Minutes

30. August 2005/du
GCT/T – L 540
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EFCE Working Party "Mechanics of Particulate Solids": Business Meeting 2005, 12-July-2005

Abstract:

The meeting EFCE Working Party « Mechanics of Particulate Solids » was held in Glasgow, Scotland on the occasion of the 7th World Congress Chemical Engineering.

B. Tijskens, S. Luding and R.J.M. Janssen have become delegates to the working party in 2005.

Hermann J. Feise has been re-elected as chairman of the WPMPS for his second 3 year term (07/2005-06/2008).

The working party has defined new activities for the upcoming years:

1. Repeatability and reliability of wall friction measurement
2. Guide to specification in the contractor-owner-relationship
3. Validation problems for DEM-software
4. Network funding proposal
5. Start a wider discussion with industry

out of a larger set of suggestions.

The next business meeting will take place in Sorrento, Italy in conjunction with the 5th Conference for Conveying and Handling of Particulate Solids (27-31 August 2006).

Participants

Name	Affiliation	Country
Bates, Lyn	Ajax Equipment	United Kingdom
Canu, Paolo	Uni Padova	Italy
Carson, John	Jenike & Johanson	USA
Dau, Günter	University of Kaiserslautern	Germany
Enstad, Gisle	Tel-Tek	Norway
Feise, Hermann J.	BASF	Germany
Höhne, Detlef	TU Bergakademie Freiberg	Germany
Luding, Stefan	TU Delft	The Netherlands
McGee, Eddie	Ajax Equipment	United Kingdom
McGlinchey, Don	Glasgow Caledonian University	United Kingdom
Novosad, Jan	Czech Society of Chem. Eng.	Czech Republic
Nysäter, Trude	Telemark University College	Norway
Ooi, Jin	University of Edinburgh	United Kingdom
Poletto, Massimo	University of Salerno	Italy
Tijsken, Engelbert	K.U. Leuven	Belgium
Tüzün, Ugur	University of Surrey	United Kingdom
Wright, Harold	Dr. H. Wright & Associates	United Kingdom

Distribution by Email:
Meeting participants
WPMPS delegates
WPMPS permanently invited guests
I. Honndorf, Dechema
Dr. W. Meier, Dechema
Prof. R. Pohorecki, Warzawa

1. Opening

The 2005 business meeting of the EFCE Working Party Mechanics of Particulate Solids (WPMPS) was held at the Scottish Exhibition and Conference Centre in Glasgow on the occasion of the 7th World Congress Chemical Engineering (WCCE7). Lyn Bates as the local host of the WPMPS meeting welcomed the participants to Glasgow.

The Minutes of the Nürnberg meeting were accepted without alterations.

Hermann J. Feise explained the rules for official EFCE events:

Category I for events that are genuine EFCE creations (event number plus logo, cost 10€/participant, data base, promotion)

Category II for all other events that are organized by EFCE member societies (relevance to EFCE objectives, anticipated scientific quality, international dimension, EFCE number, no cost)

2. Member Issues

Dr. W. Goosens, Belgium, has officially retired from the Working Party.

Prof. Stefan Luding (TU Delft) and Dr. Richard J.M. Janssen (DSM, Geleen) from The Netherlands and Dr. Engelbert Tijskens (KU Leuven) have been named delegates to the WPMPS. S. Luding and E. Tijskens gave an introduction to their activities, see Encl. 3. Further information can be found on the internet at

S. Luding: http://www.ica1.uni-stuttgart.de/~lui/
E. Tijskens: http://cwisdb.cc.kuleuven.ac.be/persdb-bin/persdb?lang=E&oproep=persoon&fnaam=17240

R.J.M. Janssen will asked to present his work at the next annual meeting.

[Action: Janssen]

3. EFCE WP Chairman Meeting

H. Feise gave a report on the EFCE WP Chairman Meeting held in Frankfurt earlier this year. Major items were the WP annual reports (Encl. 4), the formation of a new working party on Environmental Protection and Sustainable Development, the formulation of a recommendation for a care curriculum of Chemical Engineering by the EFCE WP on Education and the preparation of the 6th European Congress Chemical Engineering (ECCE-6) in Copenhagen in 2007, see Encl. 5 or http://www.ecce6.kt.dtu.dk/.

The General Assembly of the EFCE has accepted the above mentioned draft on recommendation for a Chemical Engineering Core Curriculum during its session on July 14th, 2005. The recommendation will be publically available through the EFCE web site at http://www.efce.info, published by ChERD and distributed on request by the Frankfurt Office of the EFCE. [addition after the meeting]

ECCE-6 has adopted the theme on “Particulate Systems” which was brought into WCCE7 by the WPMPS. H. Feise was asked to serve on the international scientific committee for ECCE-6.

4. Election

The attending delegates of the WPMPS re-elected Dr. Hermann J. Feise from Germany as the chairman of the Working Party by unanimous vote. H. Feise’s second term will run from 07/2005 to 06/2008.

H. Feise gave a report on the WPMPS activities during his 3 years of chairmanship from 2002 to 2005, see slide 7 in Encl. 2.

5. About the Future of the WPMPS

The WPMPS has considered the initial goals and activities defined in the inaugural meeting in 1969 and redefined in 1988. Background information and proposals can be found in Encl. 6 to 8 and slides 8-11 of Encl. 2.

In the discussion the following items were identified:

Problem:
- To be valuable the working party needs to have a task
- The working party needs to do all work voluntarily

Goal:
- Keep the WP a means of contacting and knowing each other
- For this meeting: define topics for possible common tasks

Suggestions:
- Wall friction project
- Scatter in testing data
- Start wider discussion with industry
- Guide to specification (contractor – user relationship)
- Characterization project (round robin testing)
- European standardization
- Fields of future research (pre-proposal work)
- Network funding proposal
- Minimum qualification of shear tests for strength
- Modelling: Validation of DEM-codes

For immediate action five activities have been selected:

5.1 Wall Friction

Lyn Bates will lead this activity where a complete test of wall friction tester, wall material samples and bulk solid shall be circulate between participants. Several delegates have already indicated their willingness to cooperate in this project: Bates, Dau, Feise, Enstad, Poletto, Ooi. This project needs to be managed rather closely. Since round robin testing with identical samples is time consuming. A quarterly information / report schedule is intended, see Encl. 9.

[Action: Bates]

5.2 Discussion with Industry

The WPMPS will attempt to start a new round of discussions with industry to evaluate current needs for research in the subject areas of the WPMPS. This shall aid researchers active in these fields in the preparation of research proposals. A possible starting point would be the survey done by SPIN – The Solids Processing Industrial Network – a few years back.

[Action: Tüzün, Feise]

5.3 Guide to the Specification of Bulk Solids for Storage and Handling Contracts

This activity shall be pursued together with the British Materials Handling Board (BMHB) and possibly the Federation of Manufactures (FEM). Possible participants from the WPMPS include Bates, Feise and Wilms.

