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ANALYSIS OF KEY PROPERTIES FOR 3D PRINTED DIE FOR EMBELLISHMENT IN PRINTING & PACKAGING USING 3D-DLP TECHNOLOGY – STRENGTH, STRESS & TEMPARATURE RESISTANCE

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Abstract

This research explores the essential properties required for die materials used in industrial applications,specifically die making for embellishments in Printing and Packaging, using 3D-Digital Light Emitting Technology (DLP). The focus is on analysing the strength, stress resilience, and temperature resistance of die made using DLP technology. The study investigates the significance of these properties and their impact on the performance and durability of dies as an alternative to metal dies used widely by printers. The findings contribute to the improvement of die design and material selection, ultimately enhancing the efficiency and reliability of industrial manufacturing of dies.

Key words: *3D Printing, Print Embellishments, Die making for printing, Die embossing and debossing, 3D die making, DLP for die making*

1. Introduction:

1.1 Background & Literature

The present method of die making requires expertise of labour and causes delays [1]. The metal dies are also costlier and lacks on certain quality parameters – inability to reproduce finer graphics, smaller and thin fonts, finer lines, complex illustrations etc. It also takes time to make dies as it either involve laser engraving and manual labour work[2].

This research explores the possibilities of using Digital Light Processing (DLP) 3D Printers [3] in directly 3D printing dies for print embellishments[4][5] using UV curable resins. The study further analyses the properties of dies 3D printed in a DLP Printer which uses polymerization reaction to cure liquid resins [6]. Different resins with specific mechanical and chemical properties[7][8][9] can be used for various dies in printing and packaging - foiling, embossing, and other decorative effects [10].

2 Objective

The experiment is to find out the Strength, Stress, and Temperature withstanding of resin-based 3D printing by using DLP technology to make die for Printing and Packaging embellishment applications.

2.1. Die Material Properties:

2.1.1 Strength

During embossing, the die applies a localized compressive stress to the substrate [11]. This stress causes resulting in deformation and pattern, creating raised or indented areas on the surface. The magnitude of the stress depends on factors such as the design of the die, the material properties of the substrate, and the applied force [12].

2.1.2 Tensile Strength

The tensile strength of the die material is crucial to withstand the forces and pressures encountered during the embossing process. Rigid materials like steel, brass, or zinc are commonly used due to their high tensile strength properties [13]. The ultimate tensile strength (UTS) values of various resins used in 3D printing are provided in Table 1.0 & Fig 1.0, demonstrating the range of tensile strengths exhibited by different resins [14][15].

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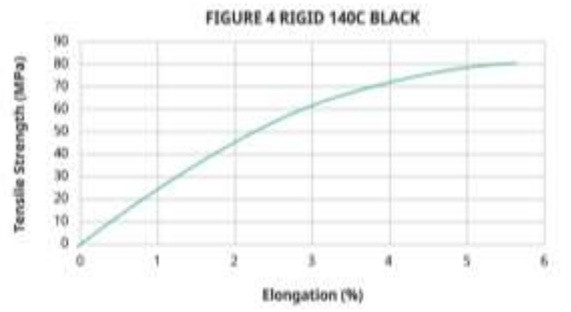
Fig. 1.0 – Ultimate tensile Strength of Resins, graph

3D Printing Materials – Resins		
Ultimate Tensile Strength (UTS)		
(ASTM D648)		
	Material	*Tensile Strengt Ultimat (MPa)*
1	High Temp	79
2	Egg shell AMP 10	72
3	Rigid White	57
4	Fl ex Black 10	56
5	Flex Black 20	36
6	High Temp 150 C FRC Black	58
7	Jewel Master Gray	67
8	Med AMB 10	69
9	Med White 10	60
10	Pro Black	63
11	Rigid 140 C White	80
12	Rigid Grey	61
13	Tough 60C White	35
14	Tough Black20	40
15	Tough Grey 15	48
16	Tough 65C Black	41
17	Tough Grey 10	50



