ORIGINAL SCIENTIFIC PAPER

ACTA GRAPHICA 237

Evaluation of binding strength depending on the adhesive binding methods

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Abstract:

A book with a personal value is worth remembering since it represents specific interests of an individual - author of the book. Therefore the original is the first issue of a book which is always bound manually. Due to cost-effectiveness, adhesive binding is most commonly used in author's edition in paperback and hardback. Adhesive binding methods differ only if a paper leaf is a binding unit in adhesive binding form. The subject of the research is the quality of book block binding for two binding methods with/without mull fabric. The assumption is that double-fan adhesive binding method shows an extraordinary binding quality as compared to the rough spine method. For the needs of this research book block parameters remained unaltered: paper type, size and book volume. The results related to strength were obtained by using an experimental method of tensile strength for individual paper leaves. The rating of book block quality was conducted in accordance with FOGRA Nr.71006 guidelines for page pull-test. Furthermore, strength results for both methods were compared in order to evaluate the importance of changing the quality of adhesive binding. Statistical method ANOVA analysis of variance and Fisher's F-test were used to evaluate the quality of book block binding.

Keywords:

craft bookbinding, adhesive method, binding edges, rating of binding strength

1 Introduction

In the digital world, books may seem like an endangered species, but craft bookbinding is more popular than ever and it is available to everyone. Although most books we use are produced commercially, some of them are produced by means of "print on demand". People either use their software to lay out their own book or they download e-books from an internet website as a PDF file (cookbooks, kids' books, scrapbooks and notebooks) so they can be printed and hand-bound one at a time (Weston, 2008), (Simpson, 2009). Scientific research works like doctoral thesis are produced the same way. Manual adhesive binding has a great potential to be used in bookbinding of paperback and hardback books in which binding unit consist of individual (loose) leaves. This is a relatively inexpensive binding style, it requires a little cold adhesive that dries quickly and remains flexible and strong.

It is best suited to binding of uncoated paper such as copy paper. Adhesive binding can be used for thin and thick books like where every loose leaf is attached to the block spine with a small amount of adhesive (Johnson, 1998.)

Two different adhesive binding methods, double-fan and rough spine method, can be used to produce block spine (Kipphan, 2001), (Roberts, Etherington, 1982). Double-fan is used more often as it can be achieved without great effort. In this method, binding edges are first fanned in one direction, afterwards the cold adhesive is applied and finally the same procedure is repeated by fanning the binding edges in the opposite direction (ANSI/NISO/LBI Z 39.78-200). This way the adhesive is applied between the leaves in a way that each loose leaf is tipped to the next. That helps to support the spine flexibility and contributes to the extended shelf life of the book. Rough spine method is based on notching the block spine. Notching is a method whereby small shallow grooves or "notches" are cut into the spine perpendicular to the length of the spine (Jerman, 2014.). Irregular notches can provide desirable binding strengths even in cases where binding units aren't tipped next to each other. Spine flexibility can only be achieved by sticking lining fabric-mull on the binding edges (Roberts, Etherington, 1982), (Jerman, 2014). The lining fabric-mull is made of cotton, reinforcing material which is positioned directly over the block spine. As both adhesive methods enable the reaching of desirable binding strengths, sometimes the difference between bookbinding types cannot be distinguished. However, the double-fan adhesive method is used more than the rough spine in a variety of different products, especially in the cases that require short bookbinding time.

Cold emulsion PVAc adhesive is usually used in craft bookbinding, its elasticity allows to block spine moving in the absence of cracking during book opening and scrolling (Packham, 2003), (Frihart, 2005). According to Jerman, its cohesive (elastic) property tends to give sufficient binding strength in spite of bookbinding style (Jerman, 2014).

Paperbacks are a popular choice with book creators. The adhesive is applied to the block spine and the cover is then wrapped around the book block. After the adhesive is dried, the book is trimmed on three sides. Hardback books are more complex, as the hardcover is indirectly connected to the text block with endpapers. According to Johnson, the case binding style (hardback) is more appropriate for frequently used volumes like reference books with long shelf lives (Johnson, 1998.)

This paper deals with the binding quality of two different adhesive methods mostly used in craft bookbinding including paperback and hardback books. The rating of the binding strengths obtained in both types of bookbinding is presented in this paper. The results are summarized with special emphasis on the joint strength of individual loose leaves depending on their position in block spine. The aim of this experiment was to suggest the most favourable adhesive method for paperback and hardback books including craft bookbinding only.

