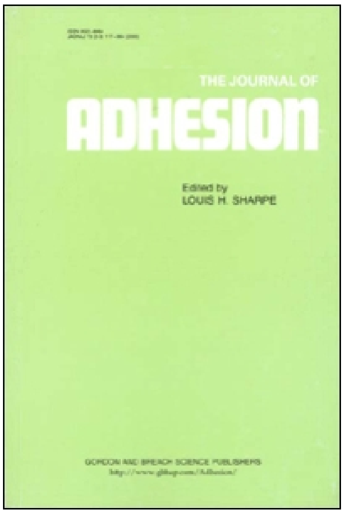

The Journal of Adhesion
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453635

On the Structure and Strength of Solvent-Welded Joints: The Intrinsic Joint Strength and the Effect of Dissolved Polymer in the Solvent Cement

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To cite this Article Yue, C. Y. and Chui, C. M.(1987) 'On the Structure and Strength of Solvent-Welded Joints: The Intrinsic Joint Strength and the Effect of Dissolved Polymer in the Solvent Cement', The Journal of Adhesion, 24: 2, 155 — 171
To link to this Article: DOI: 10.1080/00218468708075424
URL: http://dx.doi.org/10.1080/00218468708075424

J. Adhesion, 1987, Vol. 24, pp. 155–171
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Printed in the United Kingdom

On the Structure and Strength of Solvent-Welded Joints

The Intrinsic Joint Strength and the Effect of Dissolved Polymer in the Solvent Cement

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(Received January 23, 1987; in final form April 6, 1987)

It is proposed that the intrinsic strength of a solvent-welded joint can be represented by the magnitude of its critical principal strain. A large critical principal strain implied a high intrinsic weld strength. With poly(vinylchloride) adherends, solvent welds formed using pure tetrahydrofuran (THF) and cyclohexanone bonding solvents had high intrinsic joint strengths while solvent welds from pure methyl ethyl ketone (MEK) bonding solvent had lower intrinsic joint strength. In the THF bonding system, the introduction of dissolved polymer in the bonding agent led to significant decreases in the strength of the solvent-welded joint. Additions of up to 2% by weight of dissolved polymer in the MEK bonding agent increased the strength of the solvent weld. However, further increases in the dissolved polymer content in MEK bonding agent also led to decreases in strength.

KEY WORDS Composite adhesive layer; critical principal strain; interphase layer; joint strength; solvent bonding; solvent welding.

NOMENCLATURE

$P_f (N)$	failure load of joint
b (mm)	width of overlap
E (MPa)	Young's modulus of adherend
G (MPa)	shear modulus of composite adhesive layer (CAL)
η (mm)	thickness of CAL
S_1 (mm)	thickness of adherend (1)

S_2 (mm)	thickness of adherend (2)
ε_c	critical principal strain
l (mm)	overlap length
$P_f'(N)$	critical failure load
l_c (mm)	critical overlap length

INTRODUCTION

In a previous paper,[1] the influence of the bonding solvent on the structure and the plane of failure of solvent-welded joints was described and from it the influence of bonding solvent on joint strength was inferred. It was suggested[1] that strong solvent welds would be obtained when solvents with high solvency which promoted extensive intimate bonding over the mating surfaces were used. Such joints do not have any plane of weakness and crack initiation and propagation in the weld is accompanied by extensive deformation of the weld. For the rigid poly(vinylchloride) (PVC) adherends studied, it was found that such strong solvent welds were obtained by using either tetrahydrofuran (THF) or cyclohexanone (CYH). These strong solvent welds do not have distinct and separate interfacial layers at the original interfaces between the adherends. Failure in weaker solvent welds obtained from using methyl ethyl ketone (MEK) always occurred at the distinct and separate interfacial layers which existed at the original interfaces. This distinct interfacial layer has been referred to[1] as the final adhesive layer (FAL).