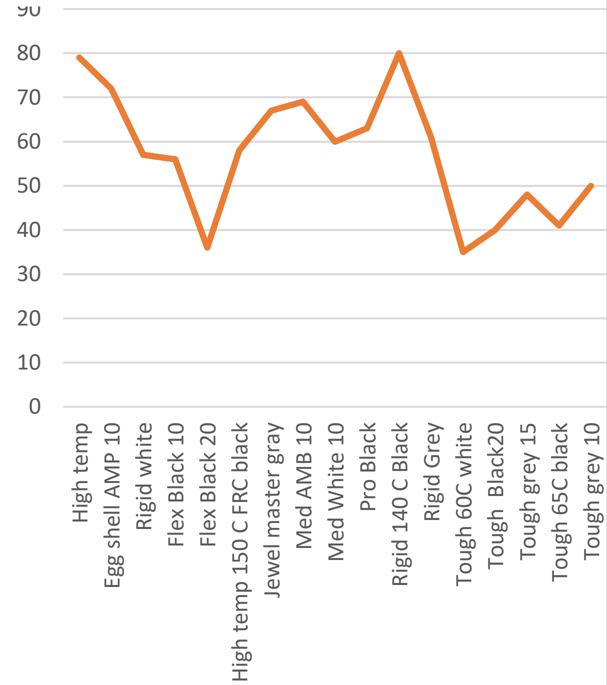


Fig.2.0 – Tensile Strength of Resins Vs. Elongation (Indoor), (Graph Source: www.3dsystems.com/)

Table 1.0 – Ultimate Tensile Strength of Resins manufactured by 3D Systems, USA

2.1.3. **Compressive Strength:**

Compressive strength [16] is a measure of a material's ability to withstand applied compressive forces without deformation or failure. It depends on resin formulation, print setting, post processing and reenforcing suitable fillers, additives or impact modifiers like carbon, glass fibers,

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metal powder etc with resins. Rigid 140C Black exhibits comparatively good elongation strength with tensile strength [14] (Fig. 2.1).

2.1.4 **Stress Resilience:** Stress resilience [17] in 3D printing is critical for ensuring the structural integrity, functional performance, and overall reliability of printed dies for printing and packaging. Rigid 140 C Resin shows comparatively good stress resilience in printing

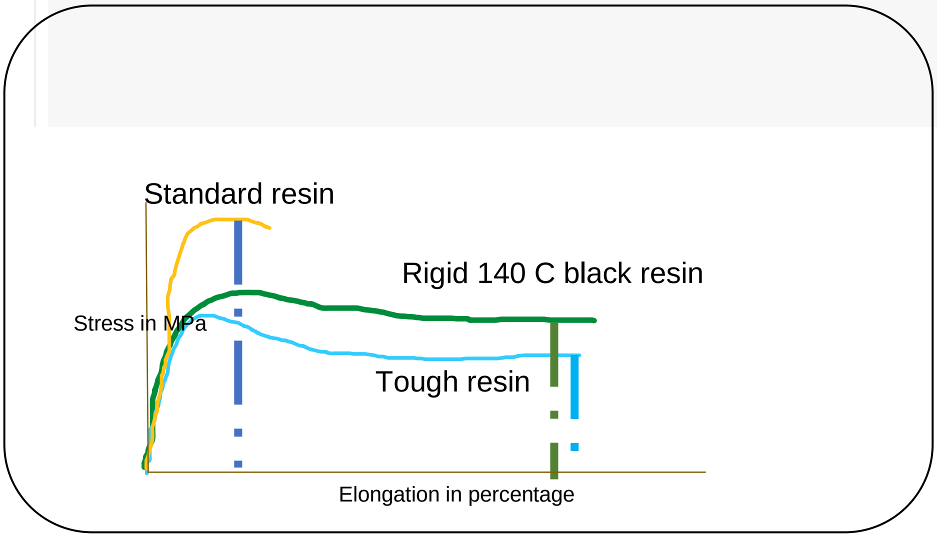

Fig 2.2 – Stress Resilience trend of Rigid 140C Black with standard resin and Tough resin (Source: 3D System)