2 Experimental

2.1. Book samples preparation

Two different adhesive methods were used to apply glue on the blank blocks with identical characteristics (size, volume, paper type, binding unit). Two blank blocks were bound to hardcovers by means of double-fan and rough spine adhesive method respectively. Similarly, the two other blank blocks were bound to the soft-covers by means of the same adhesive methods. In all of those four samples, the spine lining fabric-mull was stuck on their binding edges. Additionally, two more blocks were bound by means of both adhesive methods but without inclusion of mull fabric (Tab. 1). In paperback bookbinding the cover is bound directly onto the spine, whereas in the hardback bookbinding the cover is indirectly bound to the book block with endpapers (Fig. 1). Office paper with basic weight of 80 g/m2 was used in craft bookbinding. This is commercial photocopy paper (Navigator Universal, A4 size) which is often used for office printers (EN 643:2001). The selected paper was used in the craft binding process with the cold emulsion PVAc adhesive–Librokol I (Gross, 1981), (Leekly, 1972) (Pizzi, 2003). The optimal adhesive binding method (block spine treatment, adhesive bond application) was applied in accordance to preliminary test and standard conditions (ISO 187, ISO1180, LBI Z39.78-2000) with paper grain direction running parallel to book block binding edges (Clark, 1994). Books unprinted samples specification is 15cm (width) x 21cm (height) x 64 loose leaves (volume). The paper grain direction runs parallel with book height. Furthermore, the loose leaves binding edges run parallel with grain direction.

2.2 Methodology

The adhesive joint strength result explains book block binding quality directly. A binding endurance pull test determines the uniform force required to pull a loose leaf along the binding edge. The book

Table 1: Craft bookbinding samples characteristics

Parameters of books	gTUKL	gMUKL	MUKL	gTUKH	gMUKH	MUKH
Size, mm	150x210	150x210	150x210	150x210	150x210	150x210
Volume, binding unit	64	64	64	64	64	64
Binding unit type	Loose leaf	Loose leaf	Loose leaf	Loose leaf	Loose leaf	Loose leaf
Office paper, A4 size	Navigator-Universal	Navigator-Universal	Navigator-Universal	Navigator-Universal	Navigator-Universal	Navigator-Universal
Paper basic weight, g/m2	80	80	80	80	80	80
Adhesive type (cold emulsion PVAc)	Librokol 1	Librokol 1	Librokol 1	Librokol 1	Librokol 1	Librokol 1
Double-fan adhesive method, L	Yes	Yes	Yes	-	-	-
Rough spine adhesive method, H	-	-	-	Yes	Yes	Yes
Application of lining fabric-mull, g	Yes	Yes	-	Yes	Yes	-
Paperback book, MUK	-	Yes	Yes	-	Yes	Yes
Hardback book, TUK (case binding)	Yes	-	-	Yes	-	-

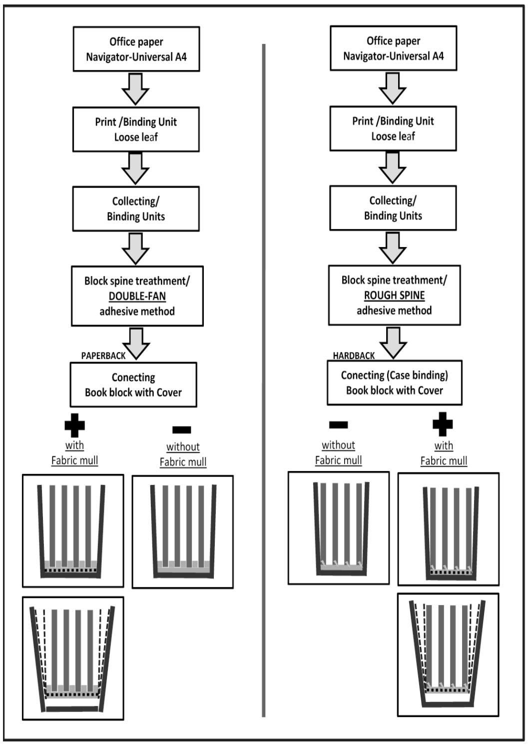

Figure 1: The adhesive methods procedure scheme in craft bookbinding

is clamped into position by the bottom jaw of the testing device with a loose leaf held in a vertical position by the top jaw. The jaws are separated and the force required for tearing the loose leaf or pulling it from bond line or adhesive-adherent layer is measured (Fig. 2). The pull test measures tensile strength of loose leaf which is observed when the force is applied to pull a loose leaf from text block spine. The applied total load force is then divided by the loose leaf height (cm) to give its pull units expressed in N/cm (Southworth, 1989), (Küen,

