TECHNICAL EVOLUTION ON CONCRETE MACHINERY

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Abstract

In the European concrete machinery market, operators ask even more for safe, ecologic and reliable machinery. The demand for lighter (complying the weight restrictions for the on-road applications), money-saving and environment-friendly equipment drives the technical evolution facing new challenges. The new R&D path is testing new composite materials, following the successful application in the aerospace industry. This technical path is a real breakthrough and with high development potential, allowing unreachable strength and lightness of the structures using traditional materials, the outcome impacts on energy saving and wear reduction, thus reducing the total cost of the ownership of the machinery.
High strength steel structures have already approached their optimization limits. In order to make a significant step further, the industry needs new materials combining the concepts of lightness, high resistance and environmental sustainability, which will impact also on the new products shape and geometry.
In order to address the demand for safety, machinery manufacturers are developing automatic (and not manual anymore) control systems which will guarantee the machinery stability in all the working conditions found on jobsites, a reduced placing boom oscillation and alarm, or blocking, systems to prevent electric-shock contacts.
Finally, simulation tests of the life-cycle machinery are even more important to offer to the customers reliable products and suggestions for fleet maintenance program management.

Keywords

R&D, Composite materials, Weight restriction, Breakthrough innovation, Energy saving, Environment, Concrete Machinery.

Biographical notes

Current position:
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Previous position:
Since 2009, Group R&D and strategic Sourcing Director of Cifa Group and also of the Zoomlion concrete division in charge of: R&D activities of the Cifa Group; Coordinate the activities and the integration with the R&D of Zoomlion concrete division; Coordinate the activities of Strategic Sourcing for the group Cifa and Zoomlion concrete division.
Previous Work experiences:
He started in the 1992 as a calculation and experimentation engineer in Cifa technical department. In 1998, responsible for Design in the Cifa Technical department. In 2006, Technical Director of Cifa with the responsibility to manage the technical department and the R&D activities. In 2008, Product and Supply Chain Director with the responsibility to coordinate and manage the activities of R&D, Material management, Production and product Quality of Cifa Group.

1. INTRODUCTION

In the European concrete machinery market, operators and customers ask even more for safe, ecologic and reliable machinery.
The demand for equipment lighter (complying the weight restrictions for on-road applications), safe in the use, money-saving and environment-friendly, drives the technical evolution facing new challenges.
The R&D in the concrete machinery field must consider very carefully these guidelines in order to develop products and technologies fitted to reach these targets and give a real answer to the market requests especially in this deep economic downturn.

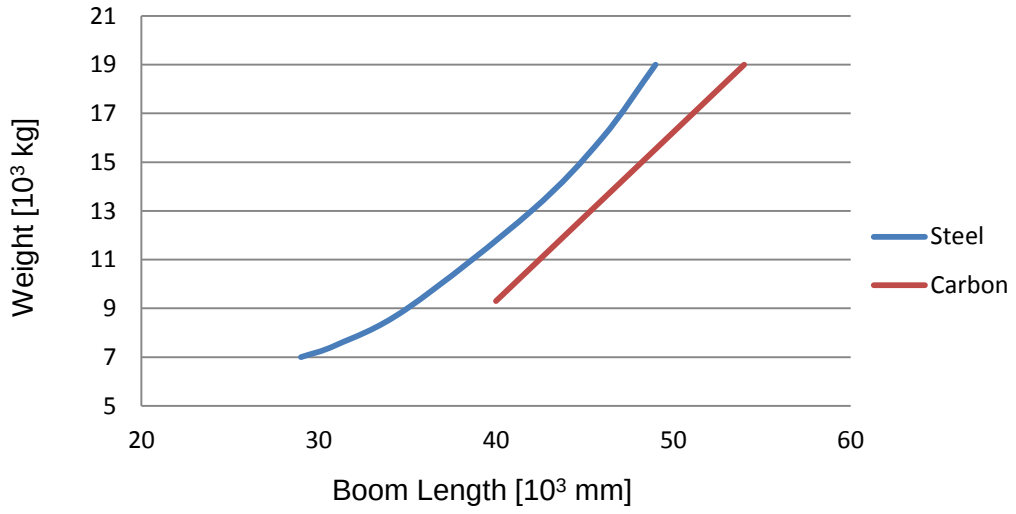
The Guidelines for the technical evolution on the concrete machinery are:

- Lightness & Strength: New Materials and Technologies
- Energy Saving and Environmental respect
- Safety & Automation control
- Reliability & Extended warranty

2. Lightness & Strength: New Materials and Technologies

High strength steel structures have already approached their development limits in their use for concrete distribution booms.

Fig. 1 - Steel Vs Carbon: Length and Weight comparison path



Only the use of different technology can drive to a significant improvement in terms of weight. One explored possibility is represented by non-ferrous materials. The experience from advanced fields of applications such as aerospace industry, the racing world indicates composite materials such as carbon fiber are a reliable alternative in structural material when the performance of steel has to be bettered.
Combining the concepts of lightness, high resistance and environmental sustainability, impacts directly on products considering not only the materials they are made of, their shape and design, but also the processes needed to manufacture them.
This effort is mainly focused in the adaptation and validation of technology to our industry and drives the R&D path into testing these new composite materials for the design of booms for concrete distribution.
This technical path is a real breakthrough and has high development potential, allowing unreachable strength and lightness with the traditional materials, impacting on energy saving because of lighter machinery travelling on the roads and using fuel, and are also applicable for wear reduction purposes, bringing the users lighter, highly technological products, reducing the total cost of the ownership of the machinery.

2.1.Technology: Carbon Fiber and Curing Oven

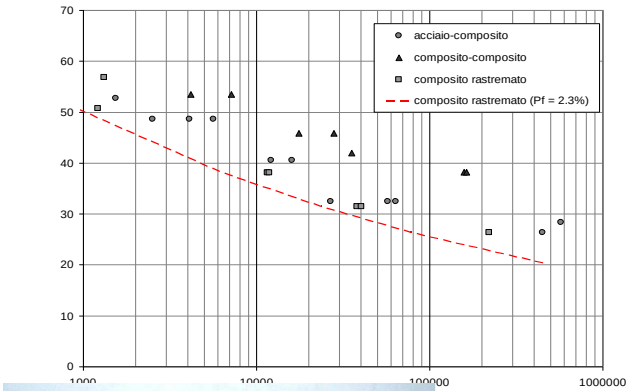
The process needed to manufacture composite material objects is completely different from the processes commonly used for steel structures. Instead of cutting and welding as the main steel processes, mould design and curing processes represent the main steps.

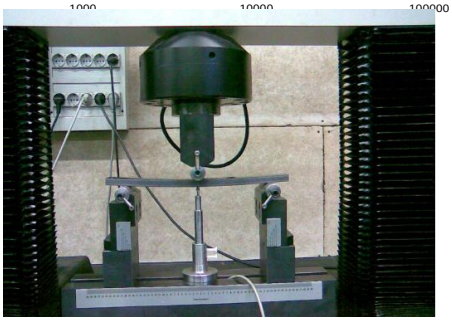
Fig. 2 - Curing oven and carbon fiber raw material

2.2. Composite materials know-how: the technology development and transfer

The first step when making such radical innovation is the choice of the right material and following validation for the industry. Also the base characterization of the candidate materials has to be carried out in order to provide a starting ground for the actual design phase of the structures using the correct stress models, considering strength but also fatigue resistance to meet the expected life of an industrial product.
These activities have to be made in cooperation with Research Institutes such as Universities.

Fig. 3 – From left to right: Tensile test, Flexural test and Fatigue test





2.3. Steel Rod vs Carbon Rod

The use of new material brings to a complete redesign of each component to best exploit its peculiar characteristics.
The weight saving of a component of the boom such as a rod can be as much as 40%.