Regardless of the technique, additive manufacturing produces components with a layered microstructure; inside each layer, the mechanical characteristics of 3D-printed materials rely on the direction of printing. This is a critical consideration in the design of load bearing 3D-printed components, regardless of the material or manufacturing technology utilised. During die embossing or debossing, the stress exerted by the machine is distributed equally on the 3D printed die. So though the strength of 3D printed dies are comparatively less, because of the distributed stress, DLP based 3D printed dies are compactible for substituting metallic dies in printing and packaging.

2.1.5 **Temperature Resistance:**

In 3D Printing using Digital Light Processing (DLP) technology, the thermal conductivity requirements and temperature resistance of resins become important considerations. The life span of dies is closely connected with temp. resistance. Most of the 3D printed resins using in DLP technology having a temp. Range from 50 to 300 degree Celsius. The list of resins from 3D systems and its temp. resistance are in the list Table2.1. The temp. resistance [18] graph is plotted as Fig, 2.3

2.1.6. **Thermal Conductivity** [19]: It plays a role in efficient heat dissipation during the die-making process, and crucial for foiling process. During heating the foils are transferred to paper by heat. The die is heated by using external source and the heated transmitted through the metal die is the main source for the prompt transfer of metallic foil[20]. Moreover, higher thermal conductivity helps prevent excessive heat build-up and maintains the performance and durability of the metal die [21][22]. However, it is important to note that most resins used in DLP 3D printing [23] have relatively low thermal conductivity compared to traditional die-making metal materials. Normally foiling process requires only 80 - 120 degree Celsius and that range of resins are also available. Some of the resins having the temperature range to meet the requirement, but it is not at all conduct heat. So new resin or composites is to be explored for this purpose

Industrial Engineering Journal
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3D Printing Materials - Resin		
HEAT DEFLECTION TEMPATARURE (HDT)		
(ISO 75- 1/2 B /ASTM D648)		
1	*Material*	*Temp*
2	High Temp	300
3	Egg Shell AMP 10	89
4	Rigid White	64
5	Flex Black 10	52
6	Flex Black 20	46
7	Hi-Temp 150 C FRC black	150
8	Jewel Master Grey	300
9	Med AMB 10	119
10	Med White 10	102
11	Pro Black	70
12	Rigid 140 C Black	140
13	Rigid Grey	120
14	Tough 60C Black	65
15	Tough Black20	55
16	Tough Grey 15	59
17	Tough 65C Black	65
18	Tough Grey 10	51

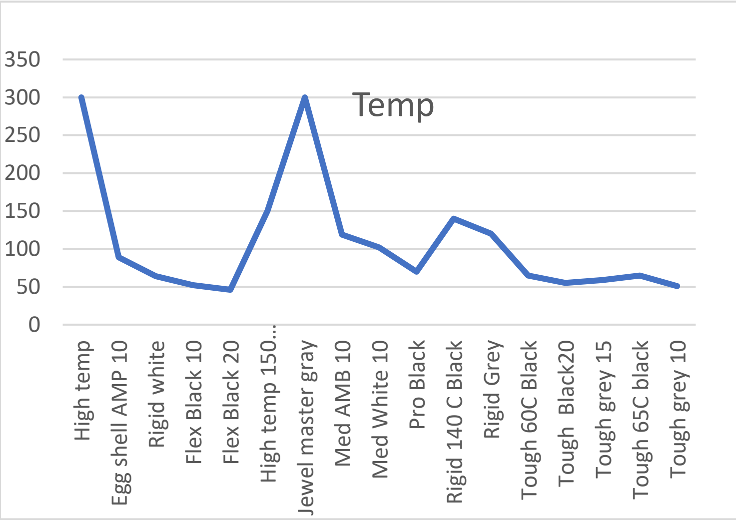


Fig.2.3 – Temp. resisting capacity of various 3D printable DLP resins from 3D systems, USA (www.3dsystems.com/)