Recent work[2] has shown that the strength of solvent-welded double lap joints, P_f, can be represented and predicted by the following equation:

$$P_f = 4b\left[\frac{EG\eta S_1S_2}{S_1+S_2}\right]^{1/2}\frac{\varepsilon_c(2+\varepsilon_c)}{1+\varepsilon_c}\tanh\left(\frac{\lambda l}{2}\right) \qquad (1)$$

where $\lambda^2 = G(S_1+S_2)/E\eta S_1S_2$. The effect of bending stresses is neglected in the derivation of Eq. (1). The equation is therefore applicable to joints with large overlaps. Equation (1) can be modified[2] to account for bending stresses when it is applied to joints with short overlaps. When the overlap length is above a critical value, such that $l_c = 5.4/\lambda$, $\tanh(\lambda l/2)$ approaches unity and Eq. (1)

reduces to

$$P_f' = 21.6b\left[\frac{E\eta}{l_c}\frac{S_1S_2}{(S_1+S_2)}\right]\frac{\varepsilon_c(2+\varepsilon_c)}{(1+\varepsilon_c)} \tag{2}$$

In contrast to earlier analytical models for adhesive lap joints, the above model assumes failure at a critical principal strain.[3] This model will be used to analyse the experimental data in this paper.

Although solvent welding of amorphous polymers can be effected using suitable pure solvents, commercially available solvent cements consisting of a blend of several solvents containing dissolved polymer are commonly utilized instead. Solvent blending is carried out to give maximum solvency and to yield solvent cement of the desired drying (setting) time and shelf life under different environmental conditions. It is generally believed that the dissolved polymer provides 'gap filling' capabilities to the solvent cement so that micro-roughness within the joint can be smoothed out, thereby reducing stress concentrations within the solvent weld. However, the actual role of the dissolved polymer in the solvent weld is not known.

The dissolved polymer may interfere with the polymer chain interaction[1] across the mating interface in solvent welds. The degree of interference may depend on the amount of dissolved polymer and the bonding solvent used. Such interference is likely to affect joint structure and joint strength which are both dependent on the nature of the solvent weld interface.

Hence, the object of the present work is to investigate the effect of the amount of dissolved polymer in the bonding solvent on both the structure and strength of solvent-welded joints. Also, on the basis of new results, conclusions on the effect of the bonding solvent on joint strength suggested in a previous paper can now be put forward.

EXPERIMENTAL

Most of the double lap specimens used were prepared[4] from 5 mm thick calendered Takiron unplasticized polyvinyl chloride (uPVC) adherends which were solvent welded using either a pure bonding solvent or a bonding solvent containing dissolved PVC powder. The two bonding solvents used were tetrahydrofuran (THF) and methyl ethyl ketone (MEK). THF and MEK were chosen since most commercial solvent cements are based on either of these solvents. The amount of dissolved polymer in a bonding agent was varied from 0 to 20 weight % of the pure bonding solvent. The double lap joints were 15 mm wide and were prepared with overlaps of between 10 to 80 mm.

A separate batch of double lap specimens was prepared from 1.5 mm thick transparent PVC adherends similar to those used in a previous[1] work. These double lap joints were also 15 mm wide and were prepared with overlaps of between 20 to 70 mm. Single bonding solvents of either THF, MEK or cyclohexanone (CYH) were used to solvent weld this second batch of specimens.

Unless specified otherwise, the double lap joints with 1.5 mm thick adherends were dried for 5 hours while specimens with 5 mm thick adherends were dried for 3 hours at 23 ± 1°C. The specimens were then tested at 23°C in shear by subjecting the specimen to tensile loading at a constant cross-head speed of 5 mm/min in an Instron testing machine. After testing, cross-sections of the joints were polished metallographically to 14 μm. The actual thicknesses of the composite adhesive layer (CAL) and the solvent affected zone (SAZ)[1] of each specimen were determined from the examination of the polished cross section of that specimen. The CAL consists of a sandwich made up of an FAL between two SAZs (see Figure 1).Each SAZ comprises a region in the adherend that has been attacked and plasticized by the solvent. The plane of failure in the solvent welds could also be determined from such polished sections. The moduli of the 1.5 mm thick and 5 mm thick adherends were determined from tensile specimens to be 3.11 GPa and 3.36 GPa respectively.

