SPLICE FAILURES

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1. INTRODUCTION

Failed splices are safety critical and should be avoided.

This paper highlights examples of some splice failures and the possible causes. It covers steel cord, fabric and solid woven splices.

2. PURPOSE

Illustrations of the failed splices are used to show the results of poor workmanship and non-compliance to procedures. Possible corrective steps are included in the paper.

3. MOST COMMON BELT SPLICING MISTAKES THAT LEAD TO PREMATURE SPLICE FAILURE

- Over and under curing of compounds
- Incorrect cutting of the fabric plies
- Buffing of the fabric plies
- Solvents captured inside the splice
- Ply damage during removal of the steps
- Incorrect splice length
- Contamination in the splice
- The use of expired materials
- The use of incompatible materials
- Off-center splice alignment
- Insufficient pressure

1.1 Over-cure or under-cure of compounds resulting from improperly controlled temperature at the platens.

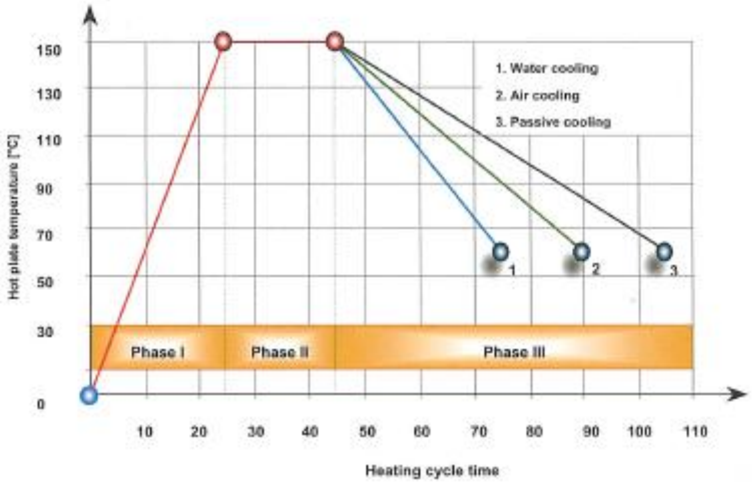

Figure 1. Typical splice cure cycle

Over-curing occurs when the rubber is exposed to excessive heat. This is caused by either the temperature being too high (>170˚C) or the cure cycle being too long.

Over-curing of the rubber results in continuous cross linking of the polymeric chains and increases the rubber hardness. Ultimately the rubber chains break down, the hardness drops and the rubber becomes tacky.

Under-curing occurs when insufficient heat is supplied during the vulcanizing process. This is caused by either the temperature being too low or the cure cycle being too short. Under-curing results in a low cross linking density and poor rubber strength.

35° Shore A

(Spec 65+/-5 Shore A)

Rubber still soft and tacky

Figure 2. Results of under-curing

Corrective Action: The use of thermocouples is required together with a data logging system.

3.2 Incorrect cutting of the fabric plies

Cutting the fabric plies with Stanley knives damages the warp and weft cords.

This reduces the splice strength even more and also creates a localised stress area that results in the breakage of the adjacent strands.

