

Combined Finite-Discrete Element Method for Simulation of Hydraulic Fracturing

Chengzong Yan¹ · Hong Zheng² · Guanhua Sun² · Niuran Ge²

Received: 16 August 2014 / Accepted: 10 August 2015
© Springer-Verlag Wien 2015

Abstract Hydraulic fracturing is widely used in the exploitation of unconventional gas (such as shale gas). Thus, the study of hydraulic fracturing is of particular importance for petroleum industry. The combined finite-discrete element method (FDEM) proposed by Munjiza is an innovative numerical technique to capture progressive damage and failure processes in rock. However, it cannot model the fracturing process of rock driven by hydraulic pressure. In this study, we present a coupled hydro-mechanical model based on FDEM for the simulation of hydraulic fracturing in complex fracture geometries, where an algorithm for updating hydraulic fracture network is proposed. The algorithm can carry out connectivity searches for arbitrarily complex fracture networks. Then, we develop a new combined finite-discrete element method numerical code (Y-flow) for the simulation of hydraulic fracturing. Finally, several verification examples are given, and the simulation results agree well with the analytical or experimental results, indicating that the newly developed numerical code can capture hydraulic fracturing process correctly and effectively.

Keywords FDEM · Y-flow · Hydro-mechanical coupling · Fracture network connectivity · Seepage · Hydraulic fracturing

✉ Hong Zheng
hzheng@whrsm.ac.cn

¹ Key Laboratory of Urban Security and Disaster Engineering, Ministry of Education, Beijing University of Technology, Beijing 100124, China

² State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan 430071, China

Abbreviations

M	Lumped mass diagonal matrices
C	Damping diagonal matrices
F	Nodal force vector
X	Vector of nodal coordinates
Δp	Pressure differential between two adjacent nodes
p_1	Pressure of Node 1
p_2	Pressure of Node 2
ρ_w	Mass density of fluid
g	Gravitational acceleration
y_1	Vertical coordinate of Node 1
y_2	Vertical coordinate of Node 2
q	Flow rate
μ	Dynamic coefficient of viscosity
a	Average aperture of crack element
α_0	Initial value of aperture
α_{min}	Minimum value of aperture
α_{max}	Maximum value of aperture
u_n	Normal displacement of crack element
L	Length of crack element
f_s	Function of saturation
f_n	Total fluid pressure on edge of triangular element
s	Saturation of current time step
s_0	Saturation of previous time step
Q	Total flow rate
Q_{21}	Flow rate from Node 1 to 2
Q_{23}	Flow rate from Node 3 to 2
Q_{24}	Flow rate from Node 4 to 2
p	Pressure of the node at the current time step
p_0	Pressure of the node at the previous time step
K_w	Bulk modulus of the fluid
k_j	Permeability factor of the j th crack element
Δt	Time step
Δt_c	Critical time step
V	Volume of the node at the current time step

Combined Finite Discrete Element Method

Lei Shi



Combined Finite Discrete Element Method:

Eventually, you will unquestionably discover a further experience and endowment by spending more cash. nevertheless when? do you agree to that you require to get those all needs behind having significantly cash? Why dont you attempt to get something basic in the beginning? Thats something that will guide you to understand even more approximately the globe, experience, some places, afterward history, amusement, and a lot more?

It is your categorically own time to put on an act reviewing habit. among guides you could enjoy now is **Combined Finite Discrete Element Method** below.

https://gandalf.roeckerfam.com/public/Resources/Documents/best_of_classic_themes_1_docxg_clavinova_cvp.pdf

Table of Contents Combined Finite Discrete Element Method

1. Understanding the eBook Combined Finite Discrete Element Method
 - The Rise of Digital Reading Combined Finite Discrete Element Method
 - Advantages of eBooks Over Traditional Books
2. Identifying Combined Finite Discrete Element Method
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Combined Finite Discrete Element Method
 - User-Friendly Interface
4. Exploring eBook Recommendations from Combined Finite Discrete Element Method
 - Personalized Recommendations
 - Combined Finite Discrete Element Method User Reviews and Ratings
 - Combined Finite Discrete Element Method and Bestseller Lists
5. Accessing Combined Finite Discrete Element Method Free and Paid eBooks