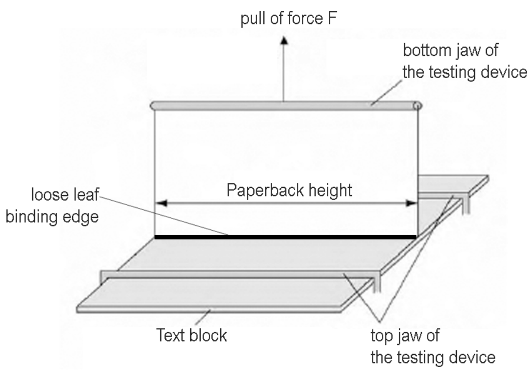

Figure 2: Adhesive joints strength measurement (pull test device)

2008). Static tensile stress was measured using a Muller Martini Tester Type VA.

The rating of the binding strength was conducted with respect to the adhesive joint strength results. The results of the adhesive joint strength of the samples bound by means of different adhesive methods were compared to the rating of adhesive joint strength (bad, sufficient, good and very good binding strength) according to FOGRA guidelines.

The results are summarised with special emphasis on the joint strength of individual loose leaves, and afterwards were compared in order to suggest the most favourable method. The measured adhesive joint strength of individual loose leaves (A-S) for adhesive methods is shown in Figure 4a-b. Results indicate that desirable binding quality was achieved in hardback bookbinding sample (gTUKL), where the double-fan adhesive method and fabric-mull were used. In those samples, the

Table 2: The rating of adhesive joint strength according to FOGRA guidelines

Book sample	Mean value of Adhesive joint strength (N/cm)	Rating of adhesive binding strength	Ranking of adhesive binding quality
gTUKL	12.37	very good	1st
gMUKL	10.89	very good	2nd
MUKL	5.52	bad	6th
gTUKH	6.59	sufficient	5th
gMUKH	9.36	very good	3rd
MUKH	6.87	good	4th

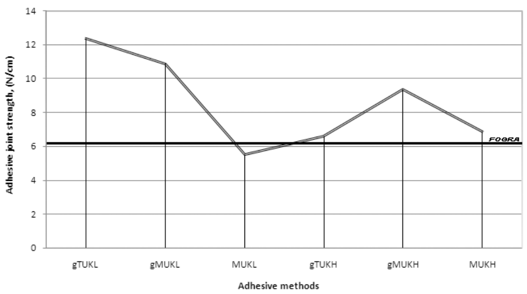

Figure 3: Estimating the similarity between adhesive methods in craft bookbinding

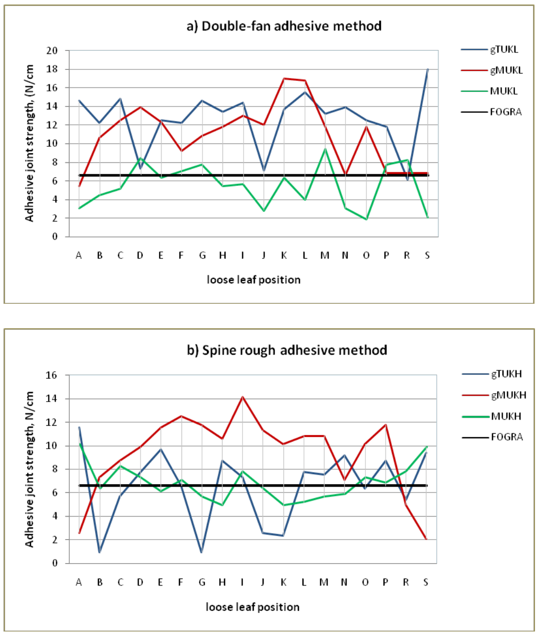

Figure 4a-b. Adhesive joint strength results of loose leaves including their position in block spine

3 Results and Discussion

The results of adhesive binding strength determination (paperback and hardback books) are presented in Table 2. According to the German FOGRA Recommendations of adhesive binding quality, the results adhesive join strength must exceed value of 6.60 N/cm. The results of the conducted analyses indicate that for the most measured samples adhesive joint strength values were good, except for two samples. As shown in Figure 3, the binding strength was insufficient in both adhesive methods and bookbinding styles where fabric-mull wasn't used. A noticeable increase in binding strength was observed in samples containing lining fabric-mull, where adhesive double-fan method was used for bookbinding both paperback and hardback books.

binding edges enabled stretching of loose leaves to high strain without damage. This result can be attributed to the inclusion of the fabric-mull which, stuck on the binding edges, increased the elasticity of the spine. However, the results for the loose leaf position D, J and R are not relevant for discussion on binding quality due to their high ratings. Furthermore, the double-fan adhesive method also achieved the binding quality of the paperback book sample with fabric-mull (gMUKL), but loose leaves didn't enable stretching because the cover is bound directly on the block spine. However, in the case (hardback) binding style, endpapers are indirectly bound to the cover, thus enabling high stretching rates to be achieved.

