VEMPTO

# Empresa Ingeniería Mecánica

Somos una empresa dedicada al análisis, diseño y simulación de componentes mecánicos, además del desarrollo de nuevos algoritmos matemáticos numéricos y simbólicos para la ingeniería

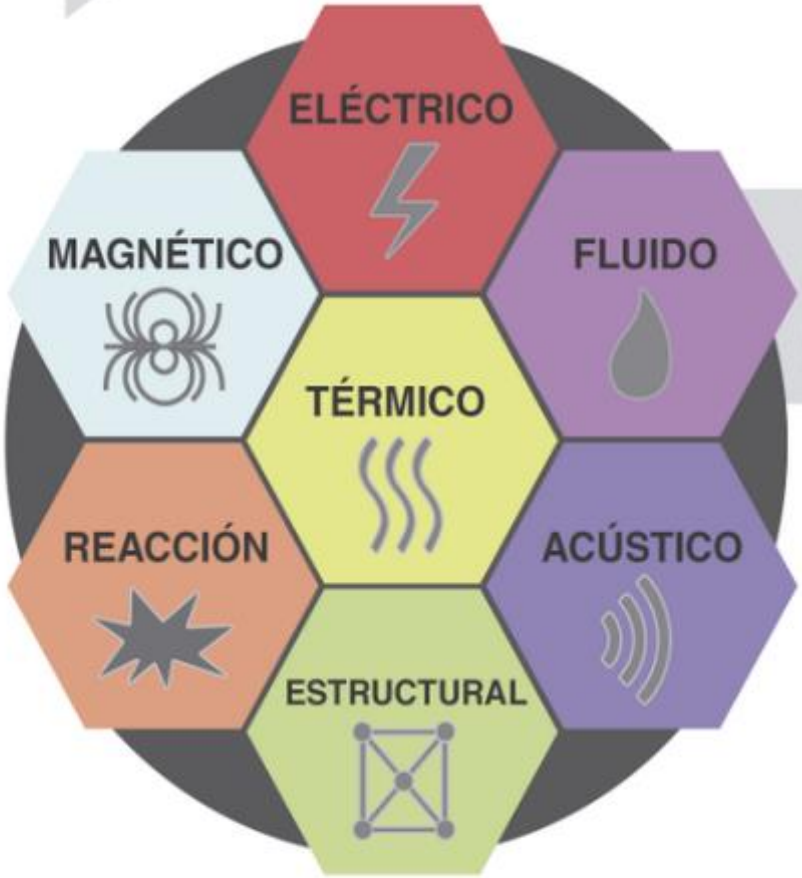
# Nuestra Diferencia

Mezcla de soluciones customizadas que permiten realizar tareas que las industrias de electrónica, matemática, aeronáutica no realizan por el nivel de desarrollo involucrado o que no se vuelven competitivas por el costo asociado.

→ Algoritmos matemáticos para distintas funciones
→ Softwares propios
→ Firmware propios
→ Electrónica propia
→ Teorías de control // sistema para detección de fallas // optimización propio.