[Action: Bates]

5.4 Modelling

The various DEM-codes around for simulation of bulk solids behaviour need to be validated for wider acceptance. This requires carefully selected problems with a good experimental database for test runs. Such a set of problems shall be identified for the subject area of bulk solids handling

possibly with the help of a workshop held during CHoPS-05 in Sorrento. *The problem to be considered is: The quantitative validation and verification of DEM type models, focusing for example on: i) distribution of contact stresses in granular media contained in plane-strain and axially symmetric containers under different packing conditions, ii) wall-particle-interactions in quasi-static and slow-shearing granular media as in silos and hoppers (exploration of particle system and wall material properties), iii) or the quantitative reproduction of standard tests (like Jenike, biaxial, ring) concerning flow parameters as friction angle, yield-surface, ff-factor, etc. [addition after the meeting]*
[Action: Luding, Tüzün]

5.5 Network Funding Proposals

To allow better collaboration and student mobility between parties involved with WPMPS activities, especially the modelling activities listed under headline 5.4, national and European funding sources shall be identified and proposals be written. *The intention is to develop a network of numerical simulations in different sites with a view to compare results from individual simulations and make recommendations to the experimental programmes to be undertaken in characterization of wall friction and tri-axial shear testing, etc. Jin Ooi and U. Tüzün will make a case to the EPSRC regarding a UK network that will fund visits of academics and S. Luding will explore link-possibilities between Dutch and other European agencies.[addition after the meeting]*
[Action: Ooi, Tüzün, Luding]

6. Activities in the Upcoming Years

2006: The WPMPS will be having its business meeting at CHoPS-05. It will also run a session on "DEM in bulk solids handling" and possibly on shear testing. *Since the presentation by S. Luding and E. Tijskens arouse so much interest, it is suggested to have a technical session at Sorrento where all delegates present their institution/company and their work. [addition after the meeting]* **[Action: Feise]**

2007: The WPMPS will have its annual meeting in conjunction with the PARTEC congress in Nürnberg. We will attempt to organizing a dedicated stream under the "Advancing the Fundaments" theme. **[Action: Feise]**

2008: CHISA will be held in Prague.

7. Any other business

7.1 WCPT5

U. Tüzün is responsible for Track 3 of the 5th World Congress Particle Technology. He has approached several members of the WPMPS to chair sessions, help solicit papers and centerstage presenters. He could also envisage a fringe meeting of the WPMPS at WCPT5 (e.g. focused workshop on nano or education). See also Encl. 10.

7.2 ECED

J. Novosad presented the European Chemical Engineering Database, which collects information about people active in Chemical Engineering. It can be found at http://www.eced.cz, see Encl. 11 for details.

7.3 WCPT6

J. Novosad reported that the 6th World Congress Particle Technology will be held in Europe. Currently two countries are considered: Germany and France.

7.4 Addresses

An address list of all working party delegates, the permanently invited guests and all active participants is given in Encl. 12.

7.5 SSTT
The German version of the SSTT has been published this spring by Dechema, Frankfurt (ISBN-No.: 3-89746-058-0). It has been distributed to all German speaking delegates of the WPMPS and to those German speaking universities active in bulk solids handling.

7.6 Terminology
The WPMPS has collected a set of terms for bulk solids handling. It is available at the Czech web site www.wpmps.cz. A link from the official EFCE web site will be placed.
[Action: Feise]

7.7 Next Meeting
The next business meeting will be held on Sunday, 27th August 2006 in Sorrento, Italy before the start of the CHoPS-05 conference.

8 Dinner
The WPMPS dinner was sponsored by the BMHB whose support is gratefully acknowledged, see Encl. 13 for background information on the BMHB.

Enclosures

1 Agenda
2 Chairman's slides
3 Presentation of E. Tijskens, KU Leuven
4 2004 Annual Report of the WPMPS
5 ECCE-6 (Slides by R. Gani)
6 Background information (W. Goossens)
7 Thoughts about the Future (H. Feise)
8 Exercise of a future strategy (W. Goossens)
9 Wall friction testing (L. Bates)
10 WCPT5 Flyer
11 ECED Flyer
12 Address List
13 BMHB Background

EFCE – Working Party

Mechanics of Particulate Solids

July 12th, 2005 from 13:30 to 16:30 hrs
Fyne Room
Scottish Exhibition & Conference Centre, Glasgow

AGENDA

1) Opening
   - Welcome [Bates]
   - Introduction [Feise]
   - Items from Nürnberg [Feise]

2) Membership Issues

2.1 Retired Delegates [Feise]

2.2 Introduction of new delegates
   - E. Tijskens, B [E.T.]
   - S. Luding, NL [S.L.]
   - (R. Janssen, NL) [S.L.]

3) Report from EFCE chairmen meeting (Frankfurt, 11 April 2005) [Feise]

4) Election of a chairman for the period 2005 – 2008 [Tüzün]

5) About the Future of the WPMPS
   - Introduction [Feise]
   - personal statements [Enstad, Bates, Höhne]
   - discussions [All]

6) Activities of WPMPS in the upcoming years [All]
   2006: CHOPS-05 – Session on "DEM in bulk solids handling"
   2007: ???

7) Any other business, Plus date and time of upcoming meetings

8) Working Party Dinner (starting 19:30hrs) [Bates]
   The Pipers' Tryst Hotel
   30 – 34 McPhater Street
   Glasgow. G4 0HWj

EFCE Working Party on the Mechanics of Particulate Solids

Annual Meeting

of the EFCE Working Party

Mechanics of Particulate Solids

July 12th, 2005 from 13:30 to 16:30 hrs
Fyne Room
Scottish Exhibition & Conference Centre, Glasgow

1

Items from Nürnberg

- **Ratification of Minutes from Nürnberg 2004**
  - Distributed by Email in May 2004
  - Available through the WPMPS – web page
- **EFCE Logo Rules**
  - ***Category I*** for events that are genuine EFCE creations (event number plus logo, cost 10€/participant, data base, promotion)
  - ***Category II*** for all other events that are organized by EFCE member societies (relevance to EFCE objectives, anticipated scientific quality, international dimension, EFCE number, no cost)
- **"Left overs" see No 7**
  - SSTT in German
  - TP7 "Terminology"

EFCE Working Party on the Mechanics of Particulate Solids

Membership Issues

- **Retired Delegates**
  - W. Goossens, Belgium
  - A, Nussbaumer, CH
- **Introduction of new delegates**
  - Belgium:
    - E. Tijskens, K.U.Leuven
  - The Netherlands:
    - S. Luding, TU Delft
    - R. Janssen, DSM

EFCE Working Party on the Mechanics of Particulate Solids

Report from EFCE chairmen meeting

- **Organizational Matters**
  - Scientific Vice-President takes over responsibilities of Science Advisory Committee (together with Executive Committee)
  - Working Parties
    - Per eligible country two delegates plus some guests (WPMPS 2005: 18 Delegates, 4 permanent Guests)
    - Reevaluation every 3 years (sVP)
  - Sections:
    - Membership not restricted
    - Strictly voluntary
    - New Section on Food (em. Prof. Schubert, U Karlsruhe) replaces dormant WP

EFCE Working Party on the Mechanics of Particulate Solids

Report from EFCE chairmen meeting

- **Scientific Matters**
  - Annual reports of working parties (WPMPS see hand-out)
  - WP Environmental Protection and Sustainable Development
  - Public Relations
    - Press releases (Frankfurt office & WP Chairmen)
    - Student mobility award
    - Best PhD-award on CAPE
  - Higher Education
    - Bologna process identifies outcomes NOT contents
    - Draft on core curricula
    - www.bologna-berlin 2003.de
    - www.bologna-bergen 2005.no

EFCE Working Party on the Mechanics of Particulate Solids

Report from EFCE chairmen meeting

- **ECCE - 6**
  - Copenhagen, 16-21 September 2007
  - Themes:
    - Sustainable process-product development through green chemistry
    - Advancing the fundamentals
      - **Particulate systems !!!**
    - Multi-scale and/or multi-disciplinary approach to process-product innovation
    - Systematic methods and tools for managing the complexity
    - Integration of life sciences & engineering
    - Sustainable chemical engineering education
  - Independent organisation is possible

EFCE Working Party on the Mechanics of Particulate Solids

Election of a WP Chairman

- **chairman: three year term, re-election once**
  - Prof. U. Tüzün, moderator
- **Report of H. Feise; 2002 – 2005**
  - 2002 BMBH Glossary of Terms in Powder and Bulk Technology (Lyn Bates)
  - 2003 Budapest (4CHoPS): Shear tester session
  - 2004 WPMPS web site (document stacker)
  - 2005 SSTT in German (Hermann Feise); Dechema - Verlag
  - 2005 Glasgow (WCCE7): Particulate systems session
  - 2006 Sorrento (CHoPS-05): Session on “DEM in bulk solids handling”
  - Members
    - Currently 18 Delegates and 4 permanent guests
    - Retired: Haaker, de Jong, Nussbaumer, Goossens
    - New: Canu, Poletto, Janssen, Luding, Tijskens

EFCE Working Party on the Mechanics of Particulate Solids

About the Future of the WPMPS

- **Introduction**
  - Thoughts about the future (Feise; 24. Feb. 2005)
- **Personal Comments**
  - Lyn Bates, UK
  - Gisle Enstad, N
  - Detlef Höhne, D
  - Hand outs (Feise, Bates, Wilms, Goossens)
- **Discussion**
  1. Define the Problem
  2. Agree on Goals
  3. Analyze the Reasons
  4. Collect Solutions
  5. Define Outcomes

EFCE Working Party on the Mechanics of Particulate Solids

About the Future of the WPMPS

Who we are (EFCE web site, 05.07.2005)

Since 1953 the European Federation of Chemical Engineering has promoted scientific collaboration and supported the work of engineers and scientists in 28 European countries. Moreover, from the very beginning Eastern and Central European countries were included.

Today the EFCE represents more than 100,000 chemical engineers in Europe. With its 22 Working Parties and 3 Sections it covers all areas of Chemical Engineering.

We invite you to participate in the wide range of EFCE activities. We would especially like to draw your attention to our events and sections, in which everyone is welcome to participate.

What we can offer you

From its very beginning, the European Federation of Chemical Engineering has set itself the objective to be a **platform for communication** and a **source of advice and support** for:

- European Institutions seeking expertise for their research programs
- Learned Societies seeking contact with their counterparts
- Individuals seeking advice or an exchange of experience

The Federation's Executive Board launched in January 1999 an EFCE Passport program which would have substantial benefits for the members of EFCE member societies who joined the scheme. To date, 17 EFCE member societies have signed the agreement.

In 2003 the EFCE adopted the title Chemical Engineering Research and Design (ChERD) as its official journal. From 2004 its sister titles, Process Safety and Environmental Protection, and Food and Bioproduct Processing have also been adopted. As a member of an EFCE Member Society you can subscribe at preferential rates. Please click here for more details.

9 Dr. Feise, BASF AG 12.07.2005

EFCE Working Party on the Mechanics of Particulate Solids

About the Future of the WPMPS

In 1969 the EFCE Working Party on the Mechanics of Particulate Solids (WPMPS) was founded to provide a platform for communication and a source of advice and support for European institutions, learned societies and individuals interested in the areas of:

1. **particle properties**
2. **bulk properties**
3. **storage and flow of powders**
4. **mixing of powders**
5. **conveying of powders**
6. **mechanical aspects of fluidization**

10 Dr. Feise, BASF AG 12.07.2005

EFCE Working Party on the Mechanics of Particulate Solids

About the Future of the WPMPS

The specific areas of activities were listed as

1. **Preparation of a directory of establishments in Europe engaged in Powder Mechanics research**
2. **Organization of working sessions**
3. **Organization of symposia**
4. **Study of critical assessment of the literature**
5. **Encourage, promote and help people in education at all levels in the field of Powder Mechanics**
6. **Conduct of industrial surveys to disclose the areas in which research is needed**
7. **Standardization of testing procedures**
8. **Standardization of terminology**
9. **Submitting annual reports on the WPMPS activities**
10. **Collaboration with existing organizations and societies active in this field**

EFCE Working Party on the Mechanics of Particulate Solids

Activities in the upcoming years

- **Conferences**

2006: **CHOPS-05 – Session on "DEM in bulk solids handling"**

2007: **ECCE – 6, Copenhagen, 16-21 September 2007**

2007: **PARTEC 2007, Nuremberg, 13.-15. March**
Building Brigdes Between the Disciplines (Aerosols, Chemistry, Colloids, Food, Pharma , Interfacial Science and Technology, Materials, e.g. Ceramics, Paper, Polymers, Nanotechnology, Soft Matter Physics, Biophysics, Unit Operations)

2008 : **???**

- **Student Conference**
- **Joint WP meeting**

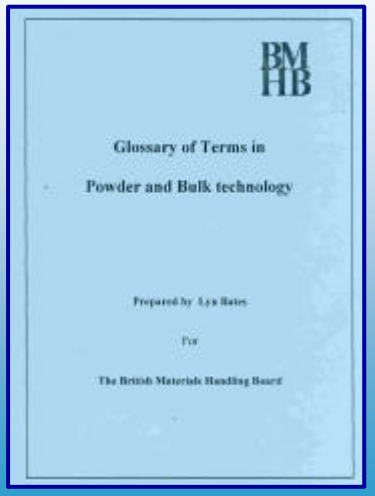
EFCE Working Party on the Mechanics of Particulate Solids

Any other Business

- **SSTT in German**
  - Translated in 1999 – 2003
  - Published by Dechema, Frankfurt (2005)
  - Distributed to WPMPS Delegates (German speakers) and universities active in bulk solids handling

EFCE Working Party on the Mechanics of Particulate Solids

Any other Business



- **SSTT in German**
  - Translated in 1999 – 2003
  - Published by Dechema, Frankfurt (2005)
  - Distributed to WPMPS Delegates (German speakers) and universities active in bulk solids handling
- **TP7: “Terminology”**
  - Lyn Bates

EFCE Working Party on the Mechanics of Particulate Solids

Date and place of next meeting

- **2006:**
  - CHoPS-05 - The 5th Conference for Conveying and Handling of Particulate Solids
  - Sorrento (Naples), Italy, on August 27-31, 2006
  - Sunday – Thursday
- **2007:**
  - ECCE-6, Copenhagen ?
  - PARTEC – 2007, Nürnberg ?
  - Special event ?

EFCE – WPMPS – WCCE7 Glasgow
Bert Tijskens

Katholieke Universiteit Leuven
Faculty of Bio-engineering Sciences

Kasteelpark Arenberg 30
B-3001 Heverlee
Belgium

engelbert.tijskens@biw.kuleuven.be

1

Education

- Master's Degree in Geology
- Postgraduate Master's Degree in Physics of Micro-electronics and Materials Sciences
- PhD in Science (materials science and computational physics)

2

Employment

- SCK/CEN Mol
- IMEC Leuven
  HPC software engineering for FEM solver of hydrodynamic semi-conductor equations
- Software engineer in a high-school
- Since 9 years now back in research at KULeuven, Faculty of Bio-engineering Sciences as a post-doc researcher

3

General interests

- Computational Whatever
- Understanding physics of processes
- Continuum mechanics, flow and deformation of materials
- Granular matter
- Particle based simulation
- Software design of computational tools

4

DEM Research Group

- 4 PhD students
- Focussing on aspects of granular matter modelling
  - Physics
  - Experimental : parameter estimation and model validation
  - Algorithm design
  - Software engineering
  - Industrial problems

5

DEMeter++

- C++ Framework for development of Particle Based Modelling applications
  - DEM/GD
  - DPD and alike
  - Soft tissue modelling
- Library of generic building blocks (classes and templates)
  - customisable
  - extensible
  - open