Table 2.1 – Temp. chart of various 3D resins of 3D systems, USA (www.3dsystems.com)

3. Conventional die making:

3.1. Challenges & Remedies: Die preparation for embossing and foil stamping [24] in the printing and packaging industry has several pain points and challenges. They are design complexity, selection of right materials, accuracy of die, cost factors, turnaround time, maintenance & storage, skill & expertise, and adaptability to different substrates. Most of these crucial challenges are easily addressed by using additive manufacturing method suggested. Collaboration between designers, die makers, and production teams is crucial to ensure seamless die preparation and achieve the desired embossing and foil stamping outcome. That can be easily achieved by this new technology with new material science and application possibilities it offers.

3.2. **Merits in 3D printed dies**: Die making in 3D printing provides printing and packaging industries with enhanced speed, cost efficiency [25], design flexibility, and customization capabilities. It enables the production of complex and precise dies while reducing lead times and promoting sustainability.

3D printing provides unparalleled design freedom. Complex and intricate designs can be easily created, including unique and creative shapes, patterns, and textures. This flexibility enables designers to create customized and visually appealing packaging solutions. Those were previously

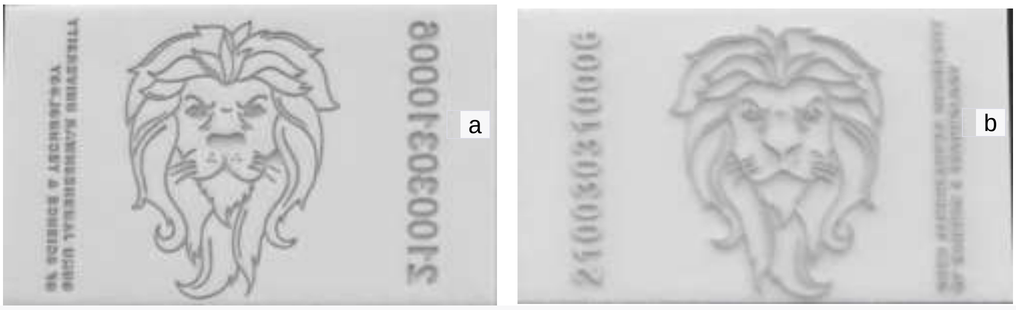
challenging to achieve with traditional die. With 3D printing, it becomes easier to create personalized packaging and printing solutions. Unique designs, logos, or customer-specific details can be incorporated into the die, allowing for greater product differentiation and brand recognition.
The additive manufacturing approach minimizes material waste by only using the necessary amount of material, reducing environmental impact [26].

4. Experimental Methods:

4.1 **Sample Preparation**

Prepared a design in Fusion 360 software, especially for additive manufacturing. The die having a ‘male’ and ‘female part’. Male part having a thickness of 3mm and female part having 4mm. *(Fig. 4.1).* It is fixed on a MDF plywood having 17mm thickness. The tolerance in between male and female die is 0.5mm. Total size of the die is 120 X 70mm. The block design is fixed in 3D system’s ‘Sprint’ software. It is printed in Figure 4 DLP 3D printer using the resin by keeping XZ position High. Resin will be Rigid 140 C Black resin from

Fig 4.1 – View of male (a) and female designs prepared by Fusion 360 software



3D System, USA. This XZ position gives extra tensile strength to the die as orientation advantage. The depth of female die elements is 1.8 mm and the height of male element is 1.5mm. The paper/board thickness will be 0.3mm (Fig.4.2)
The post processing of the printed material includes the curing of die under UV light box for a time span of one hour maximum.

