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SOFA: a new approach for quality assurance in GEM-foils

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This work presents the development of Software (SOFA hereafter) for morphological quality assurance in GEM-foils (electrodes of a GEM-like detector) through the analysis of high resolution images. SOFA (Software for Foils Analysis) performs an automated measurement of the holes geometry presented in the GEM-foils, in order to detect and quantify different defects far from their ideal geometric characteristics. This work underlines the speed, automation and precision of SOFA regarding quality visual inspection used in manufacturing process of GEM-foils. SOFA is a R&D tool, because its measurements allow establishing relation between GEM-foils defects and GEM-like detector performance.

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1. Introduction

SOFA is a R&D tool for measuring and quantification of defects of GEM-foils through high resolution images analysis. In this work we present the application of SOFA to the challenging problem of GEM-foils quality control related to the micro-pattern holes (amplification region of the GEM-like detector) geometry imperfection. SOFA allows detection of diverse geometric defects, from estimation of the internal and external diameter of the holes by measurements of radius, roundness and eccentricity among others in an efficient (computing time) and precise (defect detection) way. The techniques and methods described in this work were developed in JAVA programming language implemented in SOFA. The images used for this work have a 1.7 μm/pixel resolution for a total image size of 3488$\times$2616 pixels corresponding to $\sim$26 mm^2 of a GEM-foil. The images were originally taken by Helsinki Institute of Physics (HIP) within the RD51-CERN program and shared to Centro de Investigaciones en Ciencias Aplicadas (CICBA) at Universidad Antonio Nariño by the Heavy Ion Research Center (GSI), Germany.

2. Experimental method

A GEM-foil is a uniformly perforated thin foil, formed by three consecutive layers Copper-Kapton-Copper 5, 50 and 5 microns thick respectively. The holes are only a few microns in diameter and they are homogeneously distributed in a very dense pattern (micro-pattern) [1]. The dimension, shape and allocation of the holes in a GEM-foil vary by purpose. The importance of detecting defects, imperfections and irregularities of the holes, is associated to the local electric field distribution in the GEM-foil, subsequently disturbing the avalanches of local charges and then the quality of the information generated by the detector [2]. In this work, the geometric parameters of the holes were compared to an ideal hole geometry and pattern in GEM-foils [3].

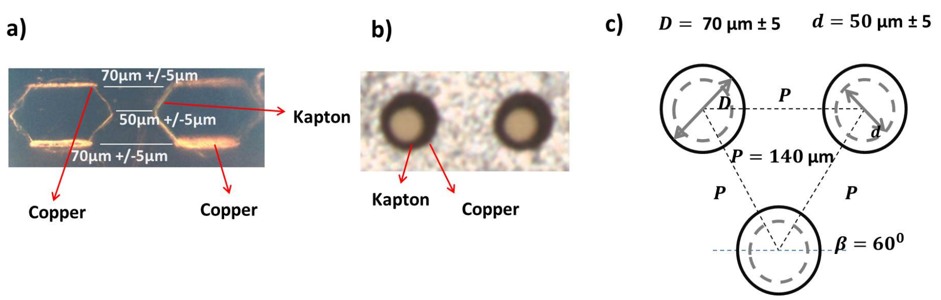

Figure 1: GEM-foil cross section and holes geometry. (a) Cross section of GEM-foil, (b) High resolution image of two holes, (c) Image describing the geometric distribution scheme.

Figure 1-a shows a GEM-foil cross section with biconical holes and hexagonal pattern: 70$\pm$5 μm in both layers of copper and 50$\pm$5 μm in the kapton layer. Figure 1-b shows an image of a hole taken from above and perpendicular to the plane of the hole. Because light reflection effects in holes, they are seen as uniform thick rings, the external perimeter corresponding to diameter of the hole in copper layer, and internal diameter corresponding to Kapton layer. Figure 1-c shows the geometric distribution scheme of the holes in the foil and its idealization with infinite resolution.

Prior to SOFA analysis, preliminary processing and visual examination is done by means of a detailed hardware setup, which complements the conventional "naked eye" inspection used for quality control of the GEM-foils by the manofacturer [4]. The images were visually row-wise scanned, inspecting each hole individually to find evident shape alterations in the hole. This inspection was intended to identify evident variations of internal radii. By using this method, the visual inspection (VI) allowed setting a comparative reference for speed, precision and performance of SOFA. Comparison took into account a wide range of defects, from evident ones to very slight variations might affect the quality of GEM-foils and its performance in the GEM-like detector.

