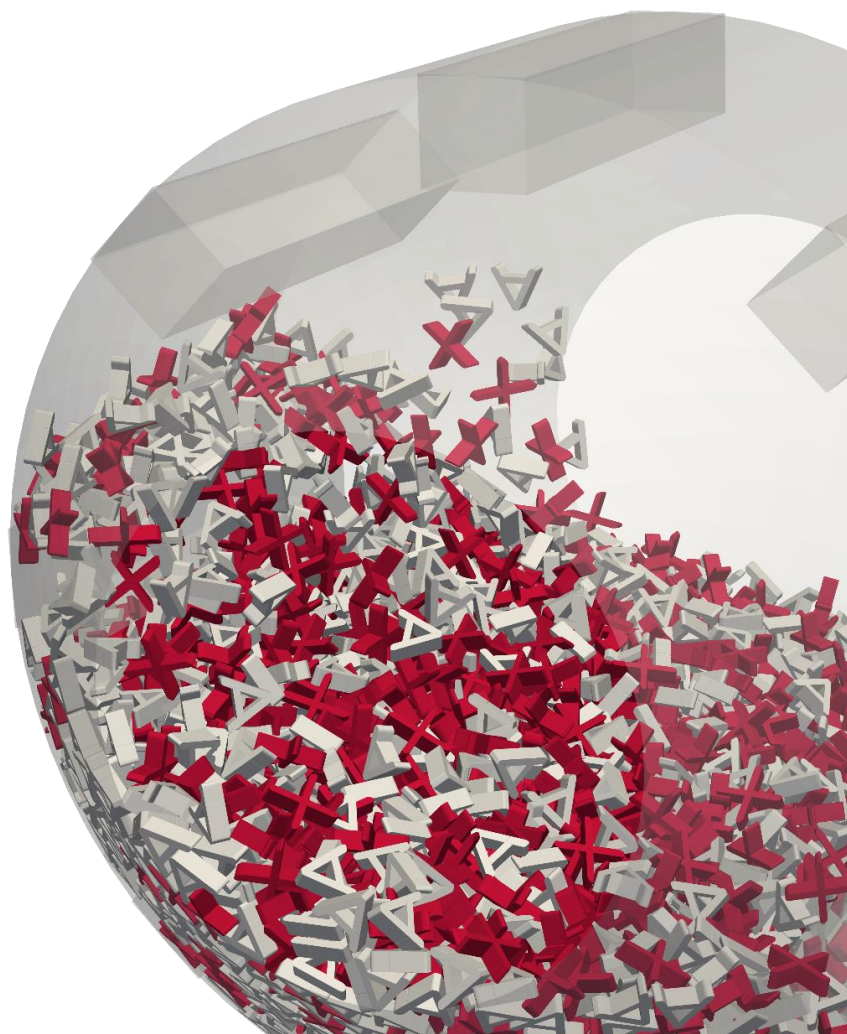
Please note that all features described in the feature list are available in Aspherix® Solver. Most features are also available in Aspherix® GUI but for technical reasons there are some restrictions.

License usage & Installations

- Arbitrarily many installations on arbitrarily many systems allowed within organisation of Customer, license only restricts number of active processes
- Each license can be used on all supported OS

**This offering is not approved or endorsed by OpenCFD Limited, producer and distributor of the OpenFOAM software via www.openfoam.com, and owner of the OPENFOAM® and OpenCFD® trade marks.*

FEATURE LIST OVERVIEW





FEATURE LIST - OVERVIEW

Physics models

6 degrees of freedom solver	body forces
bond models	bubble models ^s
cohesion	damping
drag forces	electricity*
equipment wear and attrition	fast DEM ^{s*}
fiber cutting*	fiber models*
heat transfer	liquid bridges and liquid transport
magnetic dipole*	mass transfer and chemical reactions
material property models	mesh deformation
normal models	pair styles
particle breakage and attrition	particle deformation
powder compaction*	rolling friction
sedimentation	spray coating
tangential models	



FEATURE LIST - OVERVIEW

Particle shapes

bonded	box
capsule	concave triangulated
convex triangulated	cylinder
ellipsoid	fiber
general	multisphere
rod	sphere
superquadric	tablet

Meshes and geometry

mesh controllers	mesh import
mesh manipulation	mesh modules
region	walls

Functionalities

boundary conditions	integration
neighbor list	particle deletion
particle insertion	particle manipulation

^S functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic



FEATURE LIST - OVERVIEW

Postprocessing

collision statistics	energy balance
fiber data ^{s*}	mesh residence time
meshes	other
particle data	residence time distribution
spatial and temporal averaging	stresses and force network