- Combined Finite Discrete Element Method Public Domain eBooks
 - Combined Finite Discrete Element Method eBook Subscription Services
 - Combined Finite Discrete Element Method Budget-Friendly Options
6. Navigating Combined Finite Discrete Element Method eBook Formats
 - ePub, PDF, MOBI, and More
 - Combined Finite Discrete Element Method Compatibility with Devices
 - Combined Finite Discrete Element Method Enhanced eBook Features
 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Combined Finite Discrete Element Method
 - Highlighting and Note-Taking Combined Finite Discrete Element Method
 - Interactive Elements Combined Finite Discrete Element Method
 8. Staying Engaged with Combined Finite Discrete Element Method
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Combined Finite Discrete Element Method
 9. Balancing eBooks and Physical Books Combined Finite Discrete Element Method
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Combined Finite Discrete Element Method
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Combined Finite Discrete Element Method
 - Setting Reading Goals Combined Finite Discrete Element Method
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Combined Finite Discrete Element Method
 - Fact-Checking eBook Content of Combined Finite Discrete Element Method
 - Distinguishing Credible Sources
 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development

- Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

Combined Finite Discrete Element Method Introduction

In this digital age, the convenience of accessing information at our fingertips has become a necessity. Whether its research papers, eBooks, or user manuals, PDF files have become the preferred format for sharing and reading documents. However, the cost associated with purchasing PDF files can sometimes be a barrier for many individuals and organizations. Thankfully, there are numerous websites and platforms that allow users to download free PDF files legally. In this article, we will explore some of the best platforms to download free PDFs. One of the most popular platforms to download free PDF files is Project Gutenberg. This online library offers over 60,000 free eBooks that are in the public domain. From classic literature to historical documents, Project Gutenberg provides a wide range of PDF files that can be downloaded and enjoyed on various devices. The website is user-friendly and allows users to search for specific titles or browse through different categories. Another reliable platform for downloading Combined Finite Discrete Element Method free PDF files is Open Library. With its vast collection of over 1 million eBooks, Open Library has something for every reader. The website offers a seamless experience by providing options to borrow or download PDF files. Users simply need to create a free account to access this treasure trove of knowledge. Open Library also allows users to contribute by uploading and sharing their own PDF files, making it a collaborative platform for book enthusiasts. For those interested in academic resources, there are websites dedicated to providing free PDFs of research papers and scientific articles. One such website is Academia.edu, which allows researchers and scholars to share their work with a global audience. Users can download PDF files of research papers, theses, and dissertations covering a wide range of subjects. Academia.edu also provides a platform for discussions and networking within the academic community. When it comes to downloading Combined Finite Discrete Element Method free PDF files of magazines, brochures, and catalogs, Issuu is a popular choice. This digital publishing platform hosts a vast collection of publications from around the world. Users can search for specific titles or explore various categories and genres. Issuu offers a seamless reading experience with its user-friendly interface and allows users to download PDF files for offline reading. Apart from dedicated platforms, search engines also play a crucial role in finding free PDF files. Google, for instance, has an advanced search feature that allows users to filter results by file type. By specifying the file type as "PDF," users can find websites that offer free PDF downloads on a specific topic. While downloading Combined Finite Discrete Element Method free PDF files is convenient, its important to note that copyright laws must be respected. Always ensure that

the PDF files you download are legally available for free. Many authors and publishers voluntarily provide free PDF versions of their work, but it's essential to be cautious and verify the authenticity of the source before downloading Combined Finite Discrete Element Method. In conclusion, the internet offers numerous platforms and websites that allow users to download free PDF files legally. Whether it's classic literature, research papers, or magazines, there is something for everyone. The platforms mentioned in this article, such as Project Gutenberg, Open Library, Academia.edu, and Issuu, provide access to a vast collection of PDF files. However, users should always be cautious and verify the legality of the source before downloading Combined Finite Discrete Element Method any PDF files. With these platforms, the world of PDF downloads is just a click away.