It was observed that more than half of each SAZ was embedded within the adherends (see Figure 1). To account for this the effective adherend thicknesses S_1 and S_2 (Figure 1) and not the original adherend thickness, were utilized in the analysis of the experimental data. The microstructure of joints solvent welded using different bonding agents were determined from polished cross sections of specimens that were not utilized for tensile testing. Unless specified otherwise, the microhardness of the SAZs were determined using a Shimadzu microhardness tester with a load of

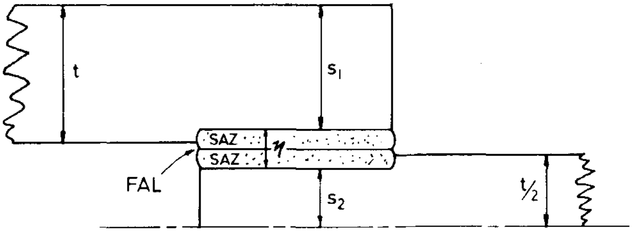

FIGURE 1 Schematic diagram of a solvent weld [assumed $S_1 = t - (\eta/2)$ and $S_2 = t/2 - \eta/2$].

15 g and a loading time of 5 seconds. The reciprocal of the size of the indentation was taken to be the hardness. Some specimens were dried for 200 days before the micro-hardness of their SAZs were determined.

RESULTS AND DISCUSSION

Experimental data from the 1.5 mm thick specimens (*i.e.*, specimens made from 1.5 mm thick adherends) are as shown in Figures 2 and 3. From Figure 2, it can be seen that the effect of

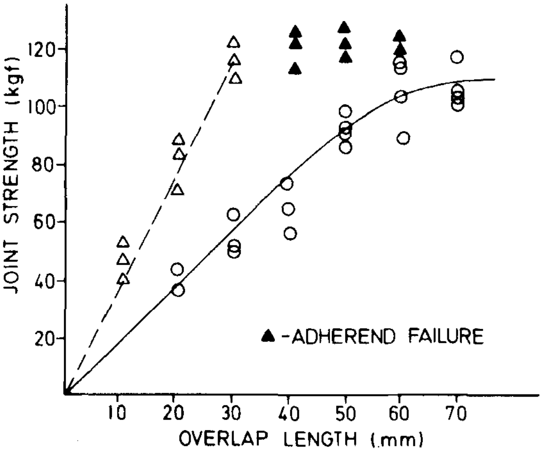

FIGURE 2 Variation of joint strength with overlap (adherend thickness of 1.5 mm, CYH bonding solvent) drying time: △▲—1 day, ○—5 hours.

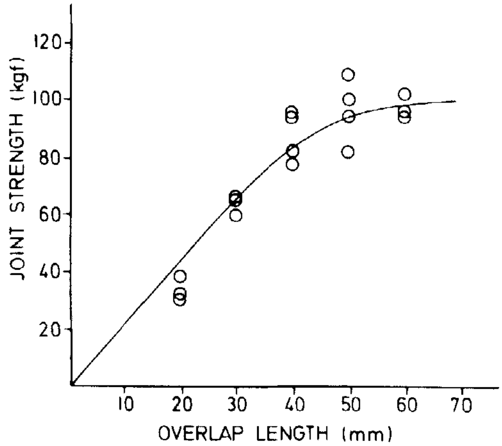

FIGURE 3 Variation of joint strength with overlap (adherend thickness of 1.5 mm, MEK bonding solvent) drying time of 5 hours.

drying time was to increase the joint strength such that specimens with large overlaps exhibited adherend failure instead of joint failure. The variation of joint strength with overlap for the 1.5 mm thick specimens that were solvent welded with THF could not be determined since adherend failure occurred in specimens with overlaps of 30 mm or more. With the 5 mm thick specimens (*i.e.*, specimens made from 5 mm thick adherends), preliminary testing revealed that a drying time of 3 hours would allow the determination of the critical overlaps for specimens welded using different bonding agents. This drying time was therefore adopted for the latter specimens.

Effect of weld structure on joint strength

From Figures 2 and 3, it can be seen that the critical overlaps of specimens solvent welded with CYH and MEK were 60 mm and 50 mm respectively. The corresponding critical joint strengths are 105 kgf and 90 kgf respectively (see Figures 2 and 3). The thickness of the CAL in the 1.5 mm thick THF, MEK and CYH specimens were 0.54 mm, 0.52 mm and 0.12 mm respectively while the microhardness were 8.4 mm, 9.6 mm and unknown respectively. The

TABLE I
Failure load of 1.5 mm thick THF specimens overlap length = 20 mm, drying time = 5 hours

Specimen	Failure load (kgf)	(N)	CAL thickness (mm)
T1	112	1098	0.55
T2	100	980	0.60
T3	123	1205	0.47

above hardness measurements were made on the Leitz microhardness tester using a load of 0.0981 N and a loading time of 15 sec. The hardness of the SAZ in the CYH specimens could not be determined because the hardness indentation extended beyond the SAZ/adherend boundaries of the CAL. The size of the indentation in the CYH specimen was much larger than the indentations in both the THF and MEK welds. This suggested that the CAL in the CYH weld was obviously softer than the CAL in the THF and MEK welds. The strength of three 20 mm overlap, 1.5 mm thick THF specimens are as shown in Table I.

