eand
engineering analysis & design pty ltd

NAME: CHRISTOPHER MEIMARIS

Current Position: Managing Director,
EAnD.

Qualifications: Bachelor of Engineering (Mechanical, Hons), 1980
Master of Engineering Science, 1982
Doctor of Philosophy, 1989
Doctor of Engineering, 2012

Contact Details: 4/53 Monash Rd
Tarragindi, QLD,
Australia, 4121
Phone: +61 4 197 18953 (b.h.)
Fax: +61 7 3892 2233
E-mail – cm@eand.com.au

FIELDS OF EXPERTISE:

- **a)** Mineral processing & mining machinery – mills, geared drives, GMDs and HPGRs
- **b)** Grinding equipment specification development
- **c)** Mill system design and analysis for geared and gearless mills
- **d)** Structural dynamics
- **e)** Foundation dynamics
- **f)** Engineering a and fitness for purpose particularly for mill non-conformances
- **g)** Quality assurance and control of mill manufacturing
- **h)** Finite element analysis
- **i)** Failure analysis

AWARDS AND HONOURS:

Doctor of Engineering 2012: The University of Queensland

Higher Doctorate awarded for contribution and achievement in comminution equipment and systems. Dissertation title “Original work on grinding mills, ring motors, foundation systems and gear drives”.

Award - Landmark Papers: SAG 2001 Conference

Awarded by the SAG 2001Organising Committee for the two papers: "Remedial Design of the World's Largest SAG Mill Gearless Drive" and "Failure Analysis of Ball Mill Gears".

PREVIOUS POSITIONS:

1994-2001 Frank Grigg & Associates Pty Ltd - Director

1988-1994 M&A Mining & Industrial Consultants Pty Ltd – Senior Mechanical Engineer

1986-1988 University of Queensland
Department of Mining & Metallurgical Engineering – Research Officer

CONTRIBUTIONS TO THE MINING INDUSTRY:

1. Failure analysis and remedial design of the world's largest gearless mill drives (GMDs);

2. Development of design procedures for GMDs adopted by Siemens AG for all their drives;

3. Development of design changes for both ABB and Siemens ring motors (part of GMD system);

4. Mill system dynamic analysis to ensure proper operation of geared and gearless driven mills. Modelling of ring motors or gears together with mill, foundations and sub-surface soil in a dynamic model that includes normal operation and accident conditions;

5. Consulting expert on ring motor design to Siemens to prove the mechanical and structural design of the world's largest ring motor prior to manufacture;

6. Instrumentation of large ring motors resulting in definition of material properties of laminations that had not been measured before. Errors in design estimates of these material properties were determined as the root cause of ring motor failures in Siemens motors.

7. Measurement and definition of loads in SAG and ball mills that leading to fundamental understanding of the ore dynamics and mill liner stiffness;

8. Reconciliation of mill design with fatigue design codes;

9. Redesign of rotor poles and hanger plates in Siemens and ABB motors now adopted by these vendors in their standard designs;

10. Statistical analysis of SG Iron casting thresholds to determine design properties of castings with sub-surface flaws;

11. Modelling of High Pressure Grinding Roles (HPGRs) to assess dynamic loads and development of foundation models;

12. First analysis of gear contact forces on mills and subsequent refinement of models to enable prediction of thermal ratcheting in gear drives;

13. Strain gauging, vibration measurement and modal measurements of mill drives, ring motors, and foundations to define design loads for mills and drives;

14. Technical responsibility for all large mineral processing equipment on Telfer and Boddington projects.

EXPERIENCE IN MINERAL PROCESSING AND MINING EQUIPMENT:

This section presents a list of projects in which Chris Meimaris acted as project manager for EAnD and Grigg and Associates. The projects have been limited to those relating mineral processing and mining equipment. Other work such as risk analysis and development of design auditing strategies for large mineral processing plant design are not included in this list but presented in publications [4] and [5].

1. **Mill Analysis:** Numerous analyses including – *Collahuasi, Chile, 2002; Telfer (Newcrest) Australia, 2002; Sossego, CVRD (Vale), Brazil, 2002; Tarkwa (Goldfields), 2003; Cerro Verde (Phelps Dodge – FMI), Peru, 2004; Rosia Montana (Gabriel Resources), Rumania, 2004-present; Yanacocha, Ahafo and Boddington (Newmont), 2004 to 2008; RPM (Kinross), Brazil, 2006; Pueblo Viejo, (Barrick), Dominican Republic, 2008; Cape Preston (CPMM), WA, 2009; Mt Milligan (Terrane Metals), Canada, 2011, Cerro Verde Expansion (FMI), Peru, 2012; Constancia (HudBay), Peru 2012.*

   This work involved design audits of mills developed by all major mill suppliers. The mills were some of the largest in the world including the Collahuasi SAG and ball mills (40 ft and 26 ft respectively) and the 40 ft AG mill at Cape Preston.

2. **Failure Analysis and Remedial Design:** *Antamina Ball Mills (Antamina); Red Dog Mine SAG Mill Foundations Remedial Design (Teck Alaska Inc); Cerro Verde Ball Mill (SMCV); Collahuasi Ball Mill (CMDIC); Cadia Hill 40 ft Ring Motor (Newcrest); Collahuasi 40 ft Ring Motor (CMDIC); Antamina Stator 38 ft Ring Motor failure analysis (Antamina); PT Freeport Indonesia GMD failure analysis and remedial design and Freeport foundations failure analysis (FMI); Cadia Hill rotor pole failures; El Teniente stator buckling.*

   At Cadia Hill: Komastu Demag Loader failure analysis; Ingersol Rand Drill Mast Failure and Redesign, 2001; Tyre Burst Modelling and Remediation (2005).

   Each of these projects involved the use of measurement and numerical modelling to determine the causes of failure. Some of the Cadia rotor pole and Collahuasi stator failure analysis is presented in [3].

3. **Gearless Mill System Analysis:** *El Teniente (Codelco), Chile, 2001; Collahuasi, (CMDIC) Chile, 2002; Telfer (Newcrest) Australia, 2002; Sossego, CVRD (Vale), Brazil, 2002; St Ives, WA, 2003; RPM (Kinross), Brazil, 2006; Lumwnana (Equinox), 2006; Pueblo Viejo, (Barrick), Dominican Republic, 2008; Antamina Expansion, (BHP), Peru, 2008; Salobo (Salobo Matais), Brazil, 2009; Cape Preston (Siemens), WA, 2009; Mt Milligan (Terrane Metals), Canada, 2011; Caserones Project (Mineral Lumina Copper Chile), 2011; Tasiast (Kinross), Mauritania, 2011; Cerro Verde Expansion (FMI), Peru, 2012; Collahuasi new SAG stator system changes (CMDIC), Chile, 2012; PT Freeport Indonesia (FMI) GMD Upgrade 2013.*

   Each of these projects involved the use of methods developed on Cadia and Antamina to assess vibration and interface forces in foundations and gearless drive stators during design. The projects include the largest motors in the world power ratings of up to 28 MW. All projects after 2007 involve the design audit of stators and rotors to assess likelihood of fatigue failures using numerical analysis calibrated from strain gauge measurements from failed gearless drives. New methods developed during these projects include:

   a. First GMD upgrade by a non-vendor;
   b. First vendor-approved design audit of both ABB and Siemens ring motors;
   c. First analytical assessment of fundamental forces in stator core support frames;
   d. First analytical assessment of fatigue in core support mechanisms including calibration against measured data by EAnD;
   e. First analytical assessment of core locating bolts;

f. First analytical assessment of rotor pole forces including calibration against measurements by EAnD of failing rotor poles;
g. First multiple ring motor foundations (Cerro Verde and Lumwana);
h. Soil structure interaction modelling development in a form that can be applied simply to mill foundations.

4. **Gear Driven Mill Foundation Analysis:** *Cadia Hill (Newcrest) NSW, 1996; Telfer (Newcrest) Australia, 2002; Sossego, CVRD (Vale), Brazil, 2002; Fimiston SAG Mill (Barrick), WA, 2004; RPM (Kinross), Brazil, 2006; Boddington (Newmont), WA, 2006; Phu Kham (PanAust), Laos, 2008; Sponifex Ridge (Moly Metals), WA, 2008; Pueblo Viejo, (Barrick), Dominican Republic, 2008; Antamina Expansion, (Antamina), Peru, 2008; Santa Rita (Mirabela Brasil), Brazil, 2008; Salobo (Salobo Matais), Brazil, 2009; Karara (Karara Mining), WA, 2009; Cadia East (Newcrest), NSW, 2010; Mt Milligan (Terrane Metals), Canada, 2011; Constancia (HudBay) 2012.*

   Each of these projects involved the use of methods developed on Cadia and Antamina to assess vibration and interface forces in foundations and gearless drive stators during design. The analyses were all based on the torque measurements of gears performed at Cadia and other plants to develop disturbing forces for the vibration analyses.

5. **HPGR Foundation Analyses, 2006 & 2009:** *Boddington (Newmont), WA, 2006; Karara (Karara Mining), WA, 2009.*

   These projects assessed the suitability of foundations to support multiple HPGR crushers. The novel aspect of the work was determining the dynamic forces. The dynamic forces provided by the vendor were found to be an order of magnitude greater than the likely operational forces.

6. **Cadia Hill Gold Mine, Newcrest Mining, NSW, 2001. Measurement of loads in a large SAG mill trommel.** This project used strain gauges to measure the charge load in a large SAG mill trommel. It showed that the loads used by vendors for the trommel design were too great.