FAQs About Combined Finite Discrete Element Method Books

How do I know which eBook platform is the best for me? Finding the best eBook platform depends on your reading preferences and device compatibility. Research different platforms, read user reviews, and explore their features before making a choice. Are free eBooks of good quality? Yes, many reputable platforms offer high-quality free eBooks, including classics and public domain works. However, make sure to verify the source to ensure the eBook's credibility. Can I read eBooks without an eReader? Absolutely! Most eBook platforms offer web-based readers or mobile apps that allow you to read eBooks on your computer, tablet, or smartphone. How do I avoid digital eye strain while reading eBooks? To prevent digital eye strain, take regular breaks, adjust the font size and background color, and ensure proper lighting while reading eBooks. What's the advantage of interactive eBooks? Interactive eBooks incorporate multimedia elements, quizzes, and activities, enhancing the reader engagement and providing a more immersive learning experience. Combined Finite Discrete Element Method is one of the best books in our library for free trial. We provide a copy of Combined Finite Discrete Element Method in digital format, so the resources that you find are reliable. There are also many eBooks related to Combined Finite Discrete Element Method. Where to download Combined Finite Discrete Element Method online for free? Are you looking for Combined Finite Discrete Element Method PDF? This is definitely going to save you time and cash in something you should think about. If you're trying to find them, search around for online. Without a doubt, there are numerous of these available and many of them have the freedom. However, without a doubt, you receive whatever you purchase. An alternate way to get ideas is always to check another Combined Finite Discrete Element Method. This method for seeing exactly what may be included and adopting these ideas to your book. This site will almost certainly help you save time and effort, money and stress. If you are looking for free books, then you really should consider finding to assist you try this. Several of Combined Finite Discrete Element Method are for sale to free while some are payable. If you aren't sure if the books you would like to download work

with for usage along with your computer, it is possible to download free trials. The free guides make it easy for someone to free access online library for download books to your device. You can get free download on free trial for lots of books categories. Our library is the biggest of these that have literally hundreds of thousands of different products categories represented. You will also see that there are specific sites catered to different product types or categories, brands or niches related with Combined Finite Discrete Element Method. So depending on what exactly you are searching, you will be able to choose e books to suit your own need. Need to access completely for Campbell Biology Seventh Edition book? Access Ebook without any digging. And by having access to our ebook online or by storing it on your computer, you have convenient answers with Combined Finite Discrete Element Method To get started finding Combined Finite Discrete Element Method, you are right to find our website which has a comprehensive collection of books online. Our library is the biggest of these that have literally hundreds of thousands of different products represented. You will also see that there are specific sites catered to different categories or niches related with Combined Finite Discrete Element Method So depending on what exactly you are searching, you will be able to choose ebook to suit your own need. Thank you for reading Combined Finite Discrete Element Method. Maybe you have knowledge that, people have search numerous times for their favorite readings like this Combined Finite Discrete Element Method, but end up in harmful downloads. Rather than reading a good book with a cup of coffee in the afternoon, instead they juggled with some harmful bugs inside their laptop. Combined Finite Discrete Element Method is available in our book collection an online access to it is set as public so you can download it instantly. Our digital library spans in multiple locations, allowing you to get the most less latency time to download any of our books like this one. Merely said, Combined Finite Discrete Element Method is universally compatible with any devices to read.

Find Combined Finite Discrete Element Method :

best of classic themes 1 docxg clavinova cvp

best of e.m. bounds

~~bermudian images the paintings of bruce stuart~~

best australian stories 2005

best friends for frances childrens choice club

berlitz european phrase

beryl e. bean

best choices in british columbia

~~best of food and wine 1989~~

~~best bug parade~~

best of friends etc cookbook easy and elegant for people on the go
bertolt brechts dreigroschenbuch 2 baende

best of george strait

berenstain bears and the new girl in town

berrien county in vintage postcards postcard history series

Combined Finite Discrete Element Method :

bing maps directions trip planning traffic cameras more - Jul 19 2023

web map multiple locations get transit walking driving directions view live traffic conditions plan trips view satellite aerial and street side imagery do more with bing maps

google maps - Aug 20 2023

web find local businesses view maps and get driving directions in google maps

google maps - Apr 16 2023

web mit google maps lokale anbieter suchen karten anzeigen und routenpläne abrufen

google - May 17 2023

web search the world s information including webpages images videos and more google has many special features to help you find exactly what you re looking for

bing maps directions trip planning traffic cameras more - Jan 13 2023

web directions bing maps 100 all you need to do is save your home and work addresses for better traffic updates earn points not now road united states va mecklenburg co feedback 2 miles

google maps on the app store - Nov 11 2022

web navigate your world faster and easier with google maps over 220 countries and territories mapped including hundreds of millions of businesses and destinations get real time gps navigation traffic and transit info and find what you need by getting the latest information on businesses including

about google maps - Mar 15 2023

web get google maps available on your computer discover the world with google maps experience street view 3d mapping turn by turn directions indoor maps and more across your devices

maps apple - Dec 12 2022

web curated guides are lists of places created by trusted partners to help you find great places to eat shop meet friends or just explore maps offers more than 1000 curated guides in cities around the world in ios 15 tap explore guides in maps to see

guides recommended by maps editors

google maps - Jun 18 2023

web find local businesses view maps and get driving directions in google maps

google maps apps on google play - Feb 14 2023

web sep 18 2023 navigate your world faster and easier with google maps over 220 countries and territories mapped and hundreds of millions of businesses and places on the map get real time gps navigation

ks1 sats tests pre 2014 curriculum primary tools - Jul 13 2023

web accompanying mark schemes for each sats paper save you time allowing you to focus on planning sats revision and interventions where needed navigate our library of sats

key stage 1 tests 2019 mathematics test materials gov uk - Jul 01 2022

web the 2009 key stage 3 mathematics tests and mark schemes were developed by the test development team at pearson research and assessment sourced from sats

2022 national curriculum tests key stage 1 gov uk - Sep 03 2022

web jun 3 2019 key stage 1 mathematics tests were administered in schools in may 2019 test administration instructions and mark schemes are also provided

key stage mark schemes test a test b and levels mental - Feb 08 2023

web jun 1 2023 key stage 1 mathematics tests were administered in schools in may 2023 test administration instructions and mark schemes are also provided

ma - Oct 04 2022

web mar 18 2016 details if you re involved in administering the key stage 1 tests in 2023 you should prepare by reading this test administration guidance tag it includes

mark scheme sats 2009 ks1 maths pdf uniport edu - Nov 24 2021

web 2009 ks3 mathematics test mark scheme paper 1 introduction 2 introduction this booklet contains the mark scheme for paper 1 at all tiers the paper 2 mark scheme is printed

2023 national curriculum tests key stage 1 gov uk - May 31 2022

web this mark scheme is for teachers marking the key stage 3 english test for 2009 it contains the complete set of mark schemes for the reading paper writing paper and

national curriculum past papers 2003 2019 testbase - May 11 2023

web ks1 mathematics 2009 level 3 mathematics booklet author sats papers co uk subject ks1 mathematics tests 2009 created date 8 7 2008 7 25 01 pm

[key stage mark scheme 3 for paper 1 all tiers tiers 3 5](#) - Apr 29 2022

web 2 mark scheme sats 2009 ks1 maths 2021 11 29 from 2000 2018 with no registration no adverts and no junk emails simply click the links below to jump to the papers along