Forma tradicional de resolución; tecnología secuencial de acople multifísico

**VEMPTO** Algoritmo de solución para ecuaciones hyperbólicas, parabólicas y elípticas.

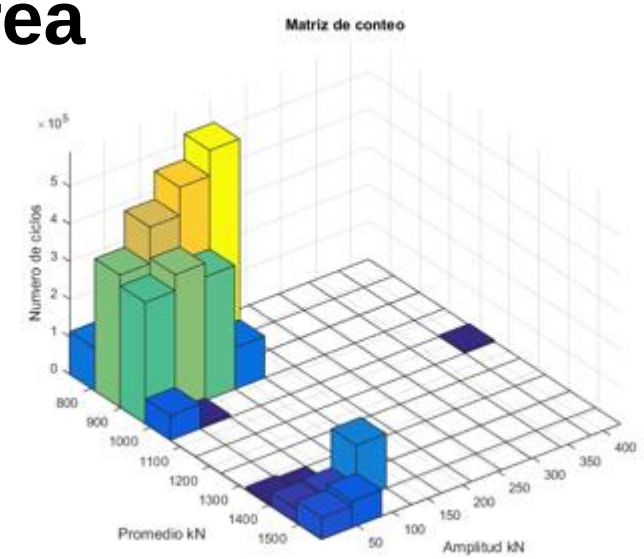


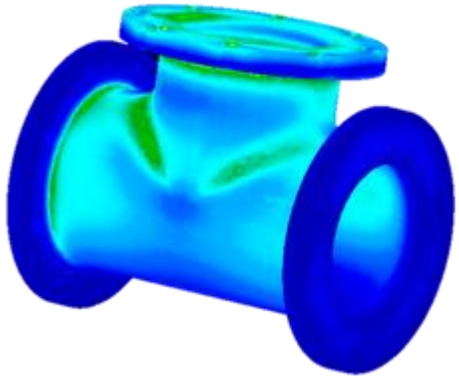

Tecnología de acoplamiento multifísico de resolución simultánea

**VEMPTO**

# Business Area

1. Simulation – Calculation
2. Consultancy
3. R&D



# Vempto in mining industry

bhpbilliton

MINERA ESCONDIDA
Operada por BHP Billiton

- 4 products & services
- R&D

EWS

- service

AngloAmerican

ANGLO AMERICAN LOS BRONCES

- 2 products & services
- R&D

ANTOFAGASTA MINERALS

CENTINELA
ANTOFAGASTA MINERALS

- 3 products & services
- 3 R&D

LOS PELAMBRES
ANTOFAGASTA MINERALS

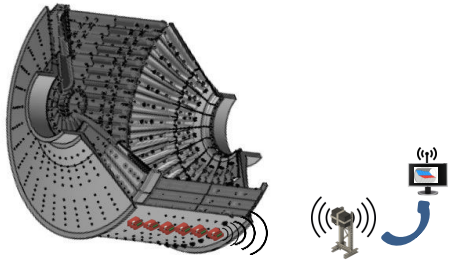
- 2 products & services
- R&D

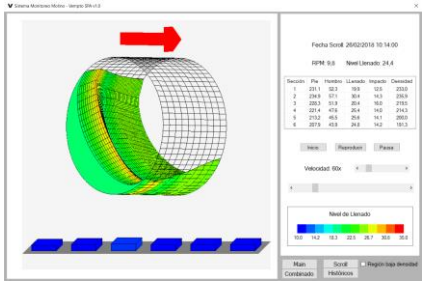
# Products and services

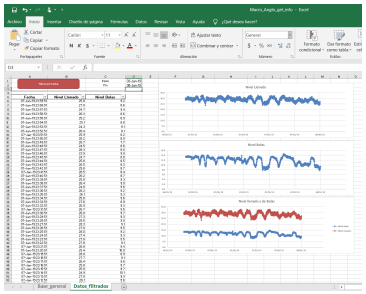
| Reability (Safety for fasteners systems and structures) | Operation (Measurement and control) |
|---|---|
| Structural integrity monitoring system for SAG and Balls mills. | On line load distribution system |
| On line bolt load system | Harness orbit measurements system |
| On line vibrating and fatigue system | |
| Harness orbit measurements system | |

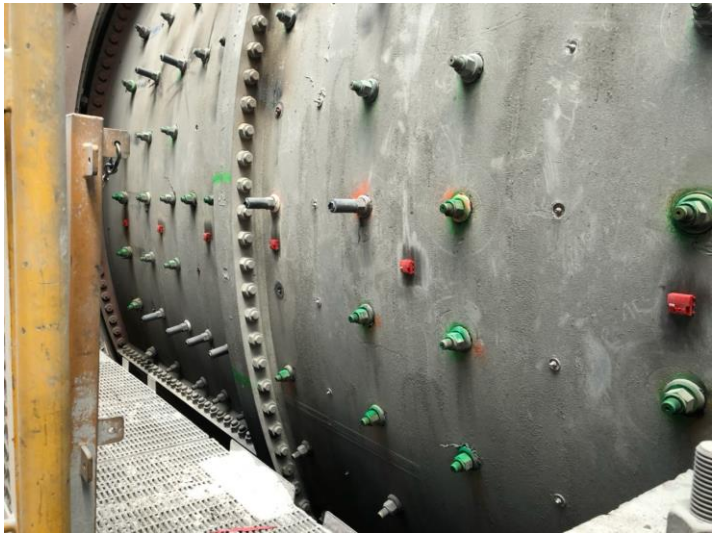
**Software and hardware…**

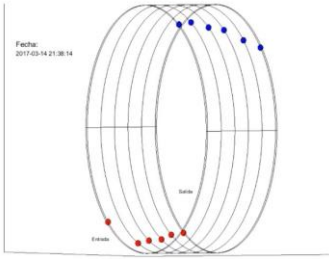
# Sistema de medición de distribución espacial de carga para molinos de minería