Fig. 3 – Left: Steel rod. Right: Carbon fiber rod

2.4. Longer and Lighter Boom

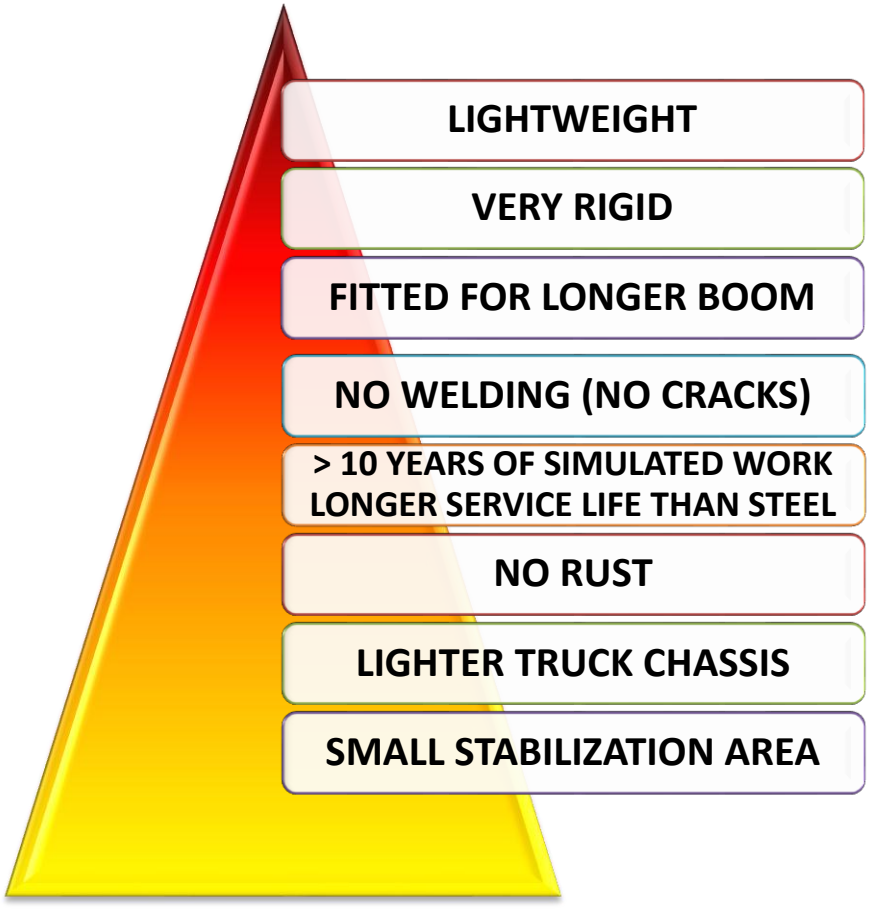
Given the lower weight and the higher resistance of carbon fiber it is possible to manufacture legal-weight-compliant truck mounted pumps with a longer boom, delivering a real advantage to the users. Comparing the 4th and 5th sections of a 40 meters class boom pump, adopting

carbon fiber allows a weight saving of 30% and 20% respectively; considering length, the carbon fiber allows a length increase of 17% and 18% respectively.

2.5. Advantages

Weight and resistance (rigidity) are not the only advantages this technology brings on the market. It is possible to brake the limits of the longest boom pump mounted on a standard road chassis. As proven from field experience, weldings are the source of fatigue inducted failures. Composite material equipments after curing become monolithic, specific tests have proven high level of fatigue resistance exceeding more then 10 years of operating life without any problems (bench tested in 1:1 scale models).
Being not ferrous-based, rust is not a concern. Lightness in the boom also means a lower tilting moment transferred to the base truck mounted pump structure. This effects directly the weight needed to stabilize the all machine (lighter truck) and the area occupied by the outriggers – extending even more the actual jobsite effectiveness of the boom length.
So it is possible to create a new complete range with higher performances. Using only same parts in carbon fiber the increase of costs can be recovered by the saving in the trucks characteristics and in homologation and fuel consumption costs.