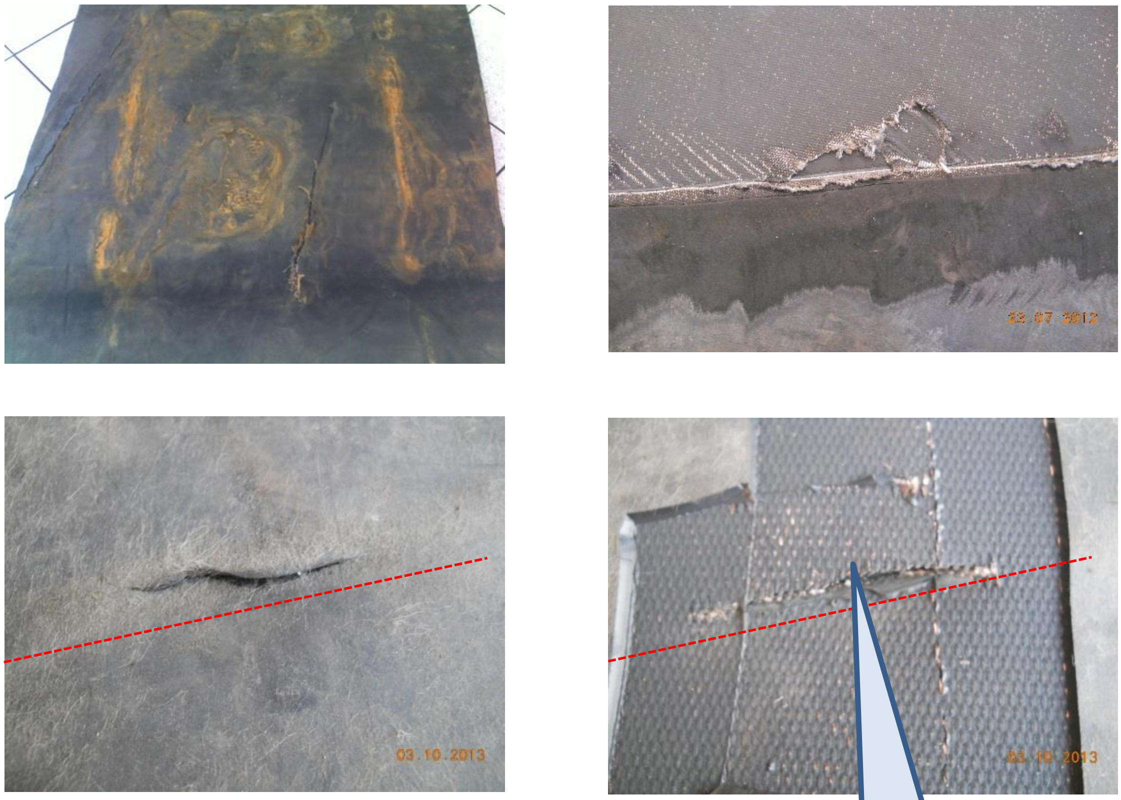

Figure 3. Results of nicking the adjacent fabric

Corrective Actions: Use of correct tools, ply knives and NOT Stanley knives, and operator training.

3.3 Buffing of the fabric plies

Buffing of the fabric breaks the warp strands and reduces the fabric strength thus buffing of fabric is not permitted. Buffing of the rubber high spots on the steps is recommended but care must be taken to not damage the fabric.

Corrective Actions: DO NOT BUFF THE FABRIC.

3.4 Solvents captured inside the splice

Wet cement and solvents that did not evaporate in the splice area can cause ply and/or cover blows.

Those solvents inside the splice convert into a gas during vulcanizing and create blows. Weather conditions influence the evaporation time of the solvents. The solvents evaporate more slowly at lower temperatures.

Corrective Actions: Allow all solvents to evaporate prior to closing a splice. Ensure the ambient temperature is not too cold and humidity is not too high.

3.5 Ply damage during removal of the steps

Prior to the removal of the fabric care must be taken to ensure all the strands were cut off. A blunt tool or ply lifter must be used to check if all the strands were cut. This is referred to as prodding.

Over prodding the fabric when lifting the plies can damage the warp and weft cords.

This reduces the fabric strength.

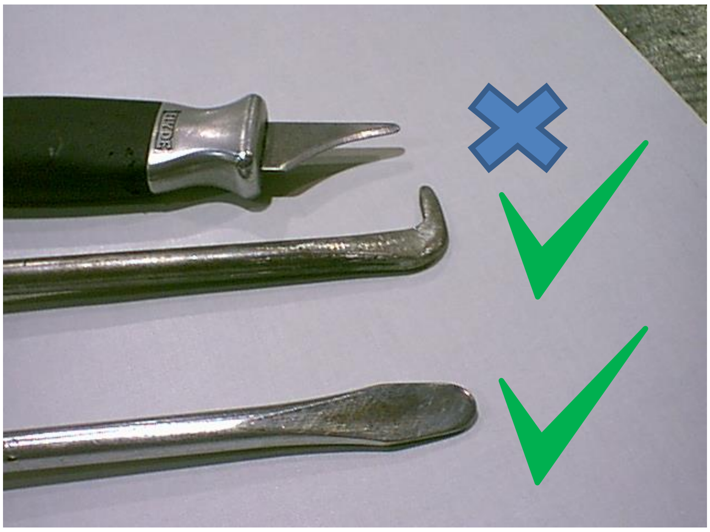

Figure 4. Splicing tools

Corrective Actions: Use the correct tools, such as a ply lifter with a blunt tip.

3.6 Incorrect splice length

One of the major reasons for splice failure is reducing the specified step lengths to fit the splice into a short vulcanizer or to save time.

Table 1 — Class of belt and step lengths

1	2	3	4	5	6	7
Minimum splice step lengths						
Belt class	**Splice allowance[a]**	**Number of plies per belt**				
		2	**3**	**4**	**5**	**6**
160	B	300				
200	B	300	250			
250	B	300	250	250		
315	B	300	250	250		
400	B	300	250	250	250	
500	A	250	250	250	250	250
630	A	300	300	250	250	250
800	A	400	400	300	250	250
1000	A	500	400	400	300	250
1250			450	400	300	300
1400			450	450	400	300
1600				450	400	400
2000				450	450	400
2500					450	450

[a] The splice allowance is expressed in millimetres.

The types of splice allowance are:

a) 2-ply jump splice: allowance = (2 × step length) