PCM-Driven Soft Facilitated Tucking Device for Preterm Infants

Levi Sulzle[1], Mahdi Tavakoli[1], and Emir Augusto Vela Saavedra[2]
[1] Mechanical Engineering, University of Alberta / Edmonton, Canada.
[2] Mechanical Engineering, University of Engineering and Technology / Lima, Peru.
Email: sulzle@ualberta.ca

INTRODUCTION

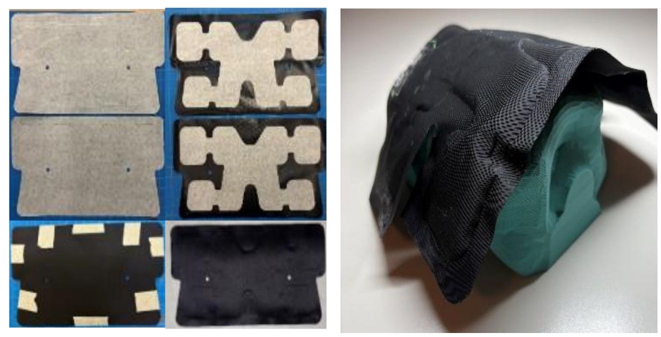
Preterm infants in the Neonatal Intensive Care Unit (NICU) undergo frequent painful procedures, which contribute to longer hospital stays and adverse developmental outcomes. Pharmacological methods such as opioids and sucrose are commonly used but become unsustainable with 7–17 procedures daily [1]. Physical therapies like skin-to-skin care and facilitated tucking have been shown to reduce pain and stabilize physiological responses, yet they require a second caregiver and are limited by infection-control protocols. This paper presents a novel device that simulates facilitated tucking that uses sodium acetate trihydrate (SAT). By embedding the phase change material (PCM) into a wearable structure, the device can replicate the warmth and containment of human hands, which aims to provide safe and autonomous boundary comfort for premature infants while reducing caregiver workload.

MATERIALS AND METHODS

The fabrication process closely followed the approach of Rajappan *et al.* [2]. Heat-sealable 70D nylon/TPU sheets (Seattle Fabrics) were masked with transfer tape and patterned using a PLS6.150D CO_2 laser cutter (Universal Laser Systems) to create chambers and channels for the PCM. Bonding regions were weeded (Fig. 1(a)), then the sheets were vertically aligned with tape and sealed using a Clam Basic Heat Press (Stahls'). An inlet was left unsealed to fill approximately 85 mL of sodium acetate trihydrate (≈70% of the internal volume), introduced in liquid form at 54 °C. A metal nucleation disk was inserted, then the inlet was sealed with a hot iron. The geometry was scaled to a 32-week gestational age (GA) preterm infant, with a central pouch incorporating a narrowed midline to facilitate bending and guide the arms into flexion near the chest and hands to the mouth for self-soothing. Upper/lower pouches were contoured to shoulders and torso. Small holes in the bonded regions aided vertical alignment during sealing and acted as tear-stops when separating the upper and lower sections.

RESULTS AND DISCUSSION

The SAT activates at approximately 54 °C and releases latent heat, its melting temperature can be tuned between 48–58 °C by concentration [3]. Higher concentrations of SAT will last longer and solidify harder. With appropriate insulation, this enables the pouch surface to be regulated near 37 °C, simulating the temperature of caregiver hands in the incubator. The pouch covered a 3D-printed scan of the torso of a 32 GA preterm infant, and the channels bent in the expected locations (Fig. 2(a)). For future work, a secondary textile sleeve is needed to insulate the PCM pouch and provide a soft interface for the infant. This layer may also incorporate NiTi metamaterials [4] to automatically apply gentle boundary pressure. The sleeve can be worn directly by the infant or placed externally. Fabrication challenges, including PCM leakage during reheating, indicate that higher-denier nylon/TPU sheets, as well as controlled electrical reheating methods like those used for hospital PCM devices, are required.



(a) (b)

Fig 1 (a) Fabrication with heat-sealed nylon/TPU. (b) Prototype fitted to 3D-printed torso of a 32-week preterm infant.

CONCLUSIONS

This work presented the design and fabrication of a PCM pouch intended to simulate facilitated tucking for preterm infants. SAT was selected for its ability to provide warmth and solidify to create pressure. A secondary insulating sleeve was proposed to provide both thermal regulation and a soft, wearable interface, with potential integration of NiTi auxetic metamaterials to replicate the gentle boundary pressure of caregiver hands. Although prototype testing revealed fabrication challenges, including PCM leakage during reheating, proposed improvements such as thicker TPU films and controlled heating methods may enhance the watertightness and durability. Overall, this paper demonstrates the feasibility of PCM-based devices to provide autonomous thermal and tactile comfort.

REFERENCES

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