Results indicate that in the rough spine method, the strength values are reduced although the spine was stuck with fabric-mull. Lower strength rating occurred because loose leaves weren't stuck together side by side. The results indicate that desirable binding quality was achieved just in soft-cover bookbinding sample (gMUKH). In case bookbinding (gTUKH) loose leaves didn't enable stretching like in samples where double-fan was used. Furthermore, soft-cover (paperback) book samples that didn't contain fabric-mull, showed different strength rating. By increasing of the surface area with irregular notches (MUKH), higher strength results are achieved. Results indicate that binding strength was insufficient in the samples where lining fabric-mull was not used. Moreover, the double-fan method appears to be more appropriate for achieving the desired binding strength. According to the results, the lining fabric-mull holds up the spine flexibility regardless of the bookbinding type used. The review of binding quality ratings is presented in Figure 5. The binding strength of the loose leaves was measured for eighteen regular positions (A-S) in the book sample (gTUKL, gMUKL, gMUKH). The rating of the binding strength was studied in respect of the book volume. Case binding (hardcover) achieved very good rating for the most positions compared to paperback books. It was furthermore noticed that paperback bookbinding (gMUKL) achieved lower strength values, in the first and the second part of the book where the double-fan method was applied. Furthermore, a significant decrease in the strength for great number of loose leaves was observed in the other method.

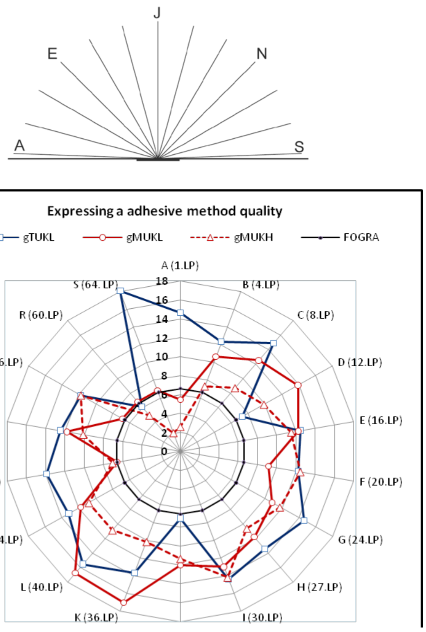

Figure 5. Results of craft bookbinding quality achievement

The statistical analysis compared the book block adhesive binding methods in order to evaluate the binding strength. The method ANOVA analysis of variance was used in the comparison, implemented with STATISTICA 7 software (Soong, 2004). The descriptive statistics of the measured variables used to evaluate the strength results contains the mean value, 95 percent reliability intervals, minimum and maximum values, variance, standard deviation and standard error. By analysing the descriptive statistics (Tab.3) and Box-Whisher chart (Fig.6) it can be seen that the best characteristics are in Book1 (gTUKL), Book2 (gMUKL) and Book5 (gMUKH).

By using Shapiro-Wilk test (Tab.4) which is suitable because of the smaller sample volume, the normality of results distribution from each sample was verified (Creswell, 2003).

The lower 5 percent limit for Shapiro-Wilk test statistics W, for n=18 and p=0.05 is W0=0.8970. The Shapiro-Wilk test shows that the majority of measurement results is normally distributed. Smaller deviation from the normal distribution was observed in only two cases (Tab.4). By using

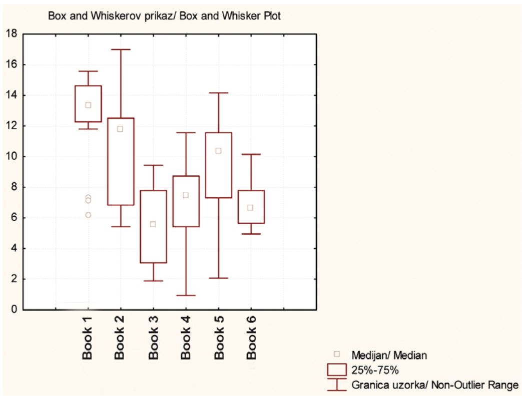

Figure 6. Box-Whisher chart of Adhesive joint strength results

univariate ANOVA analysis of variance, and since the data are distributed normally (Tab.4), the hypothesis is tested that there is no statistically significant difference between mean values per samples. In other words the following hypothesis is tested:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 \quad (1)$$

where μi, i = 1,…,6 is the mean value of the tensile force in ith book.

The testing is conducted in comparison with the alternative hypothesis according to which

Ha: at least two groups show statistically significant difference.

Table 3: Descriptive statistics of adhesive binding technique samples

	Samples	Number	Mean	Conf.-95%	Conf. +95%	Min	Max	Var	St.D.	St.Err
Book1	gTUKL	18	12.51	11.11	13.92	6.13	15.57	8.02	2.83	0.67
Book2	gMUKL	18	10.89	9.21	12.57	5.43	16.99	11.39	3.38	0.80
Book3	MUKL	18	5.52	4.35	6.68	1.89	9.44	5.49	2.34	0.55
Book4	gTUKH	18	6.59	5.06	8.13	0.94	11.56	9.56	3.09	0.73
Book5	gMUKH	18	9.36	7.70	11.02	2.08	14.16	11.12	3.33	0.79
Book6	MUKH	18	6.87	6.11	7.62	4.90	10.15	2.30	1.52	0.36

Table 4: Shapiro-Wilk test normality with significance α=0.05

	Samples	W	W > W0 = 0.8970
Book1	gTUKL	0.80901	Not normal
Book2	gMUKL	0.93140	Normal
Book3	MUKL	0.95469	Normal
Book4	gTUKH	0.92265	Normal
Book5	gMUKH	0.88521	Not normal
Book6	MUKH	0.92410	Normal

Table 5: Univariate ANOVA test results of Adhesive joint strength results Including level of significance α=0.05

Univariate Tests of Significance for adhesive joint strength Sigma-restricted parameterization, Effective hypothesis decomposition					
	SS	Df.	MS	F	p
Intercept	8032.98	1	8032.98	1006.68	0.0000
Adhesive joint strength	677.91	5	135.58	16.99	0.0000
Error	813.93	102	7.98		

Table 6: The results of Fisher's LSD post hoc test with significance level α=0.05

LSD test; Strength variables of adhesive joint; Probabilities for Post Hoc, Tests Error: Between MS = 7.9797, df = 102.00						
	Book1	Book2	Book3	Book4	Book5	Book6
Book1	-	-	-	-	-	-
Book2	0.088382	-	-	-	-	-
Book3	0.000000	0.000000	-	-	-	-
Book4	0.000000	0.000014	0.256513	-	-	-
Book5	0.001131	0.106147	0.000090	0.004104	-	-
Book6	0.000000	0.000043	0.154712	0.770390	0.009492	-

The test statistics is F-statistics or Fischer's statistics (Richard at all. 2011). According to the results from Table 5, statistically significant differences between the observed groups were found (F=16.99, p=0.0000). By applying ANOVA analysis of variance the conclusion follows that the obtained differences result from the differences in arithmetic means. In other words this test rejected the Ho hypothesis.

Post hoc analysis was conducted by using Fisher's LSD test (Tab.6) in order to determine which measurement groups show statistically significant difference.

It was determined (Tab.6) that there are no significant differences between groups Book1 and Book2, Book2 and Book5 and between Book4 and Book6 considering the adhesive joint strength. In the above-mentioned groups the binding of mull fabric to the book block spine was included. This group of books show larger spine flexibility so the book pages showed larger resistance to tensile force which is not the case in groups Book3 and Book4 which have showed the limit values of the binding quality, F < 6.60 N/cm (Fig.3).

3 Conclusion

The research on the adhesive method suitable for craft bookbinding was conducted with both paperback and hardback books. Two adhesive methods were used (double-fan and rough spine), for bookbinding the block samples of same characteristics onto the soft-covers (paperback) and hard-covers (hardback), respectively. The covers were bound to the block spine in two different manners, with or without inclusion of the fabric-mull.

In the case of the double-fan adhesive method, the results of analyses conducted on the samples treated with fabric-mull had a positive impact on the binding strength. Moreover, in the rough spine method, the binding strength was reduced due to the lack of tipping. However, the achieved binding strength results were still higher than the rating values proposed by FOGRA Recommendation. It can therefore be concluded that the rough spine method is suitable exclusively in paperback bookbinding. Furthermore, the use of lining fabric-mull in both adhesive binding methods regarding the analyses conducted within this research is proven to contribute to the extended shelf life of the book. Statistical analysis of strength results confirms that adhesive binding method has no direct influence on binding quality. Pages in book block have larger resistance to tensile forces due to binding with cold adhesives, so the set hypothesis can be rejected.

Based on the research the authors of this paper can propose that double-fan method is perfectly suitable to be used in bookbinding of books intended to have long shelf lives. On the other hand, in paperback bookbinding, both adhesive methods are suitable for craft bookbinding of the books with short shelf lives.

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