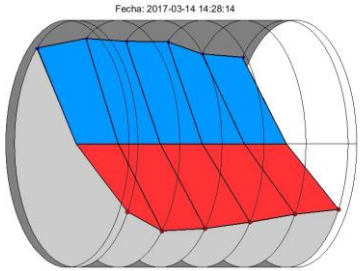


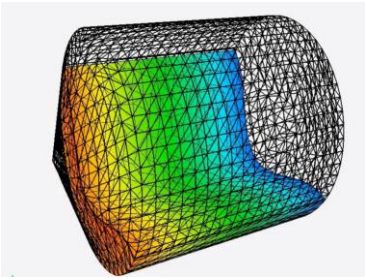










# Benchmark

| benchmark, suppliers for charge, Jc and Jb, level online monitoring | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| supplier | product | country | product status | description | scope | patent | %Error |
| Vempto | OLLDS | Chile | under development | set of sensors (magnetic, accelerometers, gyroscope) that would determinate toe and shoulder position and create a charge 3D model and with a self algorithms determinate load distribution. Online monitoring | toe shoulder, load distribution, filling levels, Jc, Jb, operative curves. | no (?) | <1% |
| Netos | onmill | Chile | completed | System that combines sensor and operational data to model charge level and toe-shoulder position to output Jc and Jb. Online data reporting under a customized platform. | Jc and Jb out of operational sensor based modeling. Online real time reporting | ? | ? |
| kscape | Millscaner | US | validation | Part of a expert control system, "grinding expert SAG Mill", that integrate operational data and shell installed sensor data to provide charge position and angle. | accurately and continuously monitors a mill's contents to provide invaluable information regarding charge toe and media angles, liner/steel impact detection, and volumetric loading in real time | ? | ? |
| digital control labs | Millslicer* | US | completed | array of sound sensors installed at feeding and discharge bearing, and at the shell, to determine charge level and toe-shoulder position. | mill fill level measurement for automated loop control. maximum ball strike location on the mill as well as toe/shoulder trajectory estimations. | yes | 5% |

** http://www.totalmetric.cl/MillSlicer-Jc%20Model%20Validation_Eng_R2.pdf

# Benchmark

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## The relationship between charge shape characteristics and fill level and lifter height for a SAG mill

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Shoulder
Toe

ABSTRACT

A predictive model that allows mill fill level and the lifter height to be determined from measurements of the head, bulk and impact toe positions for a generic SAG mill has been developed using data from a series of three dimension DEM simulations. A Design of Experiment (DOE) approach is used to define a series simulation conditions with the two factors being the lifter height and the fill level. The charge structure is characterised by the locations of the head, shoulder, bulk toe and impact toe. These are determined by visual analysis of the particle trajectories. The spatial variation of the liner pressure distribution can provide valuable information on the structure of the charge. This was found to vary systematically with lifter height and fill level. The relationships between the visual key locations and the key features of the pressure distributions were identified and found to be well described by linear equations. Finally, parametric models are fitted to the DEM data for both the lifter height and fill level allowing them to be estimated from measurements of the key charge locations. These could be used as part of a control strategy for the mill and/or to assist with re-line scheduling.

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### 1. Introduction

Tumbling mills are large cylindrical chambers that rotate about their central axis at a reasonable fraction of the speed required to centrifuge the particulate charge. This usually consists of a combination of grinding media (steel balls) and rocks (in various stages of size reduction). The rotation of the mill leads to shear between adjacent layers of particles. Grinding is produced by a range of mechanisms including high speed impact, abrasion, chipping and nipping of small particles between large ones (Delaney et al., 2013). SAG mills are the largest type tumbling mills used (with diameters up to 42 ft or 12.6 m) and are used for primary grinding, mainly in mineral processing, using a coarse feed (typically up to 250 mm diameter rock) coming from a crushing stage of the grinding circuit. Ball mills are somewhat smaller and use a larger fraction of grinding media with a finer feed size and are typically used for some form of second stage grinding.

The charge distribution within such mills usually has a kidney like shape with particles moving upwards near the mill liner, reaching a high point where the centrifugal and gravitational forces balance (usually called the "shoulder") and then flowing downwards with a free surface that is typically bi-linear with a steep gradient down from the shoulder followed by a shallower gradient out to the start of the charge (usually called the "toe"). If large and/or steep lifters are used in the liner design to lift the charge then some particles are thrown on high ballistic trajectories (in what is usually called the cataracting part of the flow) and impact on the liner in a region above the toe. The top of this direct liner impact region is often called the "impact toe". The highest point of the liner that is still in contact with the particles is also called the "head". The locations of these key characteristic locations of the charge provide significant information about the current operation of the mill and can be used in controlling the mill. These locations all vary with critical mill conditions such as the mill speed, the fill level and the conditions of the lifters.