6

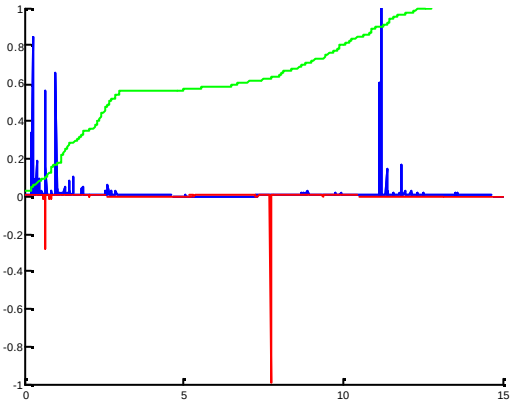
- Example: potato handling

50 ton/hour ~ 200 potatoes/s

Trajectory 30s => Simulate 6000 potatoes during 30s

7

Example: Potato handling



8

DEM Reseach Group

- Mission: develop methodology and software tools to enable industry to optimise the operation of granular processes
- Important features (requiring research)
  - Large scale simulation: long times, many particles (10^9 and more)
  - Realistic particle shape
  - Contact force model determination

9

BePCIS

Belgian Particle, Colloid and Interface Society

- From 2006:
  Thematic Innovation Stimulation project
  Flemish Particle Technology Network
- Cross-sectorial network
  - Technology / Chemistry /
    Food / Pharmaceutics / …
- Stimulate interaction between academic institutes and companies with an interest in Particle Technology in Flanders
- Develop connections outside Flanders

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Annual Report 2004

of the EFCE Working Party on the Mechanics of Particulate Solids

1. Complete address of Working Party/Section Chairman and Secretary

Dr. Hermann J. Feise
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GC/Process Engineering T
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E-Mail: hermann.feise@basf-ag.de

Secretary:
Birgit Dullinger
BASF Aktiengesellschaft
Tel. +49 621/60-54258
Fax +49 621/60-52411
E-Mail: birgit.dullinger@basf-ag.de

2. Scientific Matters

2.1 Standard Shear Testing Technique

Since its inauguration the EFCE Working Party on the Mechanics of Particulate Solids has been concerned with the characterization of bulk solids for flow. In 1989 the project came to generate the first world wide accepted standard for shear testing, known as the “Standard Sheer Testing Technique”!
It describes the preparation of shear testing samples, the operation of shear tests and the interpretation of shear testing data. In this respect it is much more concise than the later standards which were generated from it:

ASTM-D6128: “Standard Shear Testing Method for Bulk Solids Using the Jenike Shear Cell”,

ASTM-D6773-02: “Standard Shear Test Method of Bulk Solids Using the Schulze Ring Shear Tester”.

While the above documents provide an international standard, their use in Laboratories and by lab technicians in many EFCE countries is hampered by the language barrier. Therefore the Working Party on the Mechanics of Particulate Solids has started to provide national language documents on shear testing. It started with an undated German version of the original Standard Sheer Testing Technique which has been completed in 2004 and is currently in the process of being published by DECHEMA.

2.2 Glossary

In conjunction with the British Materials Handling Board (BMHB) the Working Party on the Mechanics of Particulate Solids also developed a glossary of solids handling terms. This long ongoing work has been led by the British delegate Lyn Bates, who also arranged for the final manuscript to be published by the BMHB.

2.3 Relevant Trends

The field of the Working Party on the Mechanics of Particulate Solids has seen two major trends in the last couple of years:

a) the drive to smaller (nano)particles.
b) the wide use of Discrete Element Methods.

While nowadays nobody seems to be doing anything worth talking about which is not “nano”, the handling of such powders is looked at rather seldomly. The DFG-Schwerpunktprogramm “Handhabung hoch disperser Pulver (Handling of highly disperse powders)” in Germany devoted only two of its eight subject areas to its nameplate activity. Of the others, two were on particle formation and one each on coatings, suspensions, mixing and sintering. Nevertheless, to become truly successful dealing with nano-particles, we have to learn how to handle them.

Discrete Element Methods, developed around 1984 by Cundall and Strack from older Molecular Dynamics work, have started to impact the field of the Mechanics of Particulate Solids in the 1990’s. For the last four years they have carried the largest part of the research effort for bulk solids. By now we have ways of dealing with inter-particle cohesive forces, liquid bridges, non-spherical particle shapes and particle-wall interactions. What is still missing, is the development of a meta structure representing a cluster of particles, since the idea of representing each particle individually in a computer simulation still overwhelms today’s most powerful computers.

3. Administrative Matters

3.1 Date of election and term of office of the Working Party/Section Chairman and Secretary

Current Chairman: Dr. Hermann J. Feise

Election Date: 26.03.2002
Inauguration: 23.07.2002
Term End: 14.07.2005

3.2 Date and venue of the last scientific and business meetings

Technical and Business Meeting: 15.03.2004, Nürnberg, Germany

3.3 Next main thematic scientific European and World events

The Working Party on the Mechanics of Particulate Solids has been able to initiate a topic on "Particulate Systems" for the upcoming World Congress of Chemical Engineering held in Glasgow from 10 – 14 July 2005. The Working Party Chairman Dr. Feise serves as a topic leader. The topic is placed within the section on "Advancing the Fundamentals" led by Prof. R. Ocone.

The Working Party intends to sponsor the 5th International Conference of Conveying and Handling of Particulate Solids in Sorrento, Italy during August 2006.

3.4 Awards and prizes

None

ECCE-6: European Chemical Engineering Conference 2007
16-21 September 2007

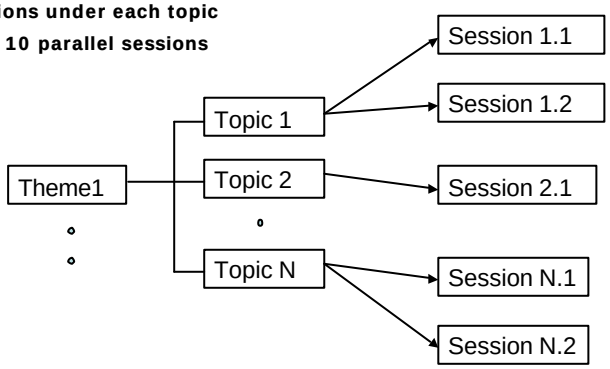
Organizations Involved

- **EFCE**
- **IDA, Danish Engineering Society**
- **Technical University of Denmark**
- **Department of Chemical Engineering**
- **Wonderful Copenhagen**

Conference Venue:
Bella Center

Scientific Program Themes (Gani, Pohorecki, Dam-Johansen)

- **Themes**
- **Topics under each theme**
- **Sessions under each topic**
- **Upto 10 parallel sessions**



Theme: Sustainable process-product development through green chemistry

Topics: Process intensification, nanotechnology, new materials, ...

2

Scientific Program Themes-Topics: 1

- Sustainable process-product development through green chemistry (NN, JV)
  - Process intensification (NN)
  - Nanotechnology (TJ)
  - New materials & structured products (SH)
  - Green organic synthesis routes
  - Process integration
  - Environmental engineering & management
  - Sustainable & clean technologies
  - ……
- Advancing the fundamentals (NN, OH)
  - Thermodynamics (GK)
  - Catalysis & reaction engineering (PGL)
  - Particulate systems (NN)
  - Fluid mechanics & microfluids
  - Interfacial & colloidal phenomena (MV)
  - Membranes and membrane science (GJ)
  - Crystallization (KTH/NN)
  - …….