IO

meshes	reader
write expert	write standard

Scalability and speed

coarsegraining	loadbalancing
parallelization	

Coupling interface

CFD 1-way coupling	CFD 4-way coupling (Linux only)*
FEM coupling (Linux only) ^{s*}	MBD couplings ^{s*}
CFD physics models (Linux only)*	

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



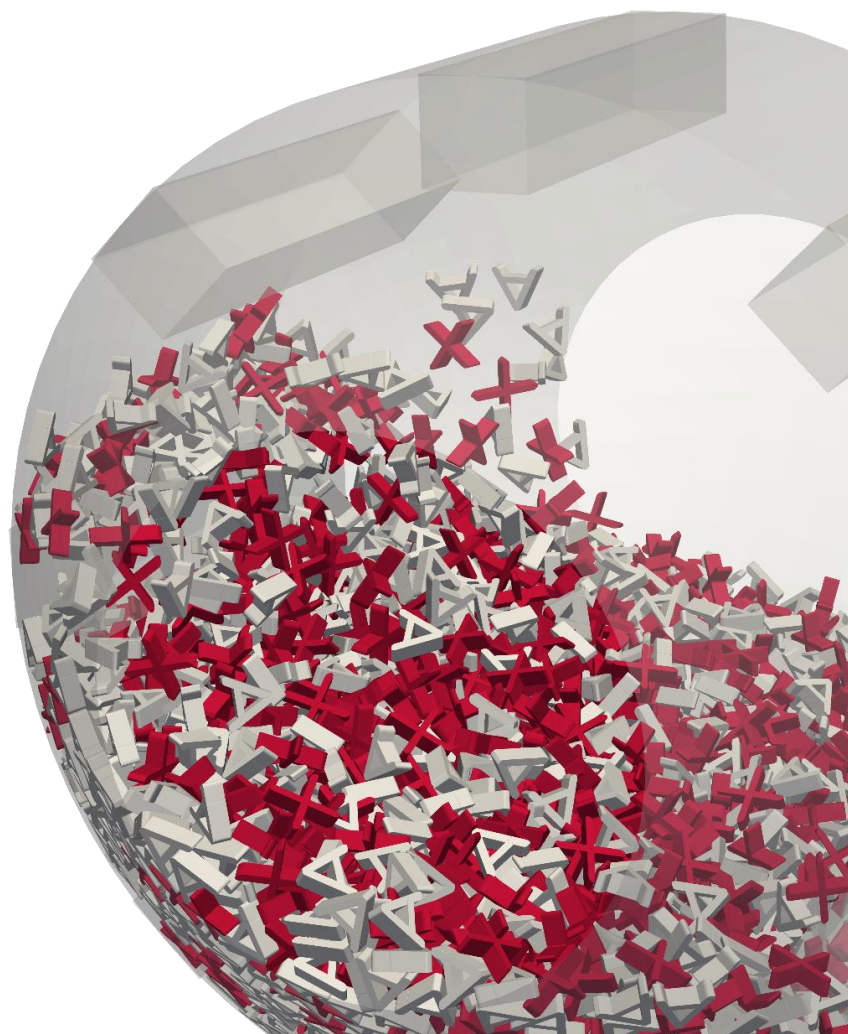
FEATURE LIST - OVERVIEW

Apis*

API: C++ ^{s*}	API: Python ^{s*}
custom contact models ^{s*}	custom equations ^{s*}
custom mesh access ^{s*}	custom particle properties ^{s*}

^s functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic

FEATURE LIST DETAILS





FEATURE LIST - PHYSICS MODELS

6 degrees of freedom solver

mesh module stress 6dof

Body forces

freeze^s

enable gravity

enable buoyancy

simplified fluid model^s

Bond models

bond

bond relativ

Bubble models^s

bubble^s

bubble coalescences^s

bubble breakup^s

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - PHYSICS MODELS

Cohesion

adaptive	asphalt*
bond	bond relativ
bubble coalescences ^s	easo capillary viscous
fiber*	fiber buckle base*
fiber plastic base*	fiber wet base*
general liquid bridge (normal: adams_perchard, pitois, washino, washino_powerlaw; tangential: goldman, xu, washino, xu_powerlaw)	lubrication
sjkr	sjkr2
powder*	sjkr selective
sjkr temp	sjkr time dependent
washino capillary viscous	

Damping

cundall damping	
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Drag forces

