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1 THESIS PROJECT VIBROHAMMER SIMULATION AND CONTROL

1.1 eQuip

Equip is a young cleantech company which had the focus on supplying advanced drive and control systems for:

- Zero-emission equipment for OEM new build Heavy duty equipment
- Diesel engine replacement kits based on a fit for purpose electrical drive system.
- Own product development for driving zero-emission equipment.

Our main customer base is in the construction industry and for this branch we are developing a medium size vibrohammer with independent controlled excentres.

For more info about eQuip: https://www.equiptech.nl

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1.2 Vibrohammer introduction

A vibrohammer is used for driving sheet piles or tubes into the ground for civil projects and currently almost all vibrohammers are hydraulically driven by hydraulic motors that are capable of driving the system under harsh conditions with accelerations in the range of 30..50g. The second reason that vibrohammers are currently hydraulically driven is due to the high power density of hydraulic systems which keep the dynamic vibrating mass low and thus increases the performance of the vibrohammer. This all is done by rotating one or more opposing excentre pares to create a vertical vibrational motion in the range of 40hz and results in the vibrohammer and sheet pile to overcome the ground resistance which eventually drives the sheet pile into the ground.

Mainly to avoid resonance frequencies, variable moment hammers were invented in the 80's, where the drivetrain consists of 4 excentres (or a multiple of 4) driven by hydraulic motors. All excentres are coupled by gears but the relative position of 2 pairs of excentres can be adjusted relative to each other with an adjustment gear. This makes it possible to adjust the eccentric moment of the vibrohammer between 0-100% . During start up the moment is adjusted to 0% which results in no vibration until an operating speed above the resonance frequency of the adjacent buildings is reached from that point the eccentric moment is increased and founding motion is started.
For more info on a standard vibrohammer drive system and moment adjustment: hydraulic vibrohammer principle animation

1.3 Development of a zero emission / energy efficient vibrohammer

Due to the global climate change and the stricter becoming emission laws, there is a high demand for zero emission equipment. This in combination with the quickly accelerating electric motor technology, mainly driven by the automotive industry, makes it possible that nowadays permanent magnet electric motors have a comparable power density as hydraulic motors and opened the door for an electric driven vibrohammer with better performance than a hydraulic vibrohammer. Furthermore it's possible to control the position of the electric motors very accurately in combination with an electric variable frequency drive(VFD) which eliminates the need of timing gears and thus less mass and higher efficiency.

The development of an electrical vibrohammer started 2 years ago with three development partners:

1. a former business owner of a Vibrohammer company
2. eQuip with a strong background in drive and control technology
3. one of the major foundation companies in the Netherlands

The goal of the collaboration was to develop and test the most energy efficient drive train for a vibrohammer that eliminates the current losses of the diesel / hydraulic powered vibrohammer and is also scalable in power from 50 kW to over 1 MW.

This resulted in a spin-off in the form of a new company, Electrical Foundation Equipment B.V.(EFE) and a proof of concept project, where an hydraulic vibrohammer was converted to a direct driven electrical vibrohammer, where field tests proven the theoretical 30..40% lower energy consumption compared to a similar diesel / hydraulic systems with gear coupled excentres. Furthermore a patent was granted to this innovative technology: NL2026179B9 - Vibratory hammer with electric motor - Google Patents

Currently several test has been done with a modified version of a hydraulic hammer to test robustness of permanent magnet motors, below an example of the modified vibrohammer where 2 motors are driving 2 excentre pair, but the relative angle and thus eccentric moment is electronically adjusted via a control algorithm in the electric drive and control system.

A conversion of a vibrohammer, as done in the proof of concept, is always sub-ideal due to the limitations of an existing periphery and therefore the next step in our development, is the design of a from sketch new electrical driven vibrohammer where all the benefits of an electric drive and control system can be fully used:

- Single motor per excentre (not per pair)
- Each motor is controlled by a VFD
- Relative position during rotation is actively controlled between zero and maximum moment
- No coupling gears at all

1.4 Thesis

An important step in the new design is to improve the mechanical part of the drive system and control strategy and gain more insight in the system dynamics and possible control concepts.

The thesis will highly contribute to the product development in the long term due to:

- Knowledge development in the field of system dynamics, energy flows and control theory
- Possibility for technical optimization of the system from a performance point of view
- Cost reduction due to increased knowledge
- Availability of a development tool for future new vibrohammer sizes/models

Topics:

- Develop a parametrizable dynamic vibrohammer model in Matlab-Simulink with:
    - Vibrohammer dynamics
      Possibility to flexibly adjust the number and location of the drivetrains and drive line parameters
    - Basic soil dynamics flexible in number of elements dynamic elements
    - Coupling between basic soil model and vibrohammer
    - 1st order approach for drive train
- Develop a basic model for a control system capable of:
    - Controlling actual position
    - Minimizing torque ripple from driving excentres by making use of the drivetrains kinetic energy
- Analysis of Energy flow
- Depending on time schedule / planning possibility to do field test for data validation of model

1.5 Benefits

Contribute to the product development of an energy efficient / zero-emission piece of foundation equipment in a young developing company.

Additionally we offer a thesis fee of 750 euro per month.