Fig. 4 – Resume of Carbon fiber use in concrete machinery



2.6. Other frontiers for new material technology

The use of new composite materials with also different composition, can open new frontiers, not only in the boom design and production, but also in many other components of the machines (batching plants also). The target is to get lighter, stronger products that deliver at the same time wear resistance, allowing cost saving.

Fig. 5 – Other possible fields of application for composite materials

Composite material in Hydraulic components

Composite material in wear components

3. Energy saving and Environmental Respect

From one side, the use of innovative composite materials instead of the traditional ferrous materials, allow to reach lightness on machines with the result of impacting on energy saving and wear reduction, reducing the total cost of the ownership and maintenance of the machinery.
From the other side, the technical evolution on concrete machinery, especially in the present economic downturn scenario, must focalize on all those technologies that have been proven to be effective in the energy saving field. Hybrid technology (Diesel engine - Electric engine) shall be explored in order to lower the energy wastes in concrete machinery and batching plants, bringing at the same time a positive impact on the environment.

4. Safety & Automation

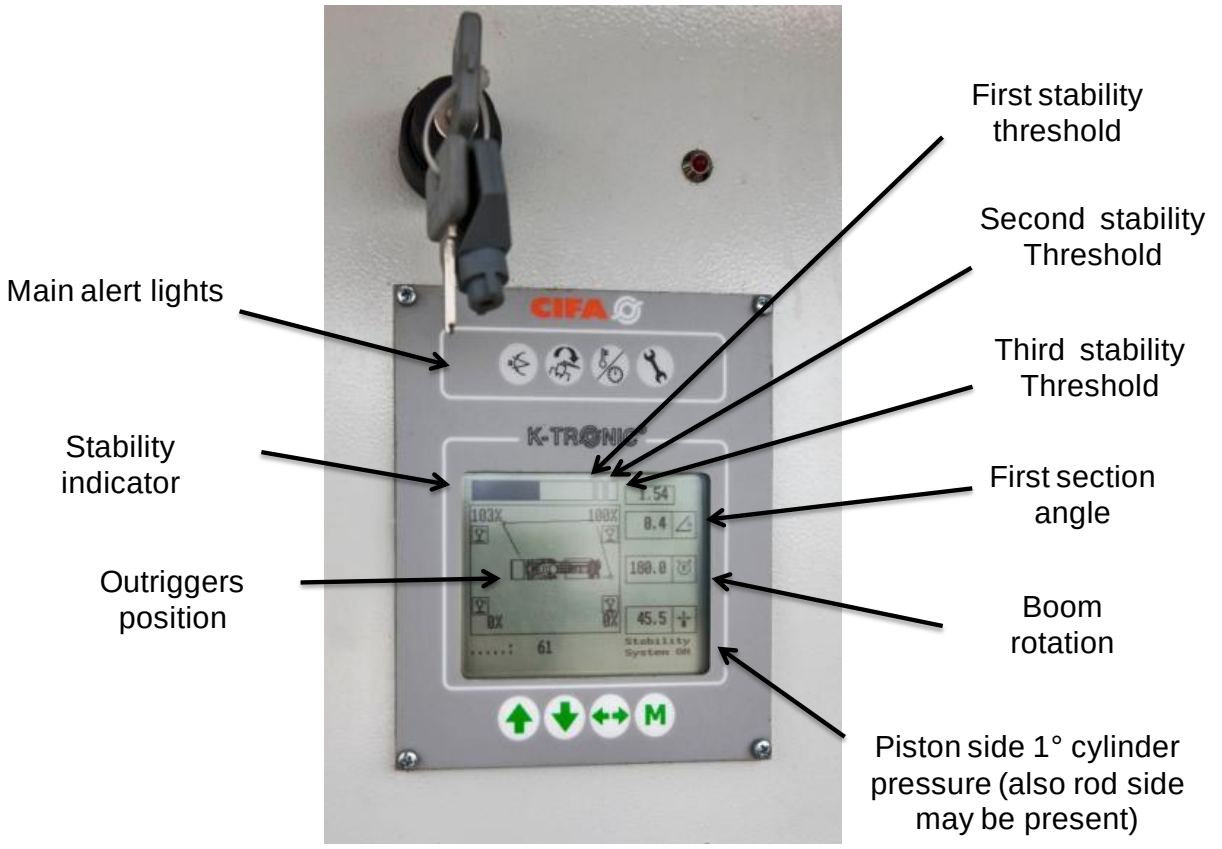
Electronics can play a major role in concrete pumps, in order to make the operation of such machines, increasingly easier and to minimize the risk of injury and accidents.