7. **Minera Escondida, Chile, 2001. Dropped charge analysis in a failed ball mill.** This project modelled the effect of dropped charges in ball mills showing that the loads generated by these events can be up to 9 times the normal operational load.

8. **Statistical analysis of fatigue thresholds in ductile iron. 2001.** This work formed the basis of the assessment criterion for fatigue thresholds in mill castings used by the world's largest mill manufacturer.

9. **Antamina, Peru, 2000. Design audit of foundations (only).** This was the first project in which the work performed on the Cadia gearless drive stator in 1996 to 2000 was used as a predictive tool during design. The plant is one of the largest in the world with one 38 ft SAG mill and three 24 ft ball mills. The equipment operated properly upon commissioning. Some results published in [8]. The subsequent failures were as a result of design details that were not audited until our first audit of ABB ring motors in 2007.

10. **Cadia Hill Gold Mine, NSW, 1998 to 2000. Measurement of vibrations and modelling of girth gear failures on two identical ball mills.** Measurement of torque and torque fluctuations in two twin-pinion gear driven ball mills. Analysis of data and development of vibration inputs for future foundation analyses. Development of first models of the mill girth gears. Root cause analysis showing that the asymmetrical design of the gear blank resulted in thermal ratcheting of the gear and hence failure [7].

11. **Cadia Hill Gold Mine, NSW, 1996 to 2000. Foundation and gearless drive stator modelling.** Modelling of SAG and ball mill foundations using modal analysis to avoid

excessive vibration. Design of vibration test set up to determine vibration characteristics of the SAG mill gearless drive stator that vibrated excessively during commissioning. Root cause analysis of stator vibration, modelling and development of nonlinear differential equations to simulate stator behaviour. Numerical analysis and remedial design. Paper presented at SAG 2001 Conference, Vancouver [6].

12. **North Parkes Mine, 1995: Numerical modelling of new ball mill foundations for Stage 2 expansion.** This was based on simple modal analysis and used to avoid recurrence of excessive vibration levels exhibited in Stage 1 ball mill foundations.

13. **Porgera Mine, Papua New Guinnea, 1993: Redesign of vertical conveyor pulleys.** Development of scope and budget for remedial design of failing conveyor pulleys for the world's largest vertical conveyor at the time. Design of instrumented idler pulley (50% with Bill Lai, then with Grigg and Associates) to determine dynamic belt tensions. Numerical modelling of conveyor tensions and calibration with measured data. Complete redesign of head, bend and tail pulleys based on measured data and finite element analysis of the pulleys.

PUBLICATIONS:

1. Meimaris, C., Lai, W. K. K. L., 2011. "On the Comparison between Measured and Calculated Stresses in Large SAG Mills". Minerals Engineering, v. 24, pp. 1631-1637, 2011.

2. Meimaris, C., Lai, W. K. K. L., 2011. "Fatigue Design of Ball Mills". Minerals Engineering, v. 30, pp. 52-61, 2012.

3. Meimaris, C., Lai, B., Price, B. F., Manchanda, S., 2006. "How Big is Big? – Revisited", SAG 2006 Conference, Vancouver.

4. Meimaris, C., Price, B. F., Manchanda, S., 2006. "Large Mill Systems – Responsibilities and Capabilities", SAG 2006 Conference, Vancouver.

5. Meimaris C., Price, B. P., Quaife, 2002. T. W., Willis, P. J., "Assessment and Management of Risk in the Purchase of Large Mills for Medium Size Mining Companies", Minerals Engineering '02, Perth.

6. Meimaris C., Lai, B., Cox, L., 2001. "Remedial Design of the World's Largest SAG Mill Gearless Drive", SAG 2001 Conference, Vancouver.

7. Meimaris, C., Duncan, M. D., Cox, L., 2001. "Failure Analysis of Ball Mill Gears", SAG 2001 Conference, Vancouver.

8. Meimaris, C., Boughey, A. M., 2001. "Modelling of Grinding Facilities", SAG 2001 Conference, Vancouver.

9. Meimaris, C., 2002, "Design of Very Large Mill Installations: Mill Design Specifications and Audits", Metallurgical Plant Design and Operating Strategies Conference, Sydney, April, 15-16 2002. The Australasian Institute of Mining and Metallurgy.

10. Meimaris, C, Day, J. D., 1995. Dynamic response of laminated anisotropic plates. Computers and Structures, vol. 55, no. 2, pp. 269-278.

11. Meimaris C. Grigg F. W., 1994. "The Design of Pulleys to Withstand the Operating Forces in a Pocketed Belt- Type Vertical Conveyor", Northern Engineering Conference. June, 1994.

12. Foster, C. G.; Meimaris, C.; Hooker, R. J., 1992. “Transverse strain behaviour in No. 2011 aluminium alloy subjected to cyclic loading”. Journal of Sound and Vibration, Volume 158, Issue 2, p. 245-256.