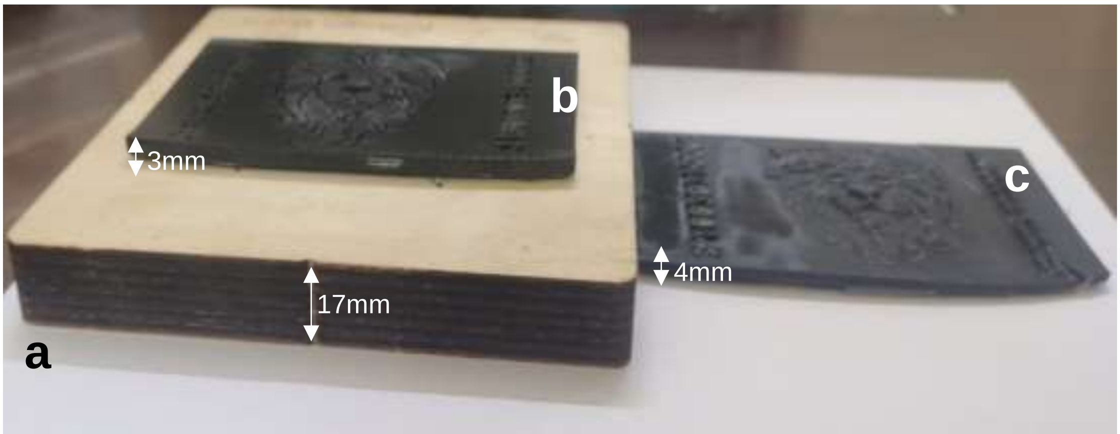


Fig 4.2 – View of actual 3D printed block for embossing. (a). MTF board as base for die female with 17mm thickness. (b). Female die part in Rigid 140 C Black material (c) Male block with 4mm height

Industrial Engineering Journal
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Fig 4.3 – Embossing on various substrates with different weight.

Printing is done by using heavy platen machine that create a stress of 28 kg/sq. meter on the die block during embossing or debossing. The image is transferred to paper and board having various weight (GSM) from 100 to 240. (Fig. 4.3))

5. Results and Conclusion:

Rigid Black140C Black resin exhibits comparatively good mechanical strength and durability. The data of the material explains that it has high impact resistance and durability, making it suitable for die printing in applications that require resistance to wear, abrasion, and repeated flexing. It is suitable for creating intricate dies that require precise tolerances and can handle moderate loads.

The material data sheet reveals that the thermal conductivity essential for foiling is zero in most of the 3D printable resins. So, we need to experiment with the possibilities of composites to use in die making for embossing and foiling in printing and packaging applications. Proper post processing is crucial to confirm the stress, shear strength and impact resistance of the die.

6. Scope of future study:

After this study, it is realized that this requires further exploration and analysis. The subject has wider implications on the printing and packaging industry. Following areas are recommended to subject to detailed analysis and study.

Along with the evolution of new materials by resin manufacturers and product developers, new materials shall be subjected to same or more vigorous studies. Also, the current practices followed by the printing industry for embellishment subject the dies to much higher impact and it warrants more impact resistance like that of metals. It is to be explore if those strength and impact could be minimized to get the present results. If there is a modification in the process which enable lighter impact transfers, it will help the industry in many ways.

The study shall explore the new materials, ideal and minimum strength required for the embellishment processes, cost implications WRT current processes, material characterization to measure the exact properties of successful samples etc. Also need to identify the life of the subjected dies WRT to number of copies produced. This run length plays a major role in long run applications like packaging. Another area is study using various 3D Printing technologies, the present study has conducted through DLP method, a subset of SLA. There are other technologies like FDM, SLS, MJP etc which are providing options for more materials and characteristics. They have to be explored further.

With packaging becoming a mainstream communication medium for brands, there is a need for brands to get the consumers interested to explore the product in first look itself. Also, they need to impress them by communicating the product benefits once they bought the product. Embellishments plays a crucial role in both, and it can demand consumers attention to the product and communications on the packaging.

Industrial Engineering Journal
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