3

Scientific Program Themes-Topics: 2

- Multi-scale and/or multi-disciplinary approach to process-product innovation (NN, EHS)
  - Process-product innovation (SK)
  - Nanomanufacturing
  - Drug design & delivery
  - Energy & nuclear sciences
  - Energy and environment
  - CFD & chemistry
  - ……
- Systematic methods and tools for managing the complexity (NN, Pistokopoulos)
  - Multiscale modelling
  - Process synthesis & design
  - Process operations
  - Supply chain management & business decision support
  - Advances in computational & numerical methods
  - Safety & risk management systems (NJ)
  - Systems biology
  - Process Analytical Technology
  - ……

4

Scientific Program Themes-Topics: 3

- Integration of life sciences & engineering (NN, NN)
  - Biochemical engineering (JM)
  - Tissue engineering
  - Product (drug, pesticide, …) delivery and/or release
  - Bio materials
  - Food and drink
  - ……
- Sustainable chemical engineering education (Molzahn, Livbjerg)
  - Bologna agreement implementation
  - Computer-aided educational modules for teaching (JA)
  - Contents for an International MSc-degree
  - Using the EU-networking program for PhD-courses (Georgiadis)
  - ……..

DTU

5

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Plenary & Keynote Speakers

Plenary (4-6 speakers; 50% from Denmark)

- From Danish Industry
- From International Agencies
- From European Industry
- …….

Keynote (12-24 with respect to themes-topics)

- From Academia
- From European Industry
- …….

Prof. J.-C Charpentier (France): Multiscale modelling for chemical product design

6

…….

Dr. ir. Walter Goossens E-mail: w.goossens@scarlet.be
28/09/05 ref:WPMPSstrategyBACKGROUND

Background information related to a future strategy of the WPMPS of EFCE

1. Extracts of the minutes of the founding meeting of WPMPS 16 Sep69

On the occasion of the III.Congress CHISA on 16SEP69 in Marianske Lazne, Cz, the WPMPS was set up under the elected Chairmanship of Mr. J.C.Williams , Bradford Univ.,GB, with elected secretary: Dr.Ing.J.Novosad, Inst.Chemical Process Fundamentals, Praha, CZ to unite all efforts made for the advancement of Powder Mechanics.

Subjects to be covered by the WPMPS:

1. particle properties
2. bulk properties
3. storage and flow of powders
4. mixing of powders
5. conveying of powders including pneumatic conveying
6. mechanical aspects of fluidisation

The field of activity was recommended as follows:

1. Preparation of a directory of establishments in Europe engaged in Powder Mechanics research
2. Organisation of working sessions
3. Organisation of symposia
4. Study of critical assessment of the literature
5. Encourage, promote and help people in education at all levels in the field of Powder Mechanics
6. Conduct of industrial surveys to disclose the areas in which research is needed
7. Standardisation of testing procedures
8. Standardisation of terminology
9. Submitting annual reports on the WPMPS activities to the Science Advisory Committee
10. Collaboration with existing organisations and societies active in this field

2. Non-exhaustive survey of the WPMPS activities

In fact, the WPMPS starts its activities only in 1971. In the exploratory period 1971-1979 full care is given to an open exchange of scientific knowledge between East and West by enlarging the membership of the WPMPS. The organisation of international symposia at annual basis (every 3 years in Prague and other years in West-Europe) is started. Various technical discussions indicates that the storage and flow in silo's is an urgent issue to be solved.

The first concrete project consists in the experimental comparison of various shear testers with the Jenike Shear Tester as reference. A world appeal results in the participation of 20 laboratories from Europe, USA, Australia and Japan. The measurements with a limestone powder scatter largely. Consequently, the WPMPS takes up the duty to develop the standardisation of shear testing. This effort in the years 1977-1987 results in a manuscript of the Standard Shear Testing Technique drafted by Dr. H. Wilms, approved in 1987 by the WPMPS and published in 1989 by the British Institution of Chemical Engineers including an appendix of glossary of terms, simultaneously developed within the WPMPS. (A German version will be published in 2005 by DECHEMA) On this occasion BCR (Bureau Centrale de Reference) of the European Commission certifies a limestone powder under BCR 215.

An inquiry amongst the WPMPS members in 1986 by Dr Novosad indicates several open problems for future activity. A detailed discussion of these problems in the meeting of 1987 results in the set up of 6 Task Groups. This working method is in 1988 consolidated in the strategy of the WPMPS for the next 10 years with as **Goal: improve the reliability of operating performance of storage, transport, metering and processing equipment for particulate solids.**

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The fate of these Task groups is:

TP1 – Silo pressures Dr H. Wilms

Silo codes from over the world are compared by about 50 persons. Quantitative exercises show large scatter. In 1999 Prof. Rotter takes over. A database is set up. The use of the database is however restricted. Hosting by DECHEMA is under discussion.

TP2 - Deaeration properties Prof. J. Schwedes: abandoned in 1992

TP3 - Wall friction properties and wear Dr. G. Haaker:

The intensive experiments show a high scatter, probably due to differences in consolidation of the samples. Activity is transferred in 1999 into a EU proposal for powder characterisation by de Silva.

TP4 - Powder interstitial phase interactions Prof G. Rossi: abandoned in 1992

TP5 segregation and segregation prevention Dr. G. G. Enstad:

Lyn Bates present a User guide to segregation in 1996, which is published in 1997 by british materials Handling Board. In 1999 Lyn Bates draft ten key steps to counter segregation.

TP6 review of particle technology education Dr. R. J. Akers

A questionnaire is set up and sent in co-operation with WP Comminution and WP Characterisation.. The result is not available as Dr Akers does not participate on WPMPS after 1995.

Additional task groups started in 1996 are:

TP7 Review of terminology of mechanics of particulate solids L. Bates

On the basis of various existing glossaries and of suggestions from WPMPS participants an extensive work document is put in 2003 on the WPMPS website for comments.

TP8 Development of a simple industrial test procedure for evaluating the strength properties of particulate solids L.Bates

A discussion paper is available stressing as basic needs: bulk density, wall friction, shear resistance, and 3D microscopic size and shape measurement and a subproject might get funds from the UK Dep of Environment, Food and Rural Affairs.

Last task group started in1999:

TP9 - Standardising powder characteristics measurements for safe and reliable equipment design Prof. S.R. de Silva:

In the autumn of 1996, Prof. de Silva prepares on behalf of the WPMPS in close co-operation with several WPMPS members the research project "Towards improvements in the characterisation of bulk properties of bulk materials for the purposes of equipment design". The application to the EC for support is rejected in 1997. Also a less ambitious application is rejected on its turn as not under the theme of Standards, Measurements and Testing Programme. At own expenses a "European Project on Powder Characterisation" is started growing to TP 9 in 1999 with 26 participants, mainly WPMPS members. This TP is terminated in 2001 without clarification of the unacceptable scatter issue revealed for shear tests with fine cohesive materials.

The strategy defined in 1988 is complemented in 1992 in a review report by Dr Novosad specifying as terms of reference:

1. Bulk properties of bulk solids
2. Storage and flow of particulate solids.
3. Mixing of particulate solids.
4. Mechanical aspects of fluidization.
5. Conveying of particulate solids.

and suggesting a WP on fluidization as this subject is out of scope of most WPMPS participants.

In 1996 some WPMPS members participate actively on an EFCE discussion forum looking for **European Commission support** to chemical engineering. But it appears that in practise, the individual members of the different working parties have to look for specific issues that might be eligible in the procedure of EC. It has to be taken into account that the preparation of a proposal takes a lot of effort and that the success rate is very low (about 10 %).

