INTISARI

Perkembangan pesat teknologi manufaktur aditif, khususnya *Fused Deposition Modeling* (FDM), telah memungkinkan fabrikasi komponen elektronik fleksibel dengan geometri kompleks dalam waktu singkat. *Flexible strain sensor* berbasis Kirigami telah muncul sebagai salah satu perangkat yang menjanjikan karena kemampuannya untuk menahan deformasi besar tanpa kehilangan kinerja fungsional. Namun, masih terdapat kebutuhan untuk melakukan optimasi desain secara sistematis guna mencapai keseimbangan antara efisiensi fabrikasi, akurasi dimensi, dan *sensing performance*, terutama pada penggunaan teknik FDM yang secara inheren melibatkan *trade-off* antara kecepatan, akurasi dimensi, dan perilaku mekanis.

Dalam penelitian ini, sensor regangan fleksibel berbentuk Kirigami difabrikasi menggunakan filamen termoplastik poliuretan (TPU) konduktif melalui proses FDM. Empat faktor desain dianalisis, yaitu pola kirigami, rasio dimensi, ketebalan sensor, dan jenis *sensor substrate*. Evaluasi dilakukan terhadap waktu pembuatan (*build time*), akurasi dimensi, sensitivitas (*gauge factor*), dan elongasi maksimum melalui uji tarik. Proses analisis dilakukan menggunakan metode *Response Surface Methodology* (RSM) dengan rancangan eksperimen yang terdiri dari 18 kombinasi perlakuan dan 5 replikasi untuk mengkaji pengaruh antar faktor dan mendapatkan prediksi respons yang optimal.

Hasil optimasi menunjukkan bahwa terdapat 3 respons yang dapat diprediksi menggunakan model RSM. Selain itu, rasio dimensi sebesar 0,09 dan ketebalan sensor 0,2 mm yang diterapkan pada *sensing film* dengan salah satu pola Kirigami dan *sensor substrate* yang berasal dari TPU *film* menghasilkan kinerja paling optimal secara keseluruhan. *Flexible strain sensor* hasil optimasi mencapai *build time* sebesar 2 menit dan deviasi dimensi sebesar 1,59%. Nilai sensitivitas maksimum dari *flexible strain sensor* hasil penelitian didapatkan sebesar 19,11 dan elongasi maksimum sebesar 133%.

Kata kunci: *flexible strain sensor*, Kirigami, FDM, RSM, akurasi dimensi, *sensing performance*

ABSTRACT

The rapid development of additive manufacturing technologies, particularly Fused Deposition Modeling (FDM), has allowed the ability to fabricate flexible electronic components with complex geometries within a short time. Kirigami-based flexible strain sensors have emerged as a promising class of devices due to their ability to withstand large mechanical deformations while maintaining functional integrity. However, there remains a need for systematic design optimization to balance fabrication efficiency, dimensional accuracy, and sensing performance—particularly in FDM processes that inherently involve trade-offs between speed, dimensional precision, and mechanical behavior.

In this study, Kirigami-shaped flexible strain sensors were fabricated using conductive thermoplastic polyurethane (TPU) filaments through an FDM process. Four design factors were analyzed, namely kirigami pattern, dimension ratio, sensor thickness, and sensor substrate type. Evaluation was conducted on build time, dimensional accuracy, sensitivity (gauge factor), and maximum elongation through tensile test. The analysis process was carried out using Response Surface Methodology (RSM) with an experimental design consisting of 18 treatment combinations and 5 replications to examine the influence between factors and obtain optimal response predictions.

The optimization results showed that there were 3 responses that could be predicted using the RSM model. In addition, a dimension ratio of 0.09 and a sensor thickness of 0.2 mm applied to the sensing film with one of the Kirigami patterns and a sensor substrate derived from TPU film resulted in the most optimal overall performance. The optimized flexible strain sensor achieved a build time of 2 minutes and a dimensional deviation of 1.59%. The maximum sensitivity value of the optimized flexible strain sensor is 19.11 and the maximum elongation is 133%.

Keywords: flexible strain sensor, Kirigami, FDM, RSM, dimensional accuracy, sensing performance