A major measurement challenge has been and remains to be the reliable measurement of these locations. Measurement is possible in laboratory scale experiments, such as when using

- Perspex front mill models as measured by Ward (1992) and used in Cleary et al. (2003). Katubilwa and Moys (2011) used a Perspex mill to explore load behaviour in a tumbling mill and its relationship to charge volume slurry viscosity. Conduction based probes (Moys et al., 1996) although tend to be more useful for identifying the slurry position rather than

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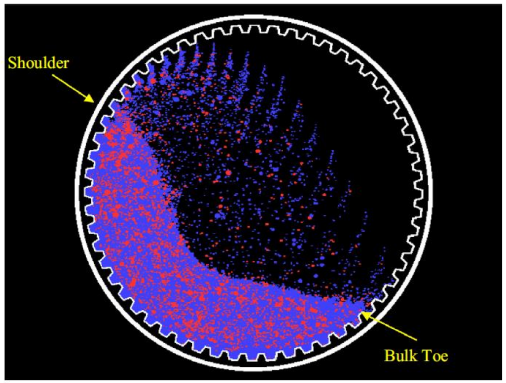
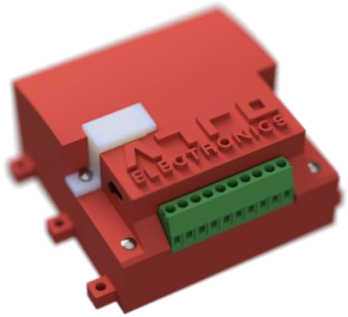


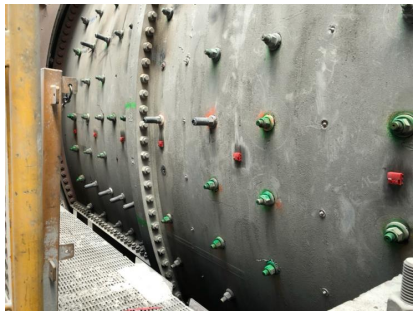

**Table 5**
Predicted locations of the bulk toe, impact toe, shoulder and head positions for the twelve 3D DEM simulation cases.

| Case | Fill level (%) | Lifter height (mm) | Head (°) | Shoulder (°) | Bulk toe (°) | Impact toe (°) |
|---|---|---|---|---|---|---|
| 1 | 27.5 | 50 | 130 | 150 | 318 | 306 |
| 2 | 27.5 | 175 | 110 | 148 | 314 | 330 |
| 3 | 32.8 | 263.4 | 104 | 146 | 318 | 334 |
| 4 | 35 | 175 | 110 | 146 | 320 | 330 |
| 5 | 27.5 | 175 | 110 | 152 | 314 | 330 |
| 6 | 27.5 | 300 | 98 | 152 | 312 | 338 |
| 7 | 27.5 | 175 | 111 | 152 | 314 | 332 |
| 8 | 22.2 | 263.4 | 104 | 158 | 306 | 336 |
| 9 | 27.5 | 175 | 112 | 152 | 314 | 332 |
| 10 | 20 | 175 | 112 | 164 | 306 | 330 |
| 11 | 22.2 | 86.6 | 123 | 160 | 310 | 316 |
| 12 | 32.8 | 86.6 | 122 | 148 | 324 | 320 |

*For the same fill level the system shows differences in shoulder angle, and that's what the other systems can't take away from those algoriths.*

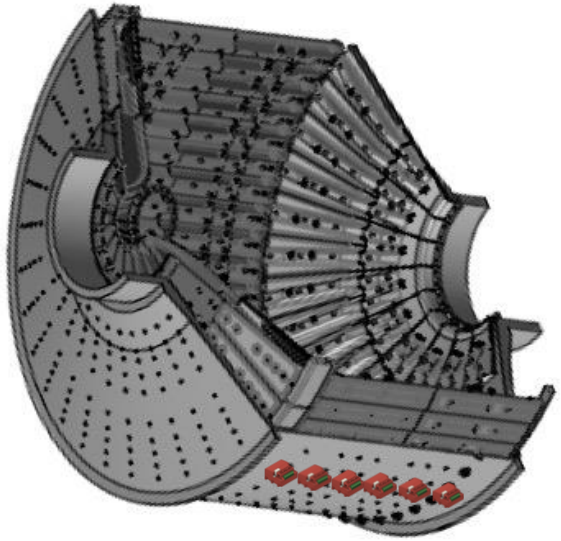
# Sistema de medición de distribución espacial de carga para molinos de minería