[key stage 1 tests test administration guidance tag gov uk](#) - Aug 02 2022

web 2023 key stage 1 mathematics test mark schemes 5 general marking guidance 5 1 applying the mark schemes to ensure consistency of marking the most frequent

national curriculum assessments practice materials gov uk - Nov 05 2022

web 2022 key stage 1 mathematics test mark schemes contents 1 introduction 3 2 structure of the test 3 3 content domain coverage 4 4 explanation of the mark schemes 5 5

ks1 sats papers for year 2 1999 2023 september 2023 - Jun 12 2023

web resources and support for improving mathematics education in schools and colleges skip to main content home teacher resources classroom materials ks1 mathematics

mark scheme sats 2009 ks1 maths pdf uniport edu - Jan 27 2022

web mar 18 2023 mark scheme sats 2009 ks1 maths 2 7 downloaded from uniport edu ng on march 18 2023 by guest classroom and shows that the influence of class size is

key stage 1 tests 2023 mathematics test materials gov uk - Dec 06 2022

web mathematics tests teacher s guide 2007 ma key stage1 levels2 3 2007 level 2 name score level and grade key stage 1 mathematics booklet 2007 level 2 level 3

key stage mark scheme for paper 1 levels tiers 3 5 4 - Mar 29 2022

web aug 10 2023 you could purchase guide mark scheme sats 2009 ks1 maths or acquire it as soon as feasible you could quickly download this mark scheme sats 2009 ks1

[mark scheme sats 2009 ks1 maths copy uniport edu](#) - Dec 26 2021

web apr 16 2023 install the mark scheme sats 2009 ks1 maths it is totally simple then before currently we extend the connect to buy and create bargains to download and

sats papers tests ks1 ks2 phonics check free gap - Jan 07 2023

web sep 12 2016 primary curriculum key stage 1 phonics collection national curriculum assessments practice materials practice materials for the phonics screening check key

ks1 mathematics 2009 level 3 mathematics booklet sats papers - Mar 09 2023

web sats papers tests ks1 ks2 phonics check free gap analysis

key stage mark scheme 3 for paper 1 all tiers tiers 3 5 4 - Sep 22 2021

mark scheme sats 2009 ks1 maths download only - Feb 25 2022

web mark scheme sats 2009 ks1 maths 2 6 downloaded from uniport edu ng on august 31 2023 by guest diagnostic information or you can pick the test s you want to give you

mark scheme sats 2009 ks1 maths pdf uniport edu - Oct 24 2021

all the 2009 sats papers mark schemes and level - Aug 14 2023

web pre 2014 curriculum ks1 sats tests the tests on this page are all for the national curriculum before 2014 and rarely used in schools now to see the tests for the current

emaths key stage 1 ks1 sat past papers - Apr 10 2023

web 2009 ks2 mathematics tests mark schemes 1 marking the mathematics tests as in 2008 external markers employed by the external marking agencies under contract to

churchill plays 1 owners traps vinegar tom light shining in - Jun 01 2022

web churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine owners traps vinegar tom light shining i contemporary dramatists bloomsbury publishing 2013 churchill caryl

churchill plays 1 owners traps vinegar tom light shining in - Mar 10 2023

web guardian owners i was in an old woman s flat when a young man offering her money to move came round that was one of the starting points of the play caryl churchill the plays in this volume represent the best of churchill s writing up to and including her emergence onto the international theatre scene with cloud nine

churchill plays 1 overdrive - Oct 05 2022

web dec 10 2013 churchill plays 1 ebook mid owners traps vinegar tom light shining in buckinghamshire cloud nine contemporary dramatists by caryl churchill

churchill plays 1 owners traps vinegar tom light shining in - Jan 08 2023

web churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine contemporary dramatists ebook churchill caryl caryl churchill amazon co uk kindle store

churchill plays 1 owners traps vinegar tom light shining in - Nov 06 2022

web churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine

churchill plays 1 owners traps vinegar tom light shining in - Apr 11 2023

web guardian owners i was in an old woman s flat when a young man offering her money to move came round that was one of the starting points of the play caryl churchill the plays in this volume represent the best of churchill s writing up to and including her emergence onto the international theatre scene with cloud nine

churchill plays 1 owners traps vinegar tom light shining in - Apr 30 2022

web abebooks com churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine contemporary dramatists 9780413566706 by churchill caryl and a great selection of similar new used and collectible books available now at