The control of the stability is an example of an available technology applied to this field addressing one of the main risk of these machines working in jobsite. Other applications are systems designed to reduce the boom oscillations during use or to prevent a contact with an electric aerial line.

4.1. Stability Electronic Control and data logger

The stability control system checks the proper levelling of the machine, the actual outriggers' layout by mean of sensors placed on the outriggers legs, and limits the operating area if the stabilization is not complete. The system continuously calculates the actual stability coefficient comparing the stabilising area with the actual overturning moment. It actively controls the boom distributor in two steps, approaching the limit of the safety area: first, reducing the speed of the boom, then alerting the operator and eventually stopping the boom if it reaches the calculated stability limit.
Furthermore, the data logger and the maintenance check displays of the operating parameters (total and partial hours, total and partial cubic metres pumped, operating frequency [number of cycles/minute], hydraulic circuit pressures and temperatures, first cylinder operating pressures, etc.). Logging and display anomalous operating events (boom overloading, temperatures and pressures). Weighted scheduled maintenance intervals, i.e. maintenance based on real use, are displayed. So these systems represent an effective help in properly keeping the machine in fully operational status.

Fig. 6 – Display mounted on a truck-pump: actual outriggers layout and stability coefficient can be easily checked by the operator together with the working parameters

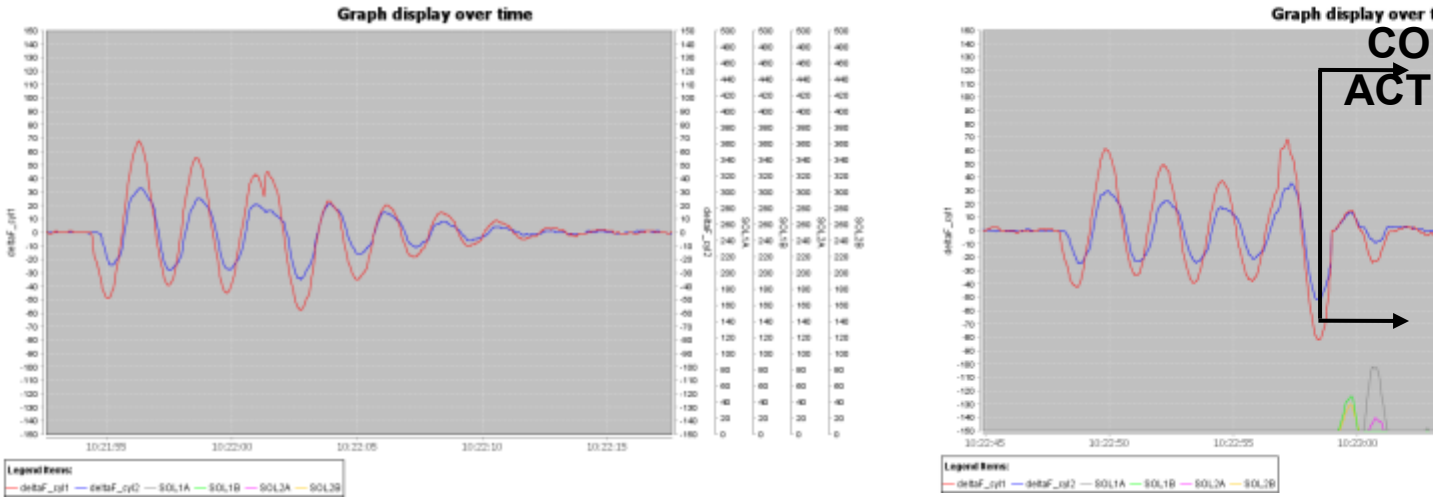


4.2. Active Boom Control

Active Electronic control of the boom reduces the vibrations during the use and increase the general safety for the operators.
