

Feasibility of Additively Manufactured ABS-GF and mSLA Resin Embossing Dies for use in Commercial Print Finishing Processes

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Short abstract

Embossing remains an important finishing process in commercial print and packaging, but the dies used to produce it are typically made from brass, copper, or magnesium through specialized subtractive or etching workflows. These conventional dies remain effective, yet they are often poorly matched to contemporary production conditions shaped by short runs, versioning, rapid revision, and the need for physical prototypes. This study evaluates whether two digitally fabricated alternatives, fused deposition modelling (FDM) using glass-fibre reinforced acrylonitrile butadiene styrene (ABS-GF), and masked stereolithography (mSLA) using an ABS-like resin, can serve as viable substitutes for selected embossing applications.

The paper combines published literature on additively manufactured embossing tools with production testing conducted at two commercial print facilities. Three die types were compared: ABS-GF FDM, ABS-like resin mSLA, and a conventional brass die control. Testing was carried out on three paper stocks: Husky 60# Text (89 GSM), Cougar 80# Text (118 GSM), and Cougar 130# Cover (352 GSM). Across runs of several hundred sheets per stock and die combination, all three die types produced commercially comparable embossing results. Visual inspection on press and macro photographic examination found no meaningful difference in emboss quality, edge definition, or feature retention between the printed dies and the brass control. Post-run inspection also showed no visible wear, rounding, chipping, or breakdown of the printed dies after runs of up to 400 sheets. Operator feedback suggested that make-ready was generally within the range of a conventional cold emboss process, although the heavier cover stock required somewhat more setup time at one site because the printed dies could not be used with the heat-assisted adjustments available in a conventional metal workflow.

These findings suggest that additively manufactured dies are not merely theoretical substitutes, but viable tooling for short-run cold embossing processes, especially where rapid fabrication, low tooling cost, or repeated iteration are important. They do not displace brass in every context, particularly where heated workflows or long-run durability are essential, but they do expand the practical tooling options available to commercial print manufacturers.

Keywords: embossing tools, additive manufacturing, stereolithography, rapid tooling, 3D printing

1. Introduction and background

Embossing occupies a distinctive place in commercial print finishing: It is a long-established process that continues to offer both practical value and communicative impact. What has changed is not the relevance of embossing in print manufacturing, but the circumstances in which commercial print manufacturers produce jobs. Shorter runs and customization mean more iterative production is required than traditional die manufacturing was designed for. The manufacture of the embossing die is often the slowest or least flexible part of the process.

Typical print embossing dies are most commonly produced in brass, copper or magnesium. Each material has a well-established role in industry. Magnesium is often the lowest-cost option and is suited to short and medium runs. Copper offers precision and good heat retention. Brass remains the premium option when durability, repeatability, and detailed sculpting are priorities. These materials remain dominant for good reason. They are proven, stable, and deeply integrated into

commercial finishing practice. At the same time, their manufacture often depends on outside vendors, specialized fabrication processes, shipping delays, and significant revision costs. That makes them harder to justify for mock-ups, samples, short-run jobs, or design work still in flux.

This is where additive manufacturing becomes relevant. Earlier research in graphic engineering has already shown that embossing dies can be produced by fused deposition modelling and used successfully on paper stocks. Delić et al. (2017) established the basic feasibility of paper embossing tools produced by FDM. Žarko et al. (2017) showed that output quality is affected by production speed, especially where dimensional accuracy matters. Banjanin et al. (2018) demonstrated that the physical and mechanical behaviour of FDM embossing dies is shaped not only by the material itself but also by process variables such as print structure and output settings. Taken together, these studies make two points clear. First, polymer embossing dies are possible. Second, their success depends on design and process control rather than on material substitution alone. More recent work has pointed to stereolithography as a strong alternative. Feldmann et al. (2021) presented a workflow for paper embossing tools produced through stereolithographic additive manufacturing, noting both fine detail reproduction and service life of 20,000 embossments without visible wear. This is especially important because it moves the discussion beyond proof-of-concept tooling and toward viable production use.

This study builds on that literature, but moves beyond theoretical assessment by reporting production testing. It asks a practical question: under what conditions can ABS-GF FDM dies or mSLA resin dies function as credible substitutes for conventional metal embossing dies in commercial print finishing? More specifically, it considers these related issues: which material and process characteristics matter most in this substitution, how the printed die types compare with brass in actual embossing use, where additively manufactured tooling makes the most operational sense in a commercial environment, and how can overall commercial return-on-investment be improved by adopting these materials and methods over traditional ones.