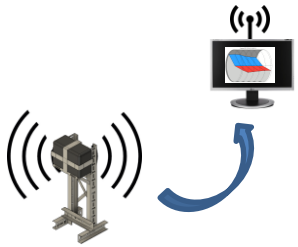




**Hardware:**

- **6 magnetic sensors**
- **1 Central computer**





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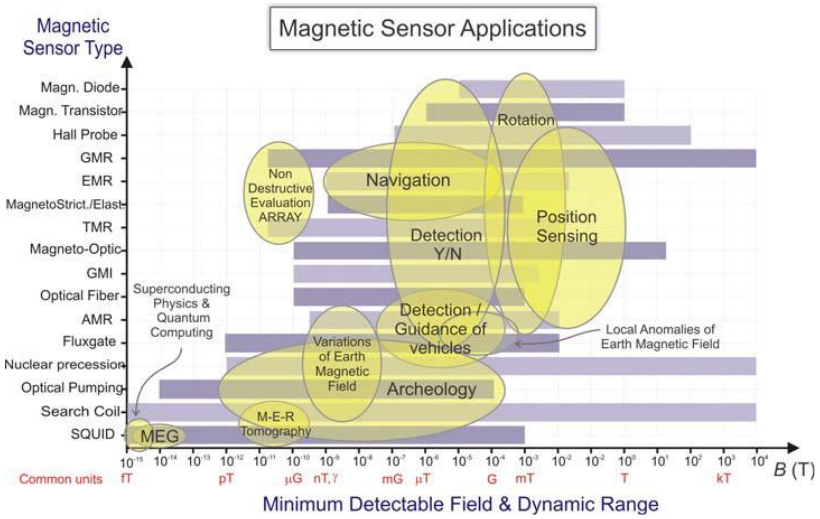


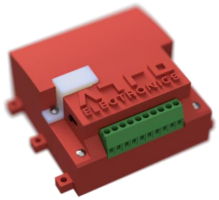

$$\text{(a)}\ \int_{\text{closed surface}} \vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0} \quad \textit{Gauss' Law}$$

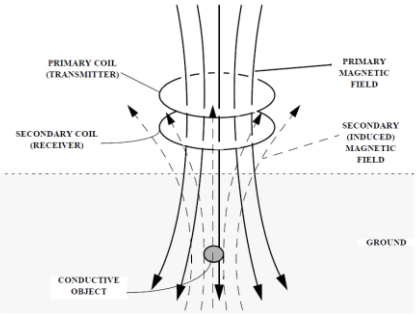
$$\text{(b)}\ \int_{\text{closed surface}} \vec{B}\cdot d\vec{A} = 0 \quad \textit{No Monopole}$$

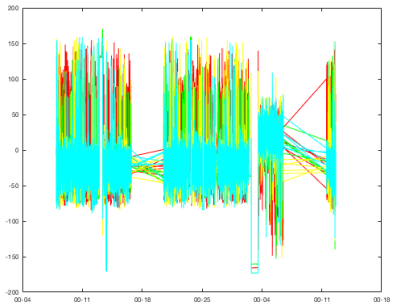
$$\text{(c)}\ \oint \vec{B}\cdot d\vec{\ell} = \mu_0 i + \mu_0\varepsilon_0\frac{d\Phi_E}{dt} \quad \textit{Ampere's Law}$$

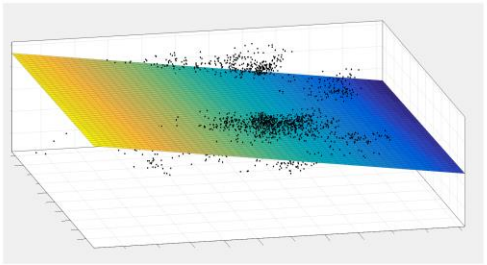
$$\text{(d)}\ \oint \vec{E}\cdot d\vec{\ell} = -\frac{d\Phi_B}{dt} \quad \textit{Faraday's Law}$$

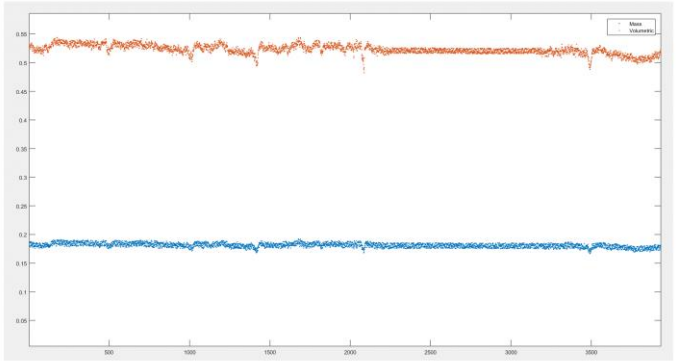
(19)