DiFelice	Schiller Naumann
Zastawny	const Cd

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - PHYSICS MODELS

Electricity*

enable_electrical_conductivity*	
---------------------------------	--

Equipment wear and attrition

archard	finnie
mesh stress wear	

Fast dems*

addforce steadystate*	addforce steadystate experimental*
fast heat conduction*	

Fiber cutting*

mesh module cutting*	
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Fiber models*

fiber*	fiber buckle base*
fiber plastic base*	fiber wet base*

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - PHYSICS MODELS

Heat transfer

enable heat transfer	enable particle melting
surface heating	roasting*
mesh heat transfer	

Liquid bridges and liquid transport

addliquid wall ^s	liquid transport
liquid transport evaporation	liquid transport porous
liquid transport sponge	easo capillary viscous
general liquid bridge (normal: adams_perchard, pitois, washino, washino_powerlaw; tangential: goldman, xu, washino, xu_powerlaw)	washino capillary viscous
mesh module liquid transfer	

Magnetic dipole*

addforce magnetic*	
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^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - PHYSICS MODELS

Mass transfer and chemical reactions

change size	change size multisphere
change size superquadric	change size superquadric anisotropic
melting*	

Material property models

custom material properties ^s	material interaction properties
material properties	materials
custom materials ^{s*}	interdependent material properties ^s

Mesh deformation

mesh module stress deform	
---------------------------	--

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - PHYSICS MODELS

Normal models

adhesive elasto plastic	hertz
hertz fragmentation bruchmueller	hertz fragmentation bruchmueller unresolved
hertz stiffness	hertz time dependent
hertz velocity dependent ^s	hooke
hooke hysteresis	hooke scale invariant
hooke stiffness	jkr
jkr/general	thornton-ning

Pair styles

hybrid ^s	hybrid overlay ^s
stokes dynamics ^s	particle contact model

Particle breakage and attrition

particle breakage force	hertz fragmentation bruchmueller
hertz fragmentation bruchmueller unresolved	history attrition
history attrition angle	

Particle deformation

multicontact halfspace	surface model multicontact
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^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - PHYSICS MODELS

Powder compaction*

powder cluster model*

Rolling friction

simplistic

cdt

epsd

epsd2

epsd3

Sedimentation

sedimentation

mesh module contact deletion^s

Spray coating

detect surface

liquid transport

liquid transport evaporation

DEM spray particles*

different spray nozzle shapes*

spray particle to surface film conversion*

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - PHYSICS MODELS

Tangential models

adhesive_elasto_plastic	burgers asphalt*
history	history attrition
history attrition angle	history powder*
history tempdep	history time dependent
no history	

^S functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - MESHES AND GEOMETRY

Mesh controllers

mesh control ^s	mesh mover linear
mesh mover rotation	mesh mover file
mesh module stress 6dof	mesh module stress servo

Mesh import

mesh	mesh modules
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Mesh manipulation

defeaturing ^s	mesh module stress deform
mesh module motion	

Mesh modules

mesh module stress 6dof	mesh 6dof external (Simulink/Simscape, MSC Adams) ^{s*}
mesh module binning ^s	mesh module stress contact
mesh module contact deletion ^s	mesh module cutting [*]
mesh module stress deform	mesh heat transfer
mesh module liquid transfer	mesh module stress servo

^s functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic



FEATURE LIST - MESHES AND GEOMETRY

Region

block	cone
cylinder	intersect
plane	prism
sphere	subtract
union	wedge
mesh vtk	

Walls

wall reflect ^s	sieving [*]
wall reflect mesh ^s	primitive wall
wall contact model	

^s functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic



FEATURE LIST - FUNCTIONALITIES

Boundary conditions

boundary conditions	simulation domain
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Integration

nve sphere limit ^s	reset timestep ^s
integrator	nonspherical integrator predictor/corrector
nonspherical integrator richardson	nonspherical integrator symplectic
nonspherical integrator woodem	velocity limit
simulate	simulation timestep

Neighbor list

multilevel neighborlist	neighbor list
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Particle deletion

delete particles	mesh module contact deletion ^s
remove ^s	

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - FUNCTIONALITIES

Particle insertion

create particles	insert rate in region
insert stream moving	insert stream predefined ^s
insert stream regionfill	prepare packings ^s
dense packing (experimental)	dilute packing
insertion	particle_distribution

Particle manipulation

displace particles ^s	add force
lineforce ^s	move
planeforce ^s	set force
viscous	replicate ^s
set ^s	variable ^s
velocity ^s	group definition
group deletion ^s	addforce steadystate ^{s*}
add weighted force	change size
change size multisphere	change size superquadric
change size superquadric anisotropic	change type
grow particles	set velocity
addforce steadystate experimental ^{s*}	set multispheres ^s
torque ^s	update_particle