From the data in Table I and Figures 2 and 3, it can be seen that for 20 mm overlap specimens, the THF solvent welds were the strongest while the CYH welds were comparable to or as strong as the MEK welds. The critical failure load of the CYH specimens was slightly greater than the failure load of the MEK specimens. These observations are in general agreement with the predictions in an earlier paper[1] based on the nature of their solvent weld structures. However, the strength of the CYH welds at any given overlap would have been expected to be much higher than the strength of the MEK welds.

A better understanding of the role of the solvent weld structure in determining joint strength can be obtained from a comparison of η, G and ε_c for the MEK, CYH and THF specimens. From equation (1), η, G and ε_c are the three independent variables which affect joint strength when similar adherends are used. Of these three parameters, only ε_c may be affected by or be associated with the nature or state of the original mating interface in the solvent weld. Although, like ε_c, G and η are dependent on the diffusion of solvent into the polymeric adherend and on the polymer-solvent interactions, they cannot be related to the nature or character of the original mating interface. The suggestion that ε_c may be associated with the nature of the original mating surface is consistent with the definition of this term and with the fact[1] that failure always occurs at or near the original interface of the weld.

The shear modulus of the CAL of the MEK and the CYH jointing systems could be calculated using the expression for l_c, while the ε_c values could be calculated using equation (2). The G and ε_c values for the THF jointing system could not be determined in the above manner since only data for 20 mm overlap specimens were available. However, an estimate of the ε_c value of the THF specimens could be obtained from Eq. (1) by assuming that G (THF) was equal to G (MEK) and neglecting the effect of adherend bending on the experimental data. Hence, an overestimate of G (THF) was utilized since the micro-hardness of the THF weld (8.4 mm^{-1}) was actually smaller than that of the MEK weld (9.6 mm^{-1}). The use of the assumed value of G (THF) and the neglect of the effects of adherend bending would yield an underestimate of the real value of ε_c for the THF jointing system. The calculated values of ε_c and G, and the experimental values of η are as shown in Table II.

From Table II, it can be seen that the calculated value of G (CYH) is lower than the value of G (MEK), consistent with the micro-hardness results. The ε_c values of the CYH and the THF jointing systems are obviously larger than the ε_c value of the MEK system (see Table II). A large ε_c value probably implies a strong

TABLE II

Values of the three independent parameters and of the first and second terms in Eq. (1) for the different solvent weld systems

Bonding solvent	η (mm)	G (MPa)	ε_c	First term $\left[\frac{G\eta S_1 S_2}{S_1+S_2}\right]^{1/2}$	Second term $\frac{\varepsilon_2(2+\varepsilon_c)}{1+\varepsilon_c}$
MEK	0.52 ± 0.08	6.60 (±25%)	0.13 (±29%)	1.10	0.25
CYH	0.12 ± 0.03	1.42 (±33%)	0.68 (±37%)	0.28	1.08
THF	0.54 ± 0.06	6.60[a]	0.17[b]	1.12[b]	0.32[b]

[a] G (THF) assumed to be equal to G (MEK).

[b] Calculation based on assumed value of G (THF).

bond across the original mating interface due to good interdiffusion[1] across the the two SAZs of the solvent weld. Hence the larger ε_c values for the CYH and the THF systems probably imply that solvent welding with these bonding solvents would give solvent welds with high intrinsic strength. The lower ε_c value for the MEK jointing system probably imply a lower intrinsic interfacial strength, probably a consequence of failure in the weak final adhesive layer formed[1] at the original interface during solvent welding. The above observations are in agreement with predictions on the intrinsic strengths of solvent welds made in an earlier paper.[1]