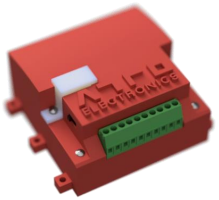






- On line load distribution system for mining mills



Direct measurements

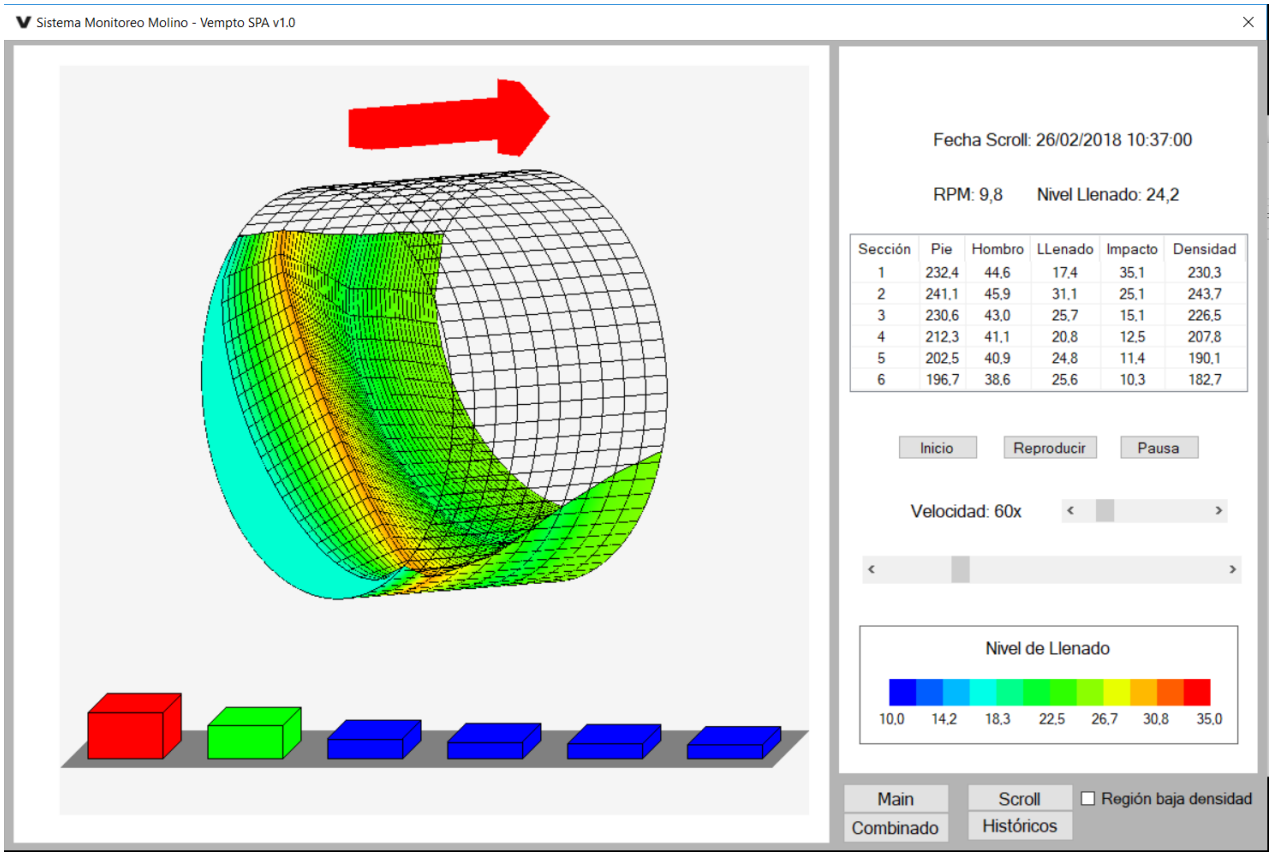
O. Variables

Stochastic model

Fill level value most likely to respond to input variables

<1% error!!

# Sistema de medición de distribución espacial de carga para molinos de minería

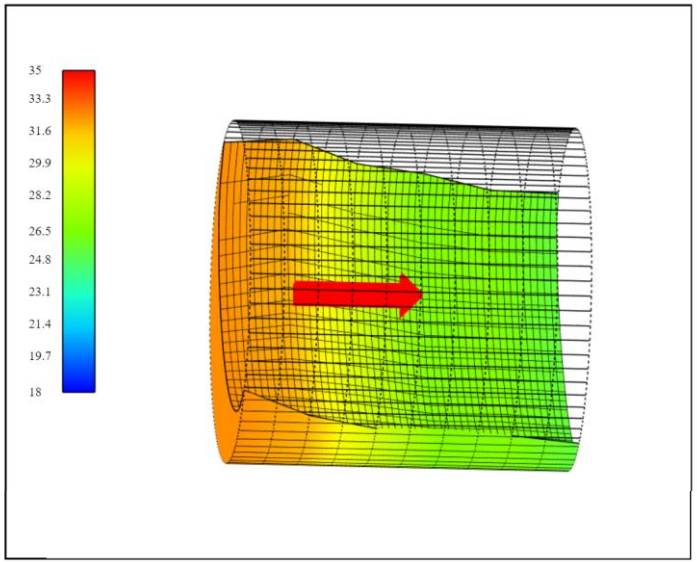



http://pablocastillo-001-site11.atempurl.com/login.php

# Sistema de medición de distribución espacial de carga para molinos de minería

**Nivel Llenado Molino SAG :**

**Histórico Llenado vs Tiempo [días]**



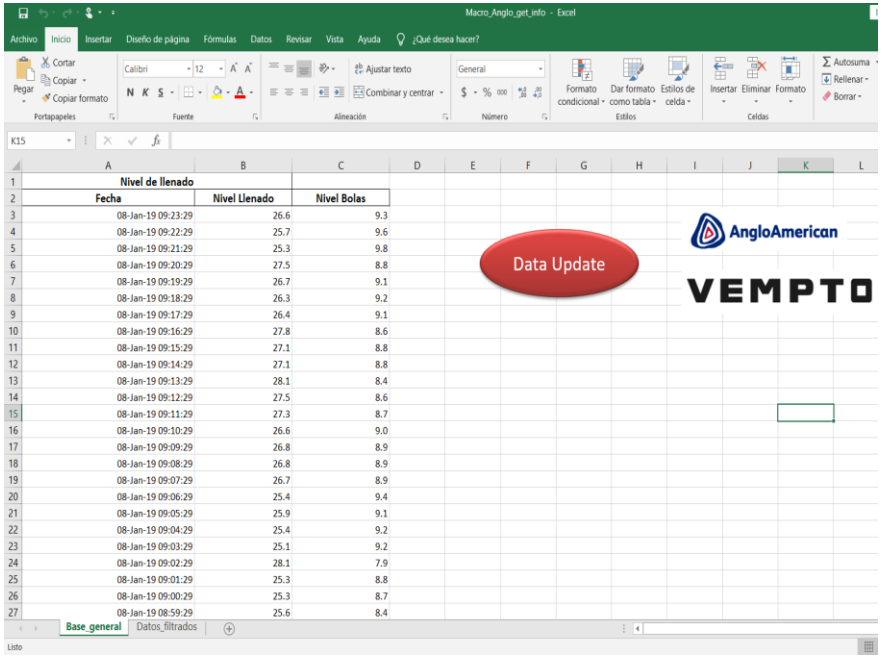

Actual | Scroll | Históricos | Combinado

**Fecha Mostrada: 08-01-2019 09:00:00**

**Nivel Llenado Global: 25.84 [%]**

**Nivel Bolas: 8.74 [%]**

| Sección | Pie [°] | Hombro [°] | LLenado [%] | Impacto [kN] | Densidad [°] |
|---|---|---|---|---|---|
| 1 | 226.15 | 71.82 | 31.53 | 19.53 | 0.00 |
| 2 | 236.57 | 75.29 | 30.58 | 18.31 | 0.00 |
| 3 | 242.26 | 61.03 | 26.83 | 17.88 | 0.00 |
| 4 | 241.67 | 56.88 | 22.78 | 16.01 | 0.00 |
| 5 | 244.50 | 50.13 | 22.70 | 15.03 | 0.00 |
| 6 | 248.02 | 49.27 | 21.09 | 13.64 | 0.00 |