2.1 Results and discussions

As already mentioned, SOFA evaluates radius, roundness and eccentricity of the holes to identify irregularities in the GEM-foil structure. Figure 2-a shows a kind of defect that is easily identified by VI and it is identified by SOFA using circularity as measure. Figure 2-b shows a defect that is difficult to identify by VI, but it is detected by SOFA using radius measuring, in other words a faulty hole is pinpointed by SOFA, whereas a standard VI can be limited. Figure 2-c represents a successful case of identification of defects by SOFA using the varying of the radius as comparative parameter, contrariwise this kind of defect is impossible to identify by VI.

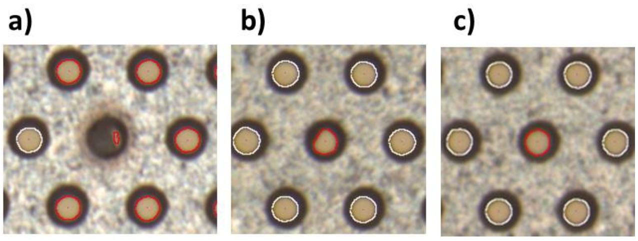

Figure 2: Typical irregular (in-red) and ideal (in-white) micro-pattern holes geometry. (a) Defect easily identified, (b) Defect difficult to identify, (c) Defect impossible to identify.

By sampling a large set of high resolution images, the VI identified 98% of the variations if the radius is less than 20 μm and identifies 60% of the variations if the radius is greater than 24.5 μm as shown in Figure 3-a. In turn, for these images the VI has an accuracy rate of 0% if the variations are between 22 and 23 μm because the VI cannot detect variations equals to 1. Figure 3-b shows the distribution of the value of internal radii in micrometers for 16386 holes where the most between 12 and 15 μm, an important contribution as quality parameter provided by SOFA.
On the other hand, Figure 4 shows the time reduction in image analysis and identification of faulty holes by SOFA when increasing computational resources (number of cores), compared with the corresponding time needed to obtain the same or less accurate results with VI.
As seen, VI takes about 4321 seconds to analyze 30 images versus the 12.7 seconds SOFA takes by running in 4-cores processor. The hole geometry evaluation plus the fast high resolution images analysis endorses SOFA capabilities as a R&D tool for GEM-foils quality control.

3. Outlook

This work presents SOFA as a new software R&D tool for the analysis and quality control of

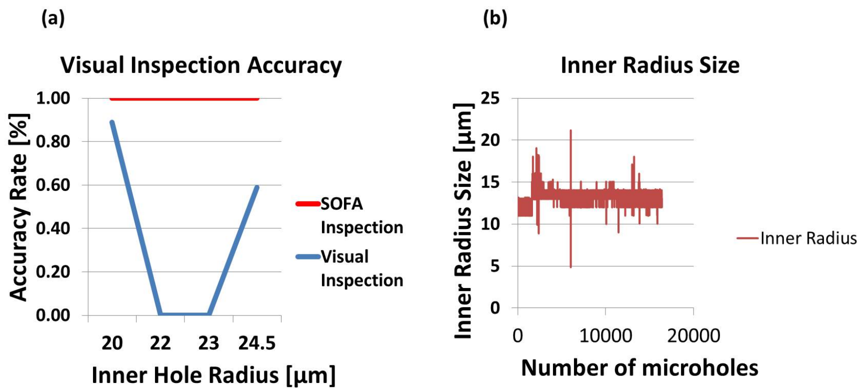

Figure 3: SOFA performance. (a) Visual inspection accuracy. (b) Distribution of the value of internal radii in micrometers.

Number of images analyzed	Number of micro holes			Analysis mean time by image [sec]				
	Analyzed	Defective identified by VI	Defective identified by SOFA	VI	P_1	P_2	P_3	P_4
30	51750	102	5200	4321	55.2	29	19	12.7

Figure 4: Efficiency in detection of defective micro holes by the two methods: VI and SOFA. P_n indicates the number of cores used to analyze the images.

GEM-foils through high resolution images analysis. Results shows SOFA is an accurate and fast computational tool for faulty micro-holes detection, linked to the GEM-like detector performance.

References

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