*Earlier, in 1994 already, WPMPS takes as WP attention to EC-funds and WPMPS members participate in a Concerted Action project called CA-SILO (1992-1996) co-ordinating all West European silo research (The results are published in 1998 by E&FN Spon, London in the book "Silos-Fundamentals of Theory, behaviour and Design").

*In 1996 and in 1997 Prof. de Silva applies without any success on behalf of the WPMPS to the EC for support related to the characterisation of bulk materials. Anyhow, in 1999 the technical project 9 is started within WPMPS at own expenses with 26 participants.

Dr. ir. Walter Goossens E-mail: w.goossens@scarlet.be
28/09/05 ref:WPMPSstrategyBACKGROUND

* The application in 1998 for the EURPARTEC project is granted under the Leonardo da Vinci programme. The initial aim of this international Pilot Project is to create a series of 100 lectures and PC based teaching aids in the field of powder technology. In the period 1999-2002 17 lectures are recorded and put available on internet.
* In 2002: 3 Expressions of interest are sent to the 6th framework programme for networks of Excellence: 1 on manufacturing of particles; 2 on processing of nanoparticles. The outcome is not known to WPMPS.

From 1994 the WPMPS is regularly informed about the development of ASTM standards and several WPMPS members participate on the procedure. The ASTM-D6128 "Standard Shear testing Method for Bulk Solids Using the Jenike Shear Cell" is approved in 1997 and published in 1999. Standards for other shear cells are now available and current subjects for standardisation are: segregation testers, fluidization/de-aeration testing; loose and tapped bulk density; pneumatic conveying.
Last years WPMPS-members are involved in ISO-, ASTM-, DIN- (DIN-1055) and EN- (EN 1991-4) standardisation committees.

3. Personal reflections

From the field of activity recommended in 1969 the following appears to be performed in the past:
Activity 3 : Organisation of symposia
Activity 7 : Standardisation of testing procedures
Activity 8 : Standardisation of terminology
with the focus on subject 3 : storage and flow of powders.

The strategy defined in 1988 to operate via Task Projects appears a good working procedure for the WPMPS. Nowadays, the progress is however very slow as long as funds are lacking. Therefore, future Task Projects should be set up with the aim to define an application for support from national and international organisations. Funds for the development of the corresponding RTD project applications might be obtainable from the 7th framework programme of the EC within a "generic" Network of Excellence between universities, industry and RTD organisations. According to the rules of the EC, the management of such a network of Excellence has to be in the hands of a person belonging to a large organisation, by preference not a university and excluding any small organisation. The manager himself of such a network needs a lot of goodwill as the project-by-project procedure of the EC is time consuming: any application has to be modelled according to the project requirements of the EC and to the eligibility criteria of the specific Community programme stressing more and more the needs of good market perspectives of any RTD proposal.

The subjects to be covered by the WPMPS are well defined at the start in 1969. Particle properties such as particle density, shape and size should not be left out as opposed to the suggestion in the list of references specified in 1992. There is thus an opportunity to operate with four "generic" Networks of Excellence within the scope of the WPMPS with as possible titles:
1. Particle properties and bulk properties in relation to the storage and flow of particulate solids.
2. Particle properties and bulk properties in relation to the mixing of particulate solids.
3. Particle properties and bulk properties in relation to the mechanical aspects of fluidization
4. Particle properties and bulk properties in relation to the conveying of particulate solids.

Personal comments on TP's:
TP2 on de-aeration should be reactivated as the small de-aeration rate of fine cohesive materials can explain the unacceptable scatter observed for these materials in TP9. See "Prediction of the flow behavior of particulate solids" submitted for the WPMPS business meeting 2004 in Nurnberg.

Dr. ir. Walter Goossens, Belgian delegate to WPMPS from 1969-2004

EFCE Working Party on the Mechanics of Particulate Systems – what is it good for?

Thoughts about the future

In 1969 the EFCE Working Party on the Mechanics of Particulate Solids (WPMPS) was founded to provide a platform for communication and a source of advice and support for European institutions, learned societies and individuals interested in the areas of:

1. particle properties
2. bulk properties
3. storage and flow of powders
4. mixing of powders
5. conveying of powders
6. mechanical aspects of fluidization

The specific areas of activities were listed as

1. Preparation of a directory of establishments in Europe engaged in Powder Mechanics research
2. Organisation of working sessions
3. Organisation of symposia
4. Study of critical assessment of the literature
5. Encourage, promote and help people in education at all levels in the field of Powder Mechanics
6. Conduct of industrial surveys to disclose the areas in which research is needed
7. Standardisation of testing procedures
8. Standardisation of terminology
9. Submitting annual reports on the WPMPS activities to the Science Advisory Committee
10. Collaboration with existing organisations and societies active in this field

During the now 35 years of its existence the working party has always relied solely on the voluntary efforts of its members, since no means of funding are available. This, inevitably, leads to reasonably slow progress in all activities the working party has ever undertaken. Whatever the ideas for the future are, this limitation has to be borne in mind.

Of the ten activities listed above, several warrant a closer look:

1) It is a common feeling that research on the Mechanics of Particulate Systems in Europe is traditionally centred in Germany and in the UK. While there was merit to this feeling when the WPMPS was founded, whether it is still true is an open question. Such a directory could serve as a valuable source of information for anybody looking for international partners in joint European research.

3) The WPMPS has run several events during its existence (e.g. a symposium in Braunschweig in 1982 and a conference session in Budapest in 2003. For 2005 it has initiated a special topic on “Particulate systems” at the World Congress in Glasgow. This appears to be a useful way of conducting scientific intercourse on a subject of common

interest. With the multitude of conferences in existence already it does not seem possible to attract enough interest/participation for a “free-standing” event.

Another possibility would be to have an European working party symposium together with a national working party meeting. Such an event was run by the EFCE working party on Drying together with the respective GVC-Fachausschuss at Nürnberg in 2004.

6) Since most delegates are rooted within their national working parties, the WPMPS might be in a position to conduct industrial surveys. Whether there is enough common interest would need to be discussed.

7) The WPMPS is not a standardization body. However, its beneficial influence can be seen from the various new ASTM standards on shear testing. Participation of WPMPS members in any upcoming standardization efforts can only be encouraged. Fortunately, standardization bodies are currently quite active in our field, such that the start of any additional effort does not seem pressing at the moment.

8) The working party has run a “Terminology Project” under the leadership of the Lyn Bates. It has by now culminated in a Glossary published by the British Materials Handling Board.

10) The WPMPS actively collaborates with the organizers of the “CHOPS” series of conferences. It will have its 2006 business meeting at CHOPS-05 in Sorranto, Italy. Collaboration with national working parties could be achieved through joint meetings e.g. in years without suitable European conference (see above).

The BMHB is currently running two projects for which WPMPS participation has been invited.

The working party 35 years ago gave itself six fields of interest and ten activities. In 1988 J. Novosad re-phrased its purpose in a mission statement “to improve the reliability of operation performance of storage, transport, metering and processing equipment for particulate solids”.

Today, while the last of the founding members are retiring from the working party, it is time to re-discuss the purpose of our working party. Only with a common vision will we be able to secure a lasting contribution and therefore the continuing existence of the WPMPS.

Dr. ir. Walter Goossens E-mail: w.goossens@scarlet.be
2005 Januari 24 ref:WPMPSstrategyEXRERCISE

Exercise for a future strategy of WPMPS

Mission statement of WPMPS: (==goal as defined in 1988 by Dr. J. Novosad)

To improve the reliability of operating performance of storage, transport, metering and processing equipment for particulate solids.