For a given overlap, the strength of the solvent-welded joint would predominantly be dependent on two terms, namely the term consisting of the square root of the multiple of η and G, and the term in ε_c [see Eq. (1)]. Despite the fact that the former term in the CYH system was significantly smaller (see Table II) than the former or first term for the MEK system, the strength of the CYH joint for any given overlap was either comparable to or slightly higher than the strength of the MEK joint (*c.f.* Figures 2 and 3). This could be attributed to the significantly larger values of ε_c in the CYH specimens compared to that in the MEK specimens (see Table II). The strength of the 20 mm overlap THF specimens was higher than that of similar MEK specimens (*c.f.* Table 1 and Figure 3) even though their former terms had about the same magnitude because the latter term in ε_c was larger in the THF system than that in the MEK system (see Table II). From the above, it is clear that the practical strength of the solvent weld depends on ε_c, G and η.

Effect of dissolved polymer in bonding agent on joint characteristics

The experimental data from the 5 mm thick specimens are as shown in Figures 4, 5 and 6. For clarity, results for the variation of joint strength with overlap length from the MEK bonding agents were plotted separately (see Figure 4). The variation of joint strength with overlap length for the THF bonding agents are as shown in Figure 5. The critical overlap length of specimens bonded with the 20% PVC–MEK bonding agent (*i.e.*, bonding agent consisting of 20% by weight of PVC dissolved in MEK) could not be determined since the joint strength was obviously increasing within the range of

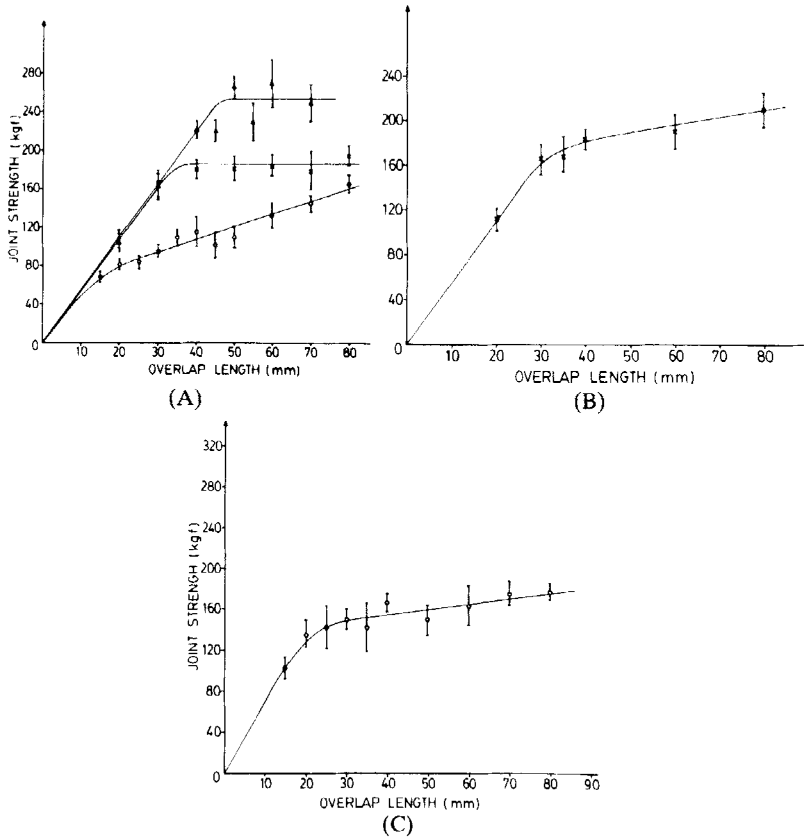

FIGURE 4 Variation of joint strength with overlap in specimens with adherend thicknesses of 5 mm. A—(×) pure MEK, (△) 2% PVC–MEK, (○) 20% PVC–MEK bonding agents, B—5% PVC–MEK bonding agent, C—10% PVC–MEK bonding agent.

specimen overlaps used. The increasing joint strength with overlap in specimens bonded with 5% PVC–MEK, 10% PVC–MEK, 20% PVC–MEK, 10% PVC–THF and 20% PVC–THF similarly suggested that the specimens with larger overlaps had to be tested (see Figures 4B, 4C and 5) before the critical overlaps could be obtained. Such tests were not conducted due to difficulty in preparing specimens with larger overlaps. A summary of the thickness of the CAL and the critical overlap lengths for the bonding systems in Figures 4 and 5 is as shown in Table III. The