Data Update

AngloAmerican

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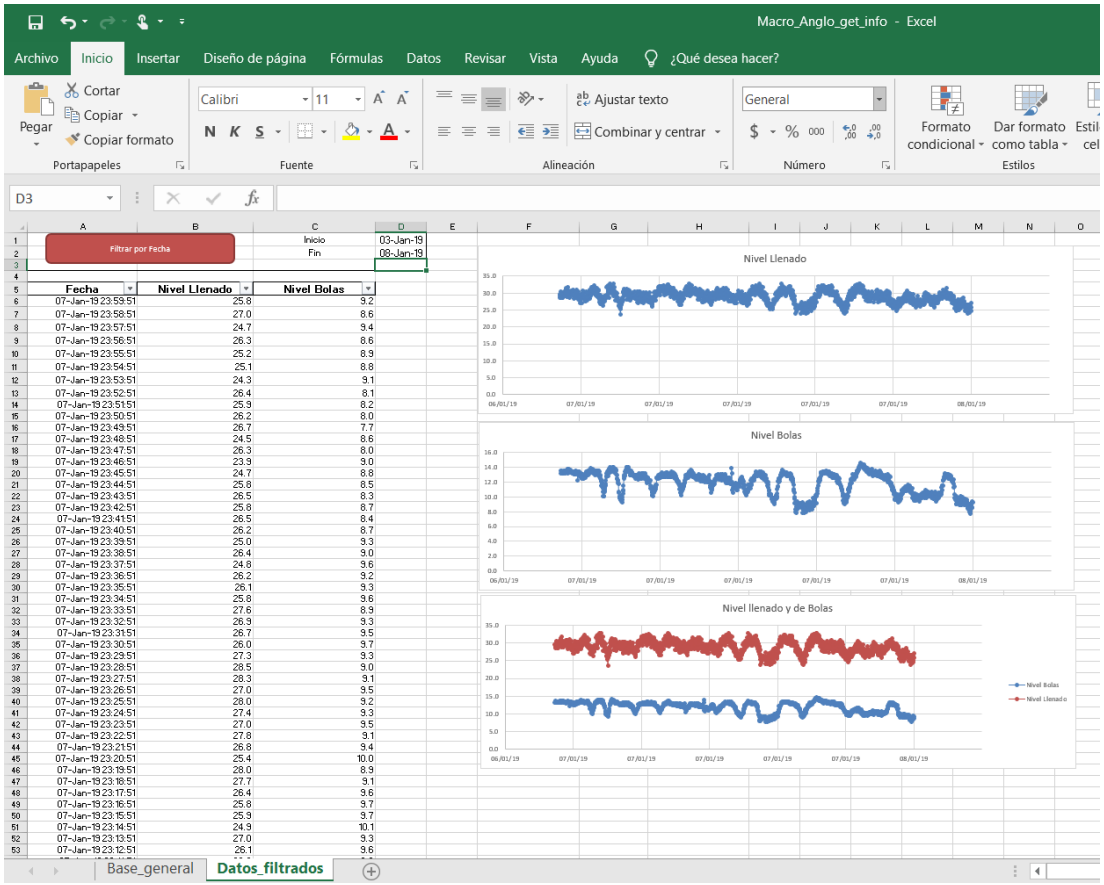
# Sistema de medición de distribución espacial de carga para molinos de minería



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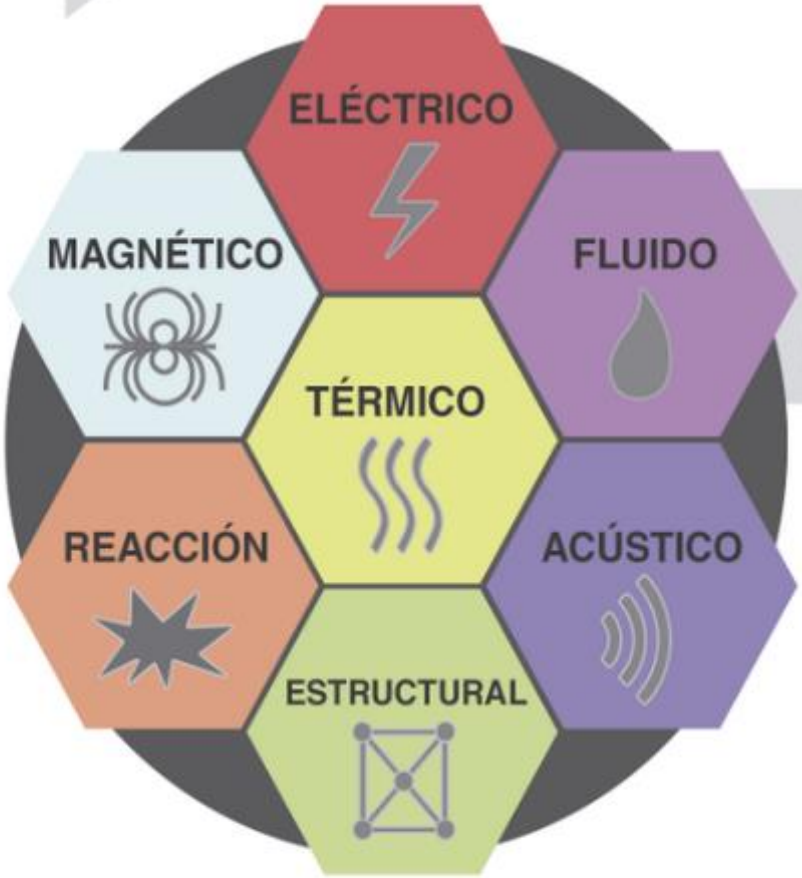


Tecnología de acoplamiento multifísico de resolución simultánea

**VEMPTO**

# Contact

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