Strategic Goals:

- to develop reliable procedures for the **characterisation of particulate solids**, namely
  - determination of **essential particle properties**
    - i.e. density and hydrodynamic diameter (dependent on interstitial fluid);
  - determination of other particle properties
    - e.g. shape, fluid (gas or liquid) adsorption, hardness;
  - determination of **essential bulk properties**
    - i.e. bulk density, de-aeration rate, stress-strain behaviour;
  - determination of other bulk properties
    - e.g. permeability, fluidisation behaviour, segregation, attrition, Hausner ratio, interparticle forces (capillary, electrostatic, Vander Waals)
    - elastic properties (elasticity modulus)

-to develop reliable procedures for the design of equipment for **storage and flow of particulate solids**;
-to develop reliable procedures for the design of equipment for **mixing of particulate solids**;
-to develop reliable procedures for the design of equipment for **fluidisation of particulate solids**;
-to develop reliable procedures for the design of equipment for **conveying of particulate solids**.

Actions

Action 1:
To organize **symposia and working sessions** on subjects related to any type of equipment for particulate solids applied in any sector of the industry

Action 2:
To set up internal **"Action Projects"** (=~ former Technical Projects) chaired by a WPMPS member. The subject of these Action Projects can be:

2A. Technical: e.g. silo issues, wall issues, de-aeration, segregation, fluidization.
2B. Standardization: e.g. terminology; specific standard committee.
2C. Informative: e.g. education; courses; own website; literature study; survey of industrial needs; analysis of and/or participation on existing websites e.g. wohlbier@bulk-online.com.
2D. Administrative: e.g. set up of network; development of specific RTD proposal/project; relation to EC, and other funding bodies; relation with other WPs.

Specific attention point:

It is clear that fine powder behaves quite different from large granular solids. On the basis of the Archimedes number (a scientifically sustained combination of particulate properties and fluid properties) 5 classes of behavior can roughly be distinguished. Special attention should thus ALWAYS be given to the value of this Archimedes number for the particulate-fluid system under consideration. (Ref: document "Prediction of the flow behavior of particulate solids" submitted for the WPMPS business meeting 2004 in Nurnberg).

PS
For the background of this exercise: See document "Background information related to a future strategy of WPMPS of EFCE".

Dr. ir. Walter Goossens, Belgian delegate to WPMPS from 1969-2004

Working Party for the Mechanics of Particulate Solids - Glasgow Meeting 12 July 2005

Re: - Wall Friction Project - Lyn Bates Proposal.

Despite some sterling work by Prof. Haaker this project ground to a halt when different groups testing the same material on similar contact surfaces secured radically different measured values. This topic is so fundamental to hopper and equipment design that the position cannot be left unresolved. It is considered to be as simple a test as can be devised so consistency must be secured to provide confidence in the technology to both advocates and inexperienced users.

It is proposed that this project be resurrected, with the objective of preparing a written procedure that will secure consistent and representative results.

It is suggested that the task group has at least five members who are prepared to conduct a set of trials on uniform samples of a three of four bulk materials and two reference surfaces of contact. Each test to be conducted three times and all results collated in a review report. One machine will be used for doing all the tests, it to be circulated sequentially to the different members of the task group. A program to be developed that allows each party to the project up to four weeks to complete their test series. Allowing for transport time between members and some slippage due to holidays or other interference, the project and its report will be completed within one year.

Contrary to the earlier round of friction test, the preparation method will not be the same as the standard shear cell technique. This is because twisting the lid to provide pre-shear within the mass does not represent the wall contact conditions prevailing in bulk storage or other interface contact circumstances where friction is initiated. Instead, a method of cell loading will be specified to reflects how deposited particles come to rest against a contact surface.

Ajax Equipment will provide the samples of bulk material, test coupons and a log-stroke wall friction machine that allows a complete set of measurements with decreasing and increasing normal loads to be completed in one continuous run.

It is expected that the use of an identical machine and a common cell filling, loading and test procedure will produce far more consistent results than those secured from previous comparative wall friction tests.

Lyn Bates

Task Force ..... of .....

..... of .....

..... of .....

..... of .....

..... of .....