FEATURE LIST - POSTPROCESSING

Collision statistics

calculate collision statistics ^s	coordination number
---	---------------------

Energy balance

calculate external_work	calculate energy dissipated
calculate energy wall dissipated	calculate energy elastic cohesion
calculate energy elastic normal	calculate energy wall elastic cohesion
calculate energy wall elastic normal	

Fiber data^{s*}

bond fiber topology ^{s*}	bond fibers ^{s*}
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Mesh residence time

mesh module stress contact	
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Meshes

calculate external_work	mesh area
reduce ^s	mesh velocity

^s functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic



FEATURE LIST - POSTPROCESSING

Other

check timestep	
----------------	--

Particle data

reduce ^s	store state ^s
variable ^s	calculate
calculate average	calculate center of mass
calculate marked particles	calculate massflow
calculate maximum	calculate minimum
calculate mixing index	calculate particle contact network
calculate residence distance	calculate residence time
calculate spatial average	calculate spatio temporal average
calculate sum	calculate temporal average
calculate voronoi decomposition	calculate wall contact network
cross-section	group definition
group deletion ^s	

Residence time distribution

calculate residence distance	calculate residence time
mark inserted particles	mark particles

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - POSTPROCESSING

Spatial and temporal averaging

calculate	calculate average
calculate center of mass	calculate maximum
calculate minimum	calculate mixing index
calculate spatial average	calculate spatio temporal average
calculate sum	calculate temporal average
calculate voronoi decomposition	detect steady state ^s
temporal steady state detection ^s	

Stresses and force network

calculate particle contact network	calculate wall contact network
pressure simplistic	mesh module binning ^s
mesh module stress_average	

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



Meshes

output settings	modify output settings ^s
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Reader

read

Write expert

dump image ^s	dump modify ^s
modify dump vtk ^s	write data
dump euler vtk ^s	dump field vtk cell ^s
dump mesh volume vtk ^s	dump region neighbor field list ^s

Write standard

origin ^s	restart ^s
status ^s	status log ^s
status modify ^s	status style ^s
undump ^s	write restart
write on signal ^s	dump decomposition
output settings	write meshed particles
modify output settings ^s	write output timestep
write to file ^s	write to terminal timestep

^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - SCALABILITY AND SPEED

Coarsegraining

coarsegraining	
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Loadbalancing

rcb loadbalancing	
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Parallelization

partitions ^s	processors
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^s functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - COUPLING INTERFACE

Cfd 1-way coupling

enable one-way coupling	dragforce field compressibles ^{s*}
dragtorque field compressibles ^{s*}	temperature fluid field [*]
resample vtk	enable one-way coupling moving reference frame (MRF)
enable one-way coupling transient	enable one-way coupling with rotating zone [*]
enable transient one-way coupling [*]	

Cfd 4-way coupling (linux only)^{*}

include foam variables ^{s*}	enable cfd coupling [*]
enable DEM drag [*]	attrition transport [*]
force ms [*]	

Fem coupling (linux only)^{s*}

FEM coupling to Elmer ^{s*}	Howto for FEM coupling (Linux only) ^{s*}
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Mbd coupling^{s*}

mesh 6dof external (Simulink/Simscape, MSC Adams) ^{s*}	
---	--

^s functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic



FEATURE LIST - COUPLING INTERFACE

Cfd physics models (linux only)*

film formation*	
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^S functionality available in Aspherix® Solver only
* Functionality not available in Aspherix® Basic



FEATURE LIST - API^{s*}

Api: c++^{s*}

aspherix ^{s*}	
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Api: python^{s*}

aspherix ^{s*}	
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Custom contact models^{s*}

aspherix contact model external ^{s*}	aspherix particle interaction ^{s*}
aspherix contact model external connector ^{s*}	normal model external ^{s*}

Custom equations^{s*}

aspherix fix ^{s*}	aspherix fix external ^{s*}
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Custom mesh access^{s*}

aspherix mesh ^{s*}	aspherix mesh elements ^{s*}
aspherix mesh element list ^{s*}	

^s functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic



Custom particle properties^{s*}

aspherix global properties ^{s*}	aspherix particle ^{s*}
aspherix particle list ^{s*}	aspherix quaternion ^{s*}
aspherix variable ^{s*}	aspherix vector ^{s*}

^s functionality available in Aspherix® Solver only
^{*} Functionality not available in Aspherix® Basic