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Application of muography to the industrial sector

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Muography can be utilized as a Non-Destructive Testing (NDT) technique to perform preventive maintenance of industrial equipment, quality control of production processes and risk assessment in the context of the heavy industry. The great penetration power of muons in matter makes this technique interesting to inspect large and dense industrial structures such as cauldrons, furnaces and pipes. At the same time, muography does not require to stop the production process allowing to decouple this kind of maintenance from the technical stops of the factories. This kind of application simplifies also the muon imaging algorithms since only small deviations with respect to a very well known nominal geometry are needed, allowing to solve the problem with parameter inference solutions. This talk will review and summarize the recent progress of the company Muon Systems on this topic ranging from detector considerations, reconstruction algorithms and new applications.

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Applications of Muography to the Industrial Sector

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Abstract

Muography can be exploited as a Nondestructive Testing technique to perform preventive maintenance of equipment and production process control in the context of the industry. The large penetration power of the muon radiation and the capability to operate the detectors without physical contact with the facility offer unique possibilities for a large variety of industrial problems. At the same time, most of the industrial applications of muography can use engineering drawings of the equipment in such a way that only the detection of small variations with respect to that equipment is pursued. This strongly reduces the mathematical complexity of the imaging algorithms. Several used cases of muography in the industry are reviewed in this paper.

Keywords: muography, muon tomography, industrial application, nondestructive testing
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1. INTRODUCTION

The processing of raw materials requires the installation of large facilities with equipment such as furnaces, cauldrons, and pipes. This equipment is usually arranged in large factories in which several chemical, electrical, or mechanical processes occur in a sequential mode transforming the raw input into the desired product. Industrial companies spend millions of Euros every year in order to perform maintenance of the equipment and control of the production processes. There is a large variety of different techniques that can be applied to fulfill these tasks. Most of them are framed in the context of the so-called Nondestructive Testing (NDT) techniques, which allow performing an inspection of the facilities without damaging the equipment. Muography can be operated as a new NDT for specific problems where other NDTs offer poor results. The use of muon radiation offers unique potential to inspect large equipment such as furnaces or cauldrons where other NDTs are lacking penetration power. Muography also allows performing an inspection without touching the surfaces of the equipment, opening the possibility of operating, while the factory is in production. Finally, since muography does not require any radiation protection control, it can be operated in a cheap and safe way, allowing even the application of permanent installations to perform continuous monitoring.

2. COMMON FEATURES OF INDUSTRIAL APPLICATIONS OF MUOGRAPHY

The number of possible applications of muography to the industrial sector is quite large since there is a wide heterogeneity of problems and challenges. Nevertheless, there are several common aspects shared by most of the use cases. The dimensions of the objects typically range from a few tenths of cm to a few m, and the most common materials are steel, concrete, refractory, and carbon. The environment surrounding the equipment is usually quite packed with concurrency of other equipment, scaffolding, and service structures. This often imposes tight constraints on the possible locations of the muon detectors. The temperature and humidity conditions can be usually relatively high (up to 60°C and above 80%) due to the residual heat irradiated by the equipment and the possible evaporation processes taking place during production processes. The atmosphere can be dirty, containing particles and dust in suspension. Muon detectors need to be conveniently isolated to be able to operate in these conditions. In many used cases, there are also time restrictions in the sense that exposure times are limited by the natural times of the production processes.

Muography applications in this context share also an important feature from the algorithmic point of view: in most of the cases, detailed drawings of the equipment including densities and dimensions are available. The imaging algorithms do not need to infer the full geometry of the system, as other muography algorithms do [1, 2, 3], but simply to find small variations on top of the nominal design. In practice, this means that the complexity of the problem can frequently be reduced to a small set of parameters, opening the possibility of using parametric estimation methods or simple regression techniques including those based on Machine Learning techniques.

In order to illustrate these features, the problem of the ladle furnace is considered. Ladle furnaces are used in the heavy industry to transport melted minerals from some locations of the facility to others. The exact amount of melted material in a ladle is hard to estimate since an opaque, several-cm-thick layer of slag appears on top of the mineral. A possible muography-based solution

FIGURE 5: Full setup of MPC-based muon detectors for scattering muography operation.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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