NUKLEONIKA 2001;46(Supplement 1):S33–S34

Ultrafast X-ray introspective imaging of metallic objects using a Plasma Focus

César H. Moreno,
Alejandro Clausse,
Javier F. Martínez,
Roberto Llovera,
Aureliano Tartaglione

Abstract A compact-chamber 4.7 kJ, 30 kV, Plasma Focus operated in deuterium was used as a ultrafast high intensity radiation source for introspective radiographic imaging of metallic objects. The samples to be imaged were located outside the Plasma Focus chamber, about 1 m away from the chamber wall. A high-sensitivity, fast-response commercial radiographic film was used as a X-ray detector. Experimentally obtained images are presented showing a very high penetration power of the X-ray beam, demonstrating that the presented compact-chamber Plasma Focus is suited for introspective visualisation of pieces manufactured on metal.

Key words dense plasmas • electrical discharges • plasma focus • X-ray imaging • X-rays

C. H. Moreno✉, J. F. Martínez,
PLADEMA and Instituto de Física del Plasma,
Departamento de Física, Universidad de Buenos Aires,
Pab 1 Ciudad Universitaria, 1428 Buenos Aires, Argentina,
Tel.: 5411/ 4576 3371 ext. 120, Fax 5411/ 4787 2712,
e-mail: moreno@df.uba.ar

A. Clausse
PLADEMA-ISISTAN-CONICET,
Comisión Nacional de Energía Atómica
and Universidad Nacional del Centro,
7000 Tandil, Argentina

R. Llovera, A. Tartaglione
Instituto de Física del Plasma, Departamento de Física,
Universidad de Buenos Aires, 1428 Buenos Aires, Argentina

Received: 23 October 2000, Accepted: 17 January 2001

Introduction

The present day experimental research on dense plasmas producing devices is strongly oriented to novel applications apart from fusion. Plasma Focus machines are pulsed X-ray and neutron sources specially fitted for applications because they are not contaminating as conventional isotopic nuclear sources are. Additionally, small Plasma Focus machines have the advantage of being compact, portable in many cases, cost-effective, and, depending on the type of chamber one chooses, very versatile for doing both basic and applied research. Regarding the utilization of these machines as powerful X-ray sources for radiographic imaging [2], several articles have been recently published devoted to soft X-ray lithography [4, 5] and radiography of biological specimens [1]. Other several interesting applications have also been recently reported where X-rays are used as probing radiation for substance recognition [3]. Aimed to find other uncommon applications for Plasma Focus devices we decided to use a compact-chamber Plasma Focus operated in deuterium for X-ray imaging of small metallic pieces.

Experimental set-up and method

A Plasma Focus device used in this work is composed of a 10.5 μF condenser bank of 15 capacitors charged up to 30 kV (4.7 kJ), and a cylindrical stainless-steel chamber 157 mm long and 96 mm in diameter, 3 mm thick. The electrode configuration is a Mather-type, the electrodes diameters and length being: 38, 72 and 87 mm, respectively. The central electrode (anode) is a hollow tube made of electrolytic copper, whereas the cathode is formed by 12 bronze bars 3 mm in diameter each. The insulator sleeve is a Pyrex tube, 4 cm in length and 4 mm of wall thickness. Peak currents of 350 kA are attained in a quarter of period (~1.1 μs). The

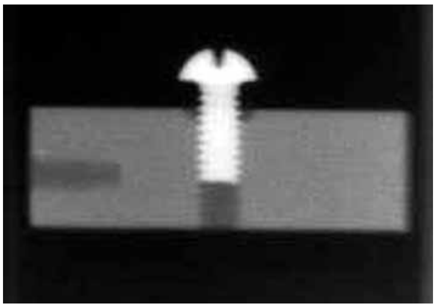

Fig. 1. Single X-ray image of an aluminum block with a 1/4-20 brass bolt screwed on it.

system operates between 1 to 8 mbar of deuterium, presenting optimum neutron production in the range 4–5 mbar. After each shot, the filling pressure increases about 0.05 mbar due to the release of impurities from the chamber, electrodes and insulator walls. Consequently, the chamber is pumped down (mechanically) after each shot in order to assure constant pressure conditions. The maximum shot frequency was 1 shot per minute, limited by the charger. Under these conditions, the frontal wall temperature (that facing the open end of the electrodes set) increases about 20°C over the ambient temperature after 30 shots, cooled passively by air natural convection and heat conduction through the metallic structure. The working gas is usually renewed after 10 shots.

The samples to be imaged were located outside the Plasma Focus chamber, 85 cm away from the chamber wall. A commercial radiographic film, Curix ST-G2 from AGFA was used together with an AGFA suggested developer and a fixer for this film. No special procedures were needed other than those recommended by the supplier, to manipulate and develop them. A photomultiplier tube coupled to a NE102A plastic scintillator was used to monitor the X-ray yield in each shot. By the time of maximum pinch compression, the photomultiplier signals show X-ray peaks of about 50 ns FWHM duration and about 1.5 V amplitude, presenting variations from shot to shot. These signals were used mainly to decide whether to develop the X-ray film or to add another shot on it, based simply, on the observed peaks amplitudes. Under normal circumstances, only one shot is needed to get an image when working in the range 3 to 5 mbar of filling pressure and placing the object and film at the above mentioned distance. Even in those cases where two or three shots were superimposed on the same film, the obtained image resulted sharp and with good contrast. This indicates that at least for this application, the radiation source can be considered as having small size and located almost in the same place from shot to shot. Additionally, since the X-ray pulse lasts only about 50 ns, the radiation source can be considered as an ultra-fast flash for many applications.

Results

Preliminary shots were made to test both the experimental setup and procedure. Several metallic objects were also tested to study the penetration power of the X-ray beam and to find the optimal distance range from the objects to the focus. We found that distances between 60 to 150 cm are adequate to get good image quality with only one shot. Outside this range, the film is either overexposed in the first shot, or too many shots are required to get a (generally blurred) image, thus making the procedure impractical.

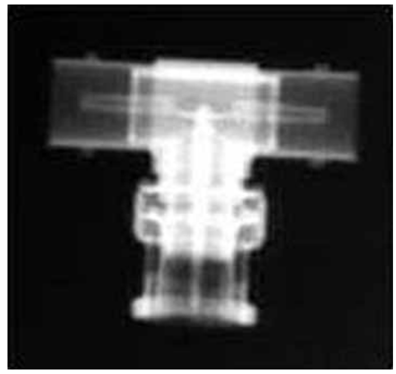

Fig. 2. Single X-ray image of a stainless steel BNC ‘T’ connector.

Fig. 1 shows a 1.56×1.56×4.93 cm^3 solid aluminum block with a bronze 1/4-20 (6.35 mm in diameter, 20 threads per inch) screw on it. An empty hole is also observed on the block. The clear contrast between both metals facilitates the introspective inspection of composed pieces. Fig. 2 shows a stainless steel BNC ‘T’ connector where the internal structures made of metal and plastic are easily identified.

Conclusion

A small-chamber 4.7 kJ Plasma Focus device operated in deuterium was used as a high-brightness X-ray source to obtain introspective radiographic images of metallic objects. The presented results constitute a proof of principle for the use of a compact Plasma Focus in non-conventional introspective imaging. It should be emphasized that the radiation used to obtain the images had to go through the frontal chamber wall, which is made of 3 mm stainless steel. This thickness was imposed by design criteria preexistent before the utilization of this Plasma Focus as a compact X-ray source. Thinner walls would be admissible, allowing consequently, for more penetration power of the beam. Our results indicate that aluminum pieces having tens of mm thick can be easily imaged with submillimetric details and that small stainless-steel pieces (having 1 to 2 mm wall thickness) can also be introspectively imaged with the same resolution.

Acknowledgments This work was supported by PLADEMA-CNEA, Fundación Antorchas grant A-13838/1, UBA grant JX64/00 and CONICET grant PIP 4523/96.

References

1. Castillo Mejia F, Milanese M, Moroso M, Pouzo J, Santiago M (1998) Research on Dense Plasma Focus hard X-ray emission with scintillator-photomultiplier and TLD measurements. In: 1998 ICPP and 25 EPS Conf on Contr Fusion and Plasma Physics, ECA 22C:2686–2689
2. Decker G, Wienecke R (1976) Plasma Focus devices. Physica C 82:155–164
3. Hussein E, Waller E (1998) Review of one-side approaches to radiographic imaging for detection of explosives and narcotics. Radiat Meas 29;6:581–591
4. Lee S, Kudryashov V, Lee P et al. (1998a) SXR lithography using a high performance Plasma Focus source. In: 1998 ICPP and 25 EPS Conf on Contr Fusion and Plasma Physics, ECA 22C:2591–2594
5. Lee S, Lee P, Zhang G et al. (1998b) High rep rate high performance Plasma Focus as a powerful radiation source. IEEE Trans Plasma Sci 26;4:1119–1126