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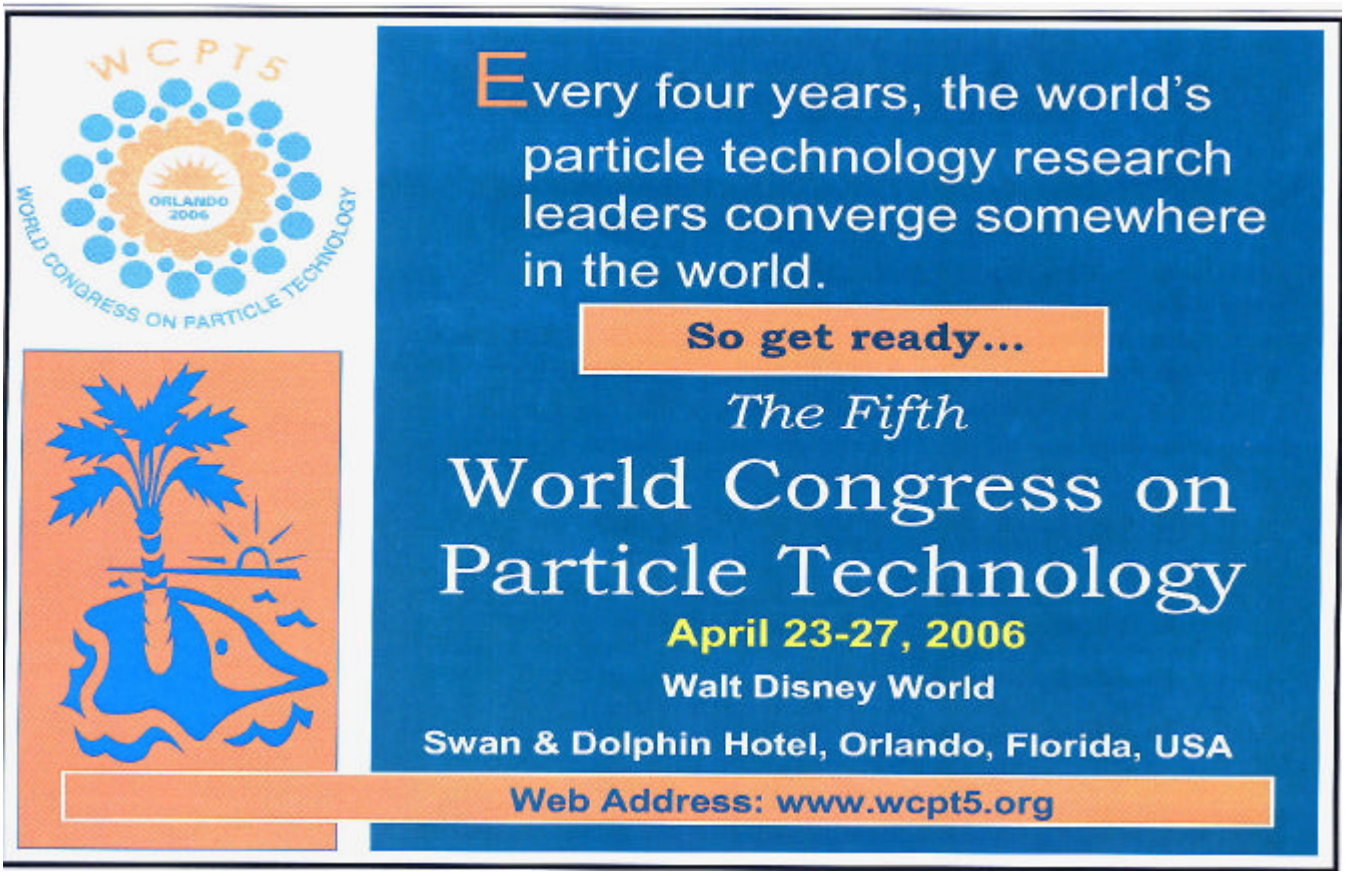
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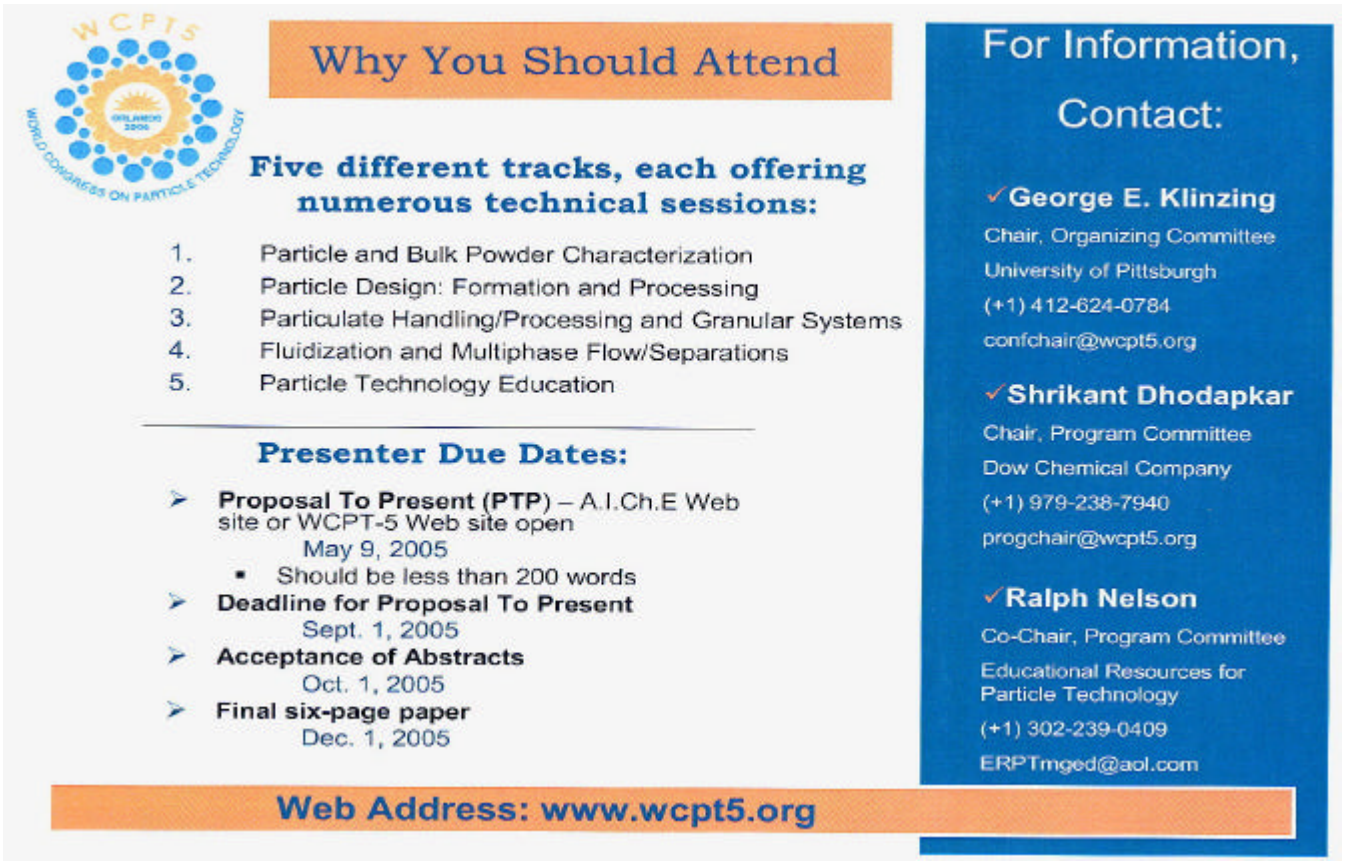
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Presenter Due Dates:
Proposal To Present (PTP) – A.I.Ch.E Web site or WCPT-5 Web site open
May 9, 2005
Should be less than 200 words
Deadline for Proposal To Present
Sept. 1, 2005
Acceptance of Abstracts
Oct. 1, 2005
Final six-page paper
Dec. 1, 2005
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- Lists of addresses available for invitations to congresses and conferences

ECED contact: info@eced.cz
European Federation of Chemical Engineering contact: www.efce.info

please turn over

Dear Colleague,

We are herewith requesting your help!

One of the main goals of the European Federation of Chemical Engineering (EFCE) is to promote Chemical and Process Engineering at European level and partly also at world level. This can best be done by knowing who the Chemical and Process Engineers in Europe are, what are their interests and what are their expertise.

To achieve this goal a European Chemical Engineers' Directory has been developed which is available on the internet at the address www.eced.cz On behalf of the European Federation of Chemical Engineering the Directory is administered by the Czech Society of Chemical Engineering.

Although the Directory is on the internet over a year and entry is free of charge, up-to-date only 679 Chemical and Process Engineers have entered the database. We were aiming at something like 5 thousand records.

Entry into the Directory will be very helpful to you. You will know who the Chemical and Process Engineers in Europe are and they will know who you are. The Directory is quite sophisticated. If you do not want your data to be available on the internet, it will be available only to EFCE bodies so taht you can be currently informed on what is going on in Europe in this field. Even if you aprove that your data can be on the internet, anyone can send you an e-mail but your e-mail address will not be disclosed.

How can you help?
Please find on the internet www.eced.cz and become acquainted with all the searches available and if you consider yourself as a Chemical or Process Engineer do fill in the "New Record" form. In case of any questions contact info@eced.cz

Thank you for your help.

Dr.Jan Novosad, Executive Secretary
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Invited Guests

Title	First name	Name	Status	Affiliation incl. Address	email Address
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The British Materials Handling Board

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The British Materials Handling Board was formed by the UK Government in 1979. A key objective was to act as a focus for the dissemination of knowledge and good practice in the materials handling industry. It was arranged to become an independent, user-oriented organisation, a status it has held since 1985. Through face-to-face meetings with users, manufacturers and Universities, it identified various areas of activity that impaired industrial efficiency, health and safety at work and the implementation of developing technologies. A topic that stood out as a major source of industrial problems was the handling of particulate solids. By means of working parties, project panels, co-operative networks, industrial and University visit, seminars, research projects and technical publications, it has stimulated technical education and the application of state-of-art practices in bulk solids handling.

Research projects sponsored include: -

Particle Handling
Vibration of Bulk Solids
Noise associated with Handling
Particle attrition
Paste Extrusion and Preforming
Investigation into Silo Flow Patterns
Investigation into Dust Explosions in Bucket Elevators

Publications include: -

Guide to Particle Attrition in Materials Handling Equipment
Standards in Material Handling
Physical Properties of Bulk Solids
Powder Test Guide
Fabric Filters
Port Dust Control
Silo Design Code
Guide to the Use of Weigh Feeders
User Guide to Segregation
Coal and Ash Handling
Guide to the Design of Circular Metal Silos
Guide to the Design, Selection and Application of Screw Feeders
Glossary of Terms in Powder Technology and Solids Handling
Hopper Design Guide

Various publications are in preparation and a series of charts and monograms being assembled to provide practical guidance to all users of particulate solids