[churchill plays 1 owners traps vinegar tom light shining in](#) - Sep 04 2022

web may 9 1985 churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine churchill caryl 9780413566706 books amazon ca

churchill plays 1 owners traps vinegar tom light shining in - May 12 2023

web guardian owners i was in an old woman s flat when a young man offering her money to move came round that was one of the starting points of the play caryl churchill the plays in this volume represent the best of churchill s writing up to and including her emergence onto the international theatre scene with cloud nine

churchill plays 1 owners traps vinegar tom light shining in - Jun 13 2023

web dec 10 2013 churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine contemporary dramatists author caryl churchill edition reprint publisher a c

[plays 1 owners traps vinegar tom light shining in](#) - Aug 15 2023

web this is a wonderful collection of the early works from the greatest playwright of her generation owners displays churchill s acerbic cynical bleak leftist dark humor and traps hints at the stylistic and formalist radicalism she would come to explore in almost every play vinegar tom is her feminist english better the crucible

churchill plays one owners traps vinegar tom light - Aug 03 2022

web churchill plays one owners traps vinegar tom light shining in buckinghamshire cloud nine churchill caryl amazon com tr kitap

churchill plays 1 owners traps vinegar tom light shining in - Feb 09 2023

web dec 10 2013 amazon com churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine contemporary dramatists ebook churchill caryl caryl churchill kindle store

churchill plays 1 owners traps vinegar tom light shining in - Jan 28 2022

web churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine owners traps vinegar tom light shining i contemporary dramatists churchill caryl download on z library z library

pdf churchill plays 1 by caryl churchill ebook perlego - Feb 26 2022

web about this book in traps a set of characters meet themselves and their pasts to create plenty of sinewy lines and joyous juxtapositions plays and players vinegar tom is set in the world of seventeenth century witchcraft but it speaks through its striking images and its plethora of ironic contradictions of and to this century

[churchill plays 1 owners traps vinegar tom light shining in](#) - Jul 14 2023

web may 14 2009 churchill plays 1 owners traps vinegar tom light shining in buckinghamshire cloud nine contemporary dramatists paperback may 14 2009 by caryl churchill author 4 4 4 4 out of 5 stars 45 ratings

caryl churchill plays vol 1 owners traps vinegar tom - Mar 30 2022

web caryl churchill plays vol 1 owners traps vinegar tom light shining in buckinghamshire cloud nine v 1 by caryl churchill at abebooks co uk isbn 10 0413566706 isbn 13 9780413566706 methuen drama 1985 softcover

[caryl churchill plays vol 1 owners traps vinegar tom](#) - Dec 07 2022

web may 9 1985 buy caryl churchill plays vol 1 owners traps vinegar tom light shining in buckinghamshire cloud nine v 1 by caryl churchill caryl churchill isbn 9780413566706 from amazon s book store everyday low

[download solutions churchill plays 1 owners traps vinegar tom light s](#) - Jul 02 2022

web 1 churchill plays 1 owners traps vinegar tom light s churchill plays 1 oct 28 2022 in traps a set of characters meet themselves and their pasts to create plenty of sinewy lines and joyous juxtapositions plays and players vinegar tom is set in the world of

pdf churchill plays owners traps vinegar tom light - Dec 27 2021

web no category uploaded by chernyshova1976 pdf churchill plays owners traps vinegar tom light shining in buckinghamshire cloud nine v 1