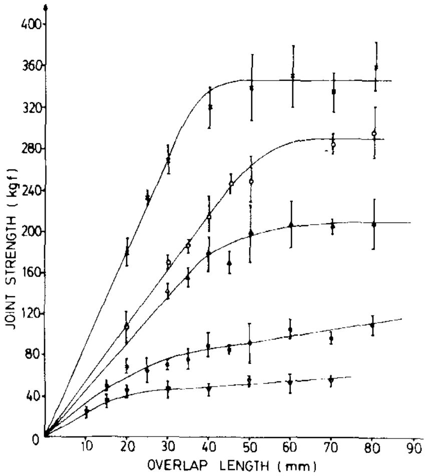

FIGURE 5 Variation of joint strength with overlap in specimens with adherend thicknesses of 5 mm solvent welded with THF bonding agents: (×)—0% PVC, (○)—2% PVC, (△)—5% PVC, (●)—10% PVC, (▽)—20% PVC.

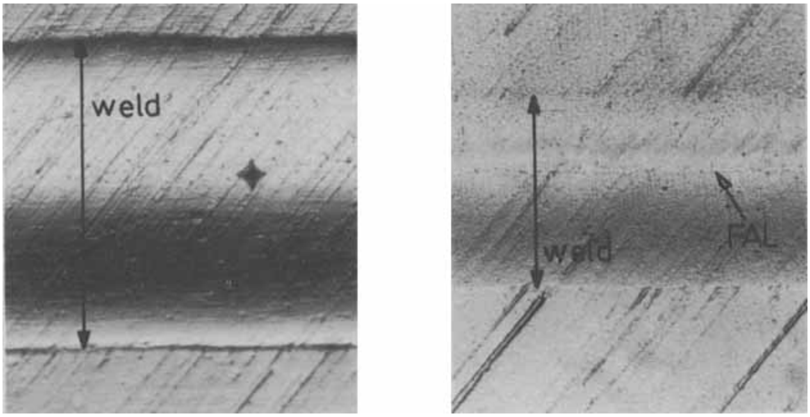

FIGURE 6 A—structure of 2% PVC-THF weld (magnification 80×), B—structure of 5% PVC-THF weld (magnification 80×).

TABLE III

A summary of the experimental values of the CAL thickness and the critical overlap length, and the calculated values of G and ε_c for both the THF and MEK bonding systems

Bonding agent	η (mm)	l_c (mm)	G (MPa)	ε_c
THF				
0 wt% PVC	0.25 ± 0.10	45	17.2 (±46%)	0.21 (±56%)
2 wt% PVC	0.30 ± 0.14	60	12.0 (±53%)	0.18 (±63%)
5 wt% PVC	0.44 ± 0.10	60	17.0 (±30%)	0.09 (±40%)
10 wt% PVC	0.58 ± 0.10	—	—	—
20 wt% PVC	0.48 ± 0.14	—	—	—
MEK				
0 wt% PVC	0.15 ± 0.05	35	18.9 (±39%)	0.13 (±49%)
2 wt% PVC	0.17 ± 0.08	45	12.9 (±53%)	0.21 (±63%)
5 wt% PVC	0.24 ± 0.06	—	12.9[a]	0.12[b]
10 wt% PVC	0.26 ± 0.10	—	12.9[a]	0.11[b]
20 wt% PVC	0.30 ± 0.08	—	12.9[a]	0.08[b]

[a] G assumed to be equal to G of the 2% PVC–MEK bonding system.
[b] Calculation based on assumed value of G.

values of G and ε_c for some of the bonding systems could be calculated (Table III) utilizing experimental data from specimens with overlaps greater than l_c.

The structure of welds from all the MEK bonding agents was similar to that observed in the previous paper[1] in that a clearly defined and distinct FAL always exists at the original mating interface. Failure always occurred within the FAL or along the SAZ/FAL interface of the weld. The structure of the weld obtained with pure THF bonding agent was also the same as that observed in the previous paper[1] in that no FAL was present at the original interface which suggested good interdiffusion between the two SAZs of the adherends. Failure in the latter welds did not occur preferentially at the original interface.