The effectiveness of concrete boom distribution arms is limited by the phenomenon of vibrations to which the arm is subjected while it is delivering concrete. The greater the overall length of the arm and the number of segments, the more this problem is felt. These vibrations cause considerable operating difficulties both for the operator who is responsible for the manual positioning and orientation of the exit tube of the concrete, and also for the operator moving the arm by remote control.
An important component of these vibrations also derives from the type of the machines and from their relative characteristics of slenderness, inertia and elasticity, as well as the constructive type. In fact, these characteristics induce dynamic stresses in the articulated arm, which are associated both with the modes of the machine itself, in a substantially static condition, or at least not pumping, and also with the dynamic loads associated with the concrete pumping step.
Indeed, in order to be used, the machine works by moving from one configuration of the arm to another: this implies that its own mode is continuously excited and dynamic variations are generated on the state of stress of the joints and in the material, which limits the working life of the machine and reduces safety for the workers.
Furthermore, to these effects are also added the forced and pulsed functioning associated with the piston pump used for pumping the concrete, which often happens at frequencies close to those of the machine itself.
A dedicated auxiliary hydraulic control circuit, depending on the signals sent by the processing unit, which in its turn receives signals from the relative sensors, provides displacements/forces to the relative actuator/actuators, in order to reduce and/or eliminate the vibrations of the whole articulated arm, by introducing or drawing hydraulic oil that is added or subtracted to the oil determined by the main commands set by the operator.

This correction range allows to reduce, and even eliminate, the vibrations on the whole articulated arm and, as well as improving its working conditions extending the expected life of the individual components that make up the boom, limiting the phenomena of fatigue and wear.