2. Materials and methods

This study combined the initial literature review with applied production testing. The literature component drew on prior research in additively manufactured embossing tools and direct polymer tooling. The experimental component tested digitally fabricated embossing dies in commercial production environments against a conventional brass die control. The purpose was not to claim universal replacement in advance, but to determine whether the proposed tooling routes were capable of producing commercially acceptable embossing results under realistic shop conditions.

2.1 Candidate materials and process routes

Two digitally fabricated die production methods were examined and tested in this study. The first was FDM using ABS-GF filament. According to the manufacturer, ABS-GF is an ABS matrix reinforced with glass fibre and formulated to offer greater stiffness, dimensional stability, and reduced warping compared with standard ABS. The reported bending modulus is 2860 ± 130 MPa in the X-Y direction and 1970 ± 110 MPa in Z, with bending strength of 68 ± 4 MPa in X-Y and 46 ± 3 MPa in Z. Heat deflection temperature is reported at 88 °C under 1.8 MPa and 99 °C under 0.45 MPa, with water absorption at 0.53% under standard test conditions (Bambu Lab, 2025). These values do not determine die life on their own, but they do suggest a stronger tooling candidate than the more commonly used PLA materials seen in earlier FDM embossing testing.

The second route was mSLA printing using a high-strength ABS-like resin. In the earlier abstract, this route was treated largely as a process class. In the present study it was also tested directly in production, allowing evaluation not only of its theoretical suitability but of its practical embossing performance relative to FDM and brass. The brass die used as control represented conventional

commercial practice. The three die types were therefore assessed comparatively rather than in isolation.

2.2 Test design and substrates

Testing was carried out at two commercial print production facilities accustomed to traditional metal die based embossing processes. At both facilities, three die types were compared: ABS-GF (produced via FDM), ABS-like resin(produced via mSLA), and a traditional brass die. The test substrates were Husky 60# Text (89 GSM), Cougar 80# Text (118 GSM, 10% post-consumer fibre), and Cougar 130# Cover (352 GSM, 10% post-consumer fibre). As coated stocks can suffer from cracking issues under the pressure of embossing dies, testing was restricted to uncoated stocks for these initial tests. Each die type was run on each stock through several hundred impressions. Output was assessed through on-press observation, comparison of finished sheets, and macro photographic inspection of embossed features. The dies themselves were also examined after the runs for visible wear, edge wear/breakdown, chipping, or loss of geometry. Sheets were numbered (first sheet to last sheet) to compare for changes in embossing result over the duration of the run, a key factor in evaluating whether subtle wear of the die was impacting the resultant embossed pieces.

The die geometry was designed to reflect conventional embossing practice. Particular attention was given to the angled shoulder between the embossing face and the die plate, as this feature helps reduce die wear and prevents tearing when the sheet is compressed. This mattered because the study was not simply testing printed objects, but testing whether printed objects could reproduce the functional geometry of existing commercial embossing tools.

2.3 Assessment Criteria

The comparison was structured around six criteria: embossing quality, edge definition, feature retention, evidence of die-wear, make-ready and setup behaviour, and broader workflow implications. The study was concerned not only with whether the printed dies *could* emboss, but whether they could do so consistently enough to be meaningful in a production environment. This included attention to the practical advantages of in-house fabrication, such as reduced turnaround time, lower material cost, and lower revision cost, alongside the constraints introduced by the printed materials themselves.

3. Results and discussion

3.1 Embossing performance across die types and stocks

Across both production facilities and all three substrates tested, the results were consistent. All three die types produced commercially comparable embossing results. Across runs of several hundred sheets per stock and die combination, the embossed output was visually consistent and, in practical terms, indistinguishable between the printed dies and the brass control when assessed on press and through macro photographic examination. No meaningful visual difference was observed in emboss quality, edge definition, feature clarity, or overall impression depth. The comparison images prepared from the test runs likewise showed no meaningful difference in emboss quality, edge definition, or feature retention across the tested conditions.

This is the most important development relative to the earlier submission. The earlier abstract argued that ABS-GF and mSLA were *plausible candidates* based on literature, material properties, and workflow logic. The updated results here show that the concept also holds up in production testing. The substitution argument no longer rests on adjacent evidence alone. At least within the limits of this trial, both printed die types were able to perform the primary task expected of them.

This makes them both viable candidates for further review of workflow, cost implications and overall impact on the embossed material production process for commercial printers.