The structure of the 2% PVC–THF weld (see Figure 6A) was similar to that of the pure THF weld. Micro-hardness indentations (see Figure 6A) within the above weld at positions where the original interface may have been located did not reveal any plane of weakness. This suggests good bonding across the original interface. Failure in this weld, however, appeared to occur at the original interface. In contrast to the above THF welds, a distinct FAL could be seen at the original interface in every 5% PVC–THF weld (see Figure 6B). The remaining welds prepared from bonding agents which contained larger amounts of dissolved PVC in THF had distinct FAL at the original interfaces. Failure in the latter welds always occurred within the FAL or along the SAZ/FAL interface.

It will now be examined if, as is commonly believed, the dissolved polymer improves joint strength by smoothing out micro-roughness (thereby reducing the stress concentration at a microscopic level) within the solvent weld. The FAL in welds prepared from THF bonding agents containing 5% or more dissolved PVC polymer consisted of excessive residual dissolved polymer at the original mating interface. This implied that more than enough dissolved polymer was available for smoothing out the micro-roughness within the above welds. Such FAL constituted a plane of weakness in which failure occurred preferentially. The absence of the FAL and of any plane of weakness (Figure 6A) in the 2% PVC–THF weld probably suggested that the amount of dissolved polymer was sufficient to smooth out micro-roughness within the weld but insufficient to form a visible interfacial layer. Hence if the above gap-filling notion is true, the intrinsic strength of the 2% PVC–THF weld would be expected to be larger than or comparable to that of the pure THF weld. However, the intrinsic strength (*i.e.*, ε_c) of the pure THF welds was higher than that for the 2% PVC–THF specimens (see Table III). Therefore the popular notion that the dissolved polymer improves joint strength by smoothing out micro-roughness cannot be true.

From Table III, it can be seen that the ε_c values of the THF bonding system decreased with increasing amount of dissolved polymer in the bonding agent. This suggests that the intrinsic strength decreases when the excess residual polymer at the original interface led to the formation of the weak FAL.

It is interesting that the intrinsic strength of the 2% PVC–MEK weld was higher than that of the pure MEK weld (see Table III). The above observation suggests that, in contrast to the THF weld, the presence of a small amount of residual polymer at the original interface increased the intrinsic strength of the MEK weld. The higher strength could probably be due to increased chain interdiffusion across the mating surfaces since it is unlikely to be a result of the gap-filling of micro-roughness within the weld. The intrinsic strength of the 2% PVC–MEK weld was comparable to the intrinsic strength of the pure THF weld (see Table III).

The ε_c values of the rest of the MEK bonding systems could not be determined accurately since the critical overlaps of these systems could not be found experimentally (see Figures 4 and 5). However, estimates of the ε_c values could be obtained by utilizing Eq. (1) and assuming that the shear moduli of the CALs in these systems were the same as that in the 2% PVC–MEK system. The above assumption is reasonable since the shear modulus of the CAL probably would not change much with further increases in residual polymer in the FAL by using bonding agents with higher (>2%) dissolved polymer content. The magnitudes of the estimates of ε_c (Table III) are in agreement with the observation that the MEK-based bonding systems used in a separate work[2] which utilized similar adherends and solvent cement containing 24 weight % dissolved PVC had a ε_c value of about 0.10. From Table III it can be seen that the intrinsic strength (ε_c) of the MEK weld would decrease with further increases (>2%) in the amount of dissolved polymer in the bonding agent.

As predicted in the earlier section (Table II), the intrinsic strength of specimens bonded with pure THF solvent was higher than that of specimens bonded with pure MEK solvent (see Table III). However, for specimens bonded with pure MEK, it is not clear if much significance can be attached to the good agreement in ε_c values of the 5 mm thick specimen (Table III) and of the 1.5 mm thick specimen (Table II). Further work on the influence of the type of resin and the molecular mass of the polymer of the adherend on interdiffusion across the mating surfaces (and hence on the intrinsic strength) is necessary before any conclusions can be made on the above observation.

