

Additive manufacturing of repair components for OSLD cases used in personnel monitoring

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ABSTRACT

The Personnel Monitoring Service of the Radiation Protection Services Section is performed through the provision of Optically Stimulated Luminescence Dosimeters (OSLD). Damage can occur to the dosimeter cases during disassembly, negatively impacting the service due to lack of usable cases. This study focuses on improving material costs on the OSLD service by rehabilitating damaged components.

Reference components and repair parts for the dosimeter were recreated using free and open-source tools. 3D resin printing with a photopolymer marketed as “PLA Pro” was used in prototyping and fabrication of the repair parts. Cost reduction of 93.31% from repair pouches, 98.50% from repair sleeves, and 99.20% from repair plates can be achieved by in-house production of these components in restoring dosimeter parts.

INTRODUCTION

The Personnel Monitoring Service of the Radiation Protection Services Section (RPSS) is provided to clients to help monitor radiation levels absorbed by workers by means of dosimeter devices as per the 2020 version of the Service Guide developed by Panlaqui et al. (2020). Personnel monitoring is carried out by providing workers with Optically Stimulated Luminescence Dosimeters (OSLD). Damage can occur to the dosimeter cases during disassembly, negatively impacting the service due to lack of

usable cases. The need to search for damaged, usable cases and the use of tape slows down disassembly and assembly of dosimeters.

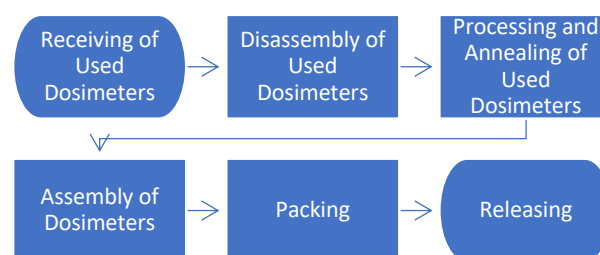


Figure 1: Overview of Personnel Monitoring Service Process as taken from the service guide

Cases used in the OSLD Personnel Monitoring Service may be structurally compromised due to plastic degradation caused by the operational factors these dosimeters are exposed to. A review of plastic degradation by Heris (2024) lists these operational factors as ultraviolet radiation, elevated and fluctuating temperatures, mechanical pressure, and chemical reactions resulting from exposure to oxygen and moisture. These operational factors adversely impact the mechanical strength of the case, rendering cases susceptible to structural failure. The disassembly tools currently used by the staff apply an unintended crushing force that can damage the case. These damaged cases are then brought back into service at the discretion of staff with damaged clip locks held in place with tape.

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KEYWORDS

3D printing, additive manufacturing, dosimetry, OSLD, personnel monitoring, radiation protection



Figure 2: Damaged cases in service

The importance of the Personnel Monitoring Service is to monitor and subsequently help limit occupational exposure to ionizing radiation. The International Atomic Energy Agency (2018) General Safety Guidelines Series 7 provides an international consensus on good practices for mitigating stochastic and deterministic effects of ionizing radiation. These practices are adopted and enforced by the Code of PNRI Regulations Part 3 (2021) as the Philippine regulatory standard.

The OSLD as a technology is widely used in medical, industrial and environmental applications. A review by Yang et al. (2024) states that the accuracy, cost-effectiveness, small size, low energy dependence of response, and broad linear range of dose response explain the wide adoption of the OSLD. Because OSL readout does not erase the stored dose signal, the OSLD can accommodate multiple readouts while maintaining measurement accuracy.

Franca et al. (2025) conducted a study on 3D printed OSLD extremity badges and demonstrated a satisfactory performance of their design under specified conditions under the IEC standard. Bustillo (2025) and Tino et al. (2020) explored 3D printing for the fabrication of anthropomorphic phantoms for radiation dosimetry applications.

This study focuses on the repair of plastic cases used for whole body OSLD. A case was considered damaged if the safety lock and clip were unable to keep it in place when fully assembled. Damaged cases were deemed viable if the damage does not expose the dosimeter and the case could still contain the dosimeter when fully assembled. Cost was compared by contrasting the cost of raw materials and electricity consumption against the baseline cost of acquiring replacement components.

MATERIALS AND METHODS

An analysis of the geometry of both damaged and undamaged cases served as the starting point of the design process. Geometry was reconstructed using a vernier caliper. Measurements were validated across five undamaged cases and three damaged, viable cases. All curves in the geometry were assumed to be decomposable into circular arcs. The reconstructed model was validated during fabrication and testing of derivative repair parts. The thickness,

length, width, depth and center distance of the holes for the safety locks were considered as key measurements in the design.

The repair parts were designed to not block the dosimeter to minimize scattering effects on the OSLD. Free and open-source software and addons were used as the design environment. The geometry was reconstructed using Blender version 3.3 with the CAD Sketcher add-on developed by 'hlorus.'

The HALOT One resin printer and Mars 4 Ultra 3D resin printer were used for the fabrication of the repair implements due to the required voxel resolution. Whichever printer was available was used under the same settings during production tests. Each layer was set to be 0.05 mm thick with an exposure time of 2 seconds and motor speed of 1 mm/s. Initial exposure was set to 40 seconds, with a turn off delay of 4 seconds, two bottom exposure layers and a rising height of 6 mm. The resin used had a viscosity of 200 to 400 mPa·s, a density of 1.05 to 1.1 g/cm³, a tensile strength of 50 to 60 MPa, a flexural strength of 70 to 80 MPa, and a Shore D hardness of 78 to 82.



Figure 3: Repaired Dosimeters (Above) and Implemented parts (Below)

Batch production models were tested using both opaque and translucent resins of similar properties, selected based on material availability and the immediate needs of the personnel monitoring service. Batch production models were optimized with varying orientations to reduce printing errors while maximizing yield. The location and function of features constraining the repair part to the case were considered key indicators of whether the repair part had printed successfully. Batch models were cured under ultraviolet light for five minutes at a maximum power draw of 60 watts.

RESULTS AND DISCUSSION

Resin used for early tests was opaque. Subsequent production runs included translucent resin given availability of materials. Interchangeable use of opaque and translucent resin was rationalized from the imposed design restriction of not blocking the dosimeter. Batch production models printed with translucent resin do not experience significant structural deviation when compared against models printed with opaque resin. Batch production models did not experience structural deviation between the two printers used.

Resin cost for each repair part type is described by Equation 1, where B_{max} is the maximum number of batches and B_{parts} is the number of parts per batch. The calculation assumes that one 1 kg bottle of resin is dedicated entirely to producing one type of repair part.

$$\text{Part Resin cost} = \frac{\text{Resin Bottle cost}}{B_{\max} * B_{\text{parts}}}$$

Equation 1: Part Resin Cost

Embedded electricity costs are described in Equation 2, where B_{CT} is the curing time per batch, MP_{CT} is the maximum power consumption of the curing machine, B_{PT} is the print time per batch and MP_{PT} is the maximum power consumption of the 3D printer. The commercial electricity rate of 13.08 PHP/kw-h was used as the basis for calculation and was retrieved from June 2026 data from

the commercial - historical summary provided by the Philippine Department of Energy.

$$\text{Embedded Electricity Cost} = ((B_{CT} * MP_{CT}) + (B_{PT} * MP_{PT})) * \frac{\text{Cost of Electricity}}{B_{\text{parts}}}$$

Equation 2: Embedded Electricity Cost per Part

Table 1 summarizes the costs. Labor cost was not accounted for in the computations. Savings achieved were compared with the PHP 100.80 cost per case.

Table 1: Cost Summary of Repair Parts

Part type	Embedded Electricity Cost (PHP)	Resin Cost (PHP)	Total Part Cost (PHP)	Relative Cost of Repair	Achieved savings
Plate	0.08	0.72	0.80	0.78%	99.20%
Sleeve	0.23	1.28	1.51	1.44%	98.50%
Pouch	1.06	5.68	6.75	6.43%	93.31%

Sensitivity analyses of relative cost for each repair part are shown in Figures 4 to 6. Resin cost has a more adverse impact compared to embedded electricity cost as the resin price factor increases. Sensitivity trends were consistent for both case cost and printing yield. An increase in the cost of purchasing new cases increases the

relative cost-effectiveness of repair parts. Print defects that rendered the repair part not fit for purpose negatively affected relative cost.

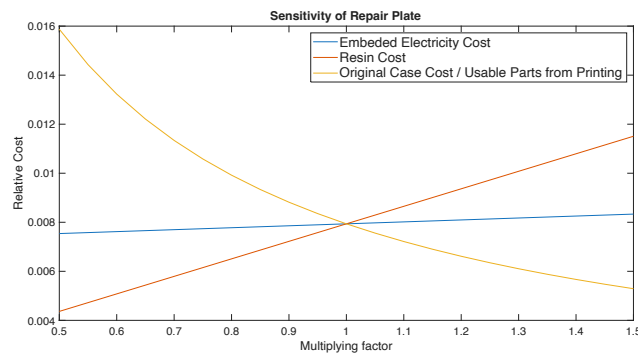


Figure 4: Sensitivity Plot of Repair Plate

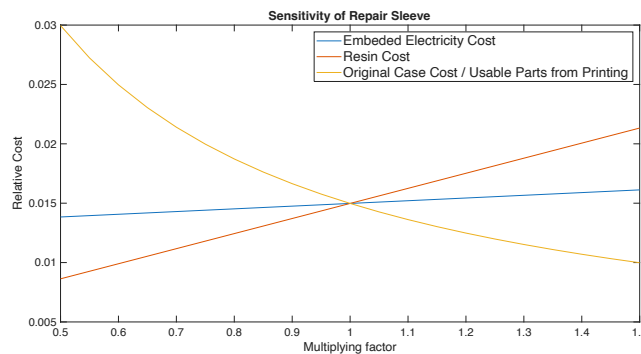


Figure 5: Sensitivity Plot of Repair Sleeve

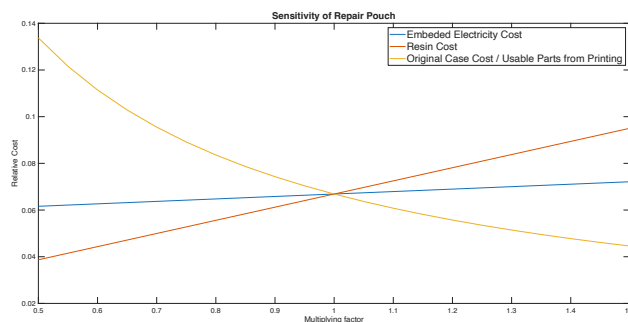


Figure 6: Sensitivity Plot of Repair Pouch

CONCLUSION

Additive manufacturing restored the functionality of damaged cases. Additive manufacturing can be integrated into dosimetry services as a cost-saving measure for repairing or replacing consumable parts. Cost savings of 93.31% from repair pouches, 98.50% from repair sleeves, and 99.20% from repair plates were achieved.

Resins with different chemical and mechanical properties were not further explored due to material availability constraints during the study period. Additional studies are recommended for comparing the dose response of undamaged OSLDs and OSLDs in repaired cases.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

DMFT: Writing – original draft, Writing - review and editing, 3D modelling, Investigation, Conceptualization; **JMSG:** Writing - review and editing, Conceptualization; **DQB:** Writing – original draft, Writing - review and editing; **MLMLG:** Writing - review and editing, Conceptualization, Funding Acquisition, Supervision

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