3.2 Durability and setup observations

Post-run inspection of the printed dies was equally encouraging. After runs of up to 400 sheets, neither the ABS-GF nor the mSLA dies showed visible wear that would suggest an immediate limitation for short-run production. There was no notable rounding, chipping, or breakdown at the embossing edges, and no visible decline in embossed feature quality from the start of the run to the end. Within the limits of the present test, both printed die types maintained their geometry and functioned as stable tooling for repeated impressions.

Operator feedback from the bindery and finishing departments of the facilities involved in testing added useful nuance. Setup and make-ready were generally within the range of a conventional cold emboss process, but this was not identical across both sites. At one facility, the operator reported that setup with the printed dies was comparable to a standard cold emboss job. At the second facility, setup took somewhat longer, particularly on the heavier Cougar 130# Cover stock. This was not attributed to failure of the die itself, but to the fact that the printed dies could not be used with the same heat-assisted adjustments available in a conventional metal workflow to help reshape the paper fibres during embossing. That distinction matters. The printed dies performed well as tooling, but they did not reproduce every operational convenience associated with heated metal dies. Notably here, both operators indicated that in most cases their professional preference is a standard (heated) embossing process vs. the cold embossing process they were asked to conduct, as the heat applied to the embossing die helps to soften the substrate fibres and this additional variable provides them with greater control over the embossing process.

This finding also sharpens the application boundary. The printed dies appear well suited to cold embossing, but not to hot foil or other heated die applications. That does not invalidate the tooling approach, but it does frame it more precisely. What is being demonstrated here is not a collapse of the distinction between polymer and metal tooling. It is a viable cold embossing alternative for particular production contexts.

3.3 Implications for commercial print manufacturing

The results suggest that the most useful industrial question is not whether additively manufactured polymer can replace metal outright, but where it can do enough, well enough, and with enough cost or turn-around time benefit to make practical sense in a production environment. On that point the evidence is now much stronger. For short-run cold embossing, prototypes, samples, rapid revisions, and exploratory production, both digitally fabricated die types performed credibly. Their value lies not only in emboss quality, but in the surrounding workflow. A comparison of traditional and digitally fabricated workflows makes this clear. A conventional die path involves artwork preparation, vendor ordering, die fabrication off-site, shipping, mounting, and counter-die preparation, typically over several days. The digital route compresses this into in-house CAD modelling, die production, mounting, and adjustment, with a turnaround measured in hours rather than days and a far lower per-die cost. The cost and speed of die production also lends itself to the possibility that even if the lifetime duration of the digitally manufactured die over a longer embossing production run is proven to be lesser than traditional metal dies, it may make sense for a print facility to produce *multiple inexpensive copies* of the digitally manufactured die and use them in succession to one another.

ABS-GF FDM and mSLA do not occupy exactly the same niche within that workflow. FDM remains attractive where speed, low cost, low operator skill and ease of replacement matter most. mSLA remains the stronger route where fine detail, shallower relief, or more visually sensitive

embossing effects are the priority. The present production testing does not overturn those distinctions. It confirms them in a more grounded way. Both routes are viable, but they solve slightly different problems.

At the same time, the results should not be overstated. The study does not yet show long-run equivalence with metal dies, nor does it erase the known advantages of conventional metal dies in heated workflows, extended service life, or highly standardized repeat production. What it does show is that the threshold for practical usefulness is lower than full equivalence. The printed dies do not need to outperform brass in every respect to be worth consideration. They need to perform well enough, for the right jobs, at the right cost and turnaround time. On the evidence now available, they do.

4. Conclusions

In short-run cold embossing, both digitally manufactured die types (ABS-GF via FDM and ABS-like resin via mSLA) produced embossing results that were visually comparable to those of the brass control across all three paper stocks tested in run lengths of up to 400 sheets. Neither showed visible wear over the scope of the trial. The principal difference observed was not embossing quality, but workflow behaviour, especially on heavier stock where heat-assisted setup adjustments available to metal dies could not be used in the same way.

This shifts the argument of the original submission in an important way: Additively manufactured embossing dies should not be framed only as a plausible future direction. They are shown here to be workable tooling for selected commercial applications. Their strongest use lies in prototypes, short runs, rapid revisions, approval samples, and other situations where speed, flexibility, and low tooling cost matter more than heated operation or extended die life. Brass and other conventional metal dies remain important, and in many contexts they will remain preferable. But the present results show that additively manufactured dies deserve to be understood as a viable addition to the embossing toolkit rather than a speculative alternative.

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