So far, the discussion has centered on the intrinsic strengths of the solvent welds from the different bonding systems. The influence of the bonding agent on the *practical* strength of the solvent welded specimen of different overlap lengths is as shown in Figure 7. It is evident that the strength of THF solvent-welded specimens of 60 mm overlap decreased rapidly with increasing amount of dissolved polymer in the bonding agent. The above trend was also true for solvent-welded THF specimens of any overlap. However, in the MEK bonding system, a significant increase in strength was only

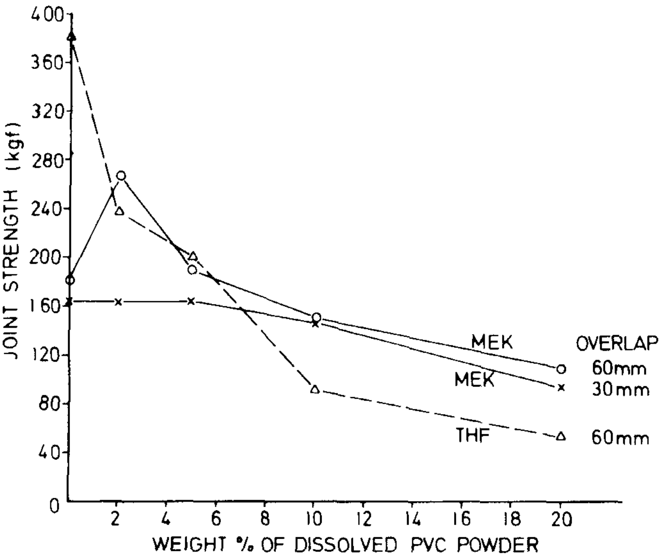

FIGURE 7 Variation in practical strength of THF and MEK joints with increasing dissolved polymer content in bonding agent.

observed in the 2% PVC–MEK specimens with large ($\geq$40 mm) overlap lengths (see Figure 7). With small overlaps ($\leq$30 mm), the strength of the solvent welds in the latter specimens seem to be independent of the amount of dissolved polymer up to a dissolved polymer content up to 5% beyond which a decrease in the practical joint strength was obtained.

The micro-hardness of the SAZ in all the MEK welds and in all the THF welds (taken at positions remote from the FAL or the original interface) were $35 \pm 5\,\text{mm}^{-1}$ and $15 \pm 5\,\text{mm}^{-1}$ respectively. In agreement with the above trend, G for pure THF bonding system was lower than G for the pure MEK bonding system (Table III). The difference in G values of the 5 mm thick specimens and of the 1.5 mm thick specimens (*c.f.* Tables II and III) can probably be attributed to the different adherends used.

In specimens which were dried for 200 days, the micro-hardness of the SAZ (at positions remote from the original interface or the

FAL) in all the MEK welds and in all the THF welds were $52 \pm 8\,\mathrm{mm}^{-1}$ and $52 \pm 5\,\mathrm{mm}^{-1}$ respectively. The micro-hardness of the PVC adherend was $72 \pm 10\,\mathrm{mm}^{-1}$. It can be seen that at long drying times, the modulus of the SAZ seems to be independent of the bonding solvent used and tends to approach that of the adherend. Since the intrinsic strength of the solvent weld and the thickness of the CAL are unlikely to change with drying time, the former factor would have a larger influence on long term strength of the solvent-welded joint [see Eq. (1)].

CONCLUSIONS

The intrinsic strength of a solvent-welded joint can be represented by the magnitude of its critical principal strain ε_c. A large ε_c value can be associated with strong bonding across the original interface and implies a high intrinsic strength. Solvent welds which exhibited preferential failure along their FAL tend to have lower ε_c values which imply lower intrinsic strength. In agreement with predictions based on an earlier work,[1] the intrinsic strengths of the THF welds and the CYH welds were higher than that of the MEK welds.

Residual polymer introduced at the original mating interface of a solvent weld does not improve joint strength by removing micro-stress concentration regions within the weld. In the THF bonding system, the intrinsic strength of the solvent weld decreased rapidly with increasing dissolved polymer content in the bonding agent. In the MEK bonding system, the intrinsic strength of the weld increased when up to 2% by weight of PVC was dissolved in the bonding agent. This could probably be attributed to increased interdiffusion across the original interface in the above weld. The intrinsic strength of the weld decreased with further increases in the dissolved polymer content in the MEK bonding agents. In both THF and MEK bonding systems, large (>5%) amounts of dissolved polymer in the bonding agents led to the formation of weak FALs at the original interface resulting in welds with low intrinsic strengths. The long term strength of a solvent weld would primarily be determined by its intrinsic strength.

Acknowledgement

Mr. S. C. Wong's assistance in the experimental work with the 1.5 mm thick specimens is gratefully acknowledged.

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