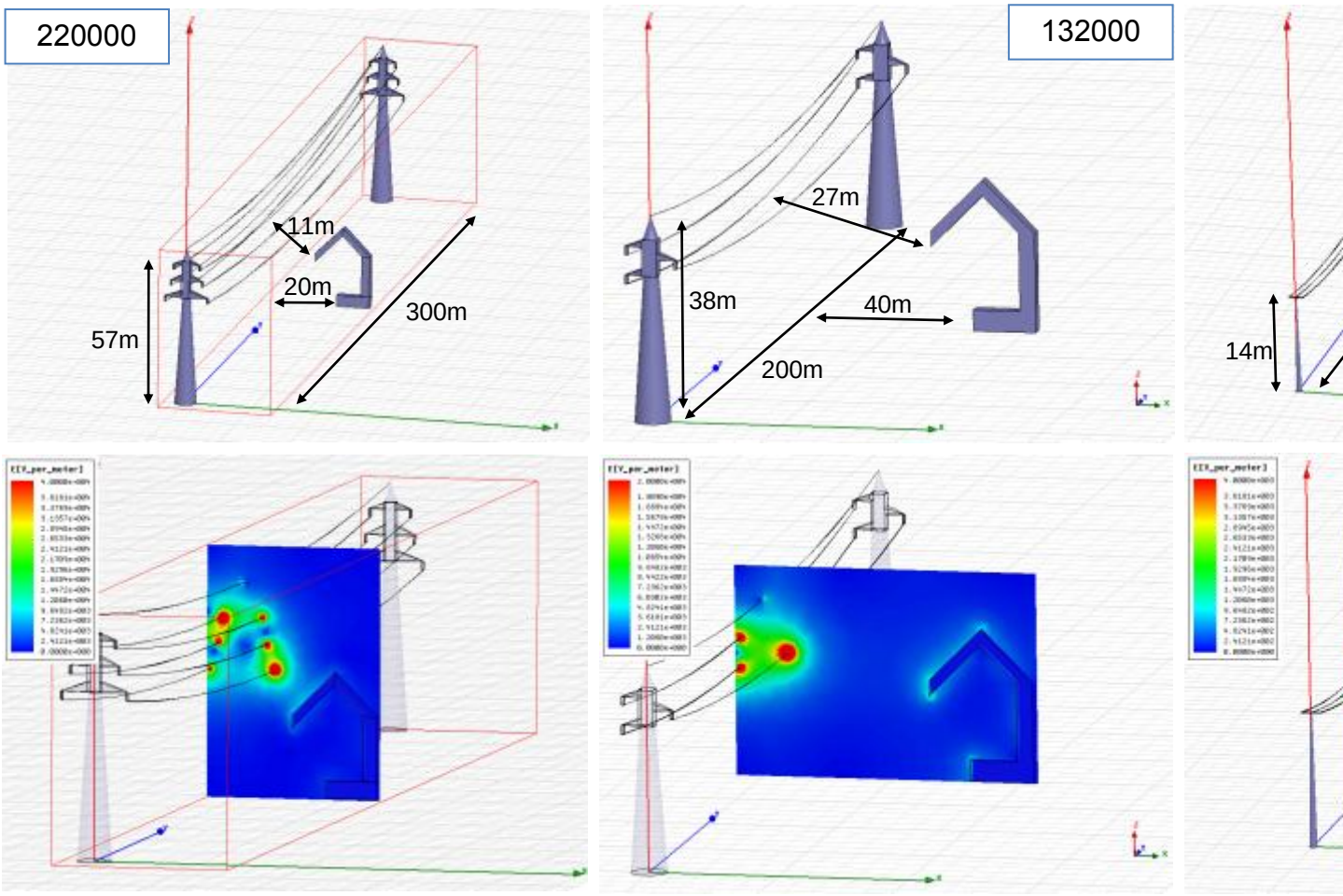
Fig. 7 – Comparison of the effect of the Active Boom Control: on the right control activated



4.3 Electric lines detection

The risk of contact between a concrete distributing boom and an electric line can be reduced introducing electronic systems to warn the operators of nearby electrical lines or even to stop the boom movements in a preventive effort. The safe distance to be maintained from a steel structure (such as a concrete boom) and an electrical line conducting current varies with the voltage and other factors such as air humidity.
It's possible to detect electric fields even at high distances from pylons and develop a new component sensor and a new software to check and stop the machine.

Fig. 8 - A technical example of studied with FEA (Finite Element Analysis)



5. Reliability and Extended Warranty

Finally, accurate simulation tests of the life-cycle of the machinery with the use of fatigue test beds on 1:1 scale are even more important to design the machines, anticipating and calculating all the possible maintenance events and to offer to the customers reliable products with extended warranties, and indications for fleet maintenance program management.

6. CONCLUSIONS

The technical evolution in the concrete machinery is mainly oriented to meet the market requirements in order to get products even more reliable, efficient and safe.
R&D is exploring 3 major fields: from the usage of new materials to the use of electronic systems and the hybrid technology. The Research and Development related to the new materials can have a positive impact on the wear of the products, as well as on the weight and on energy saving.
Besides, the use of electronic systems can support the operators safety, reliability, diagnostics as well the hybrid technology can help in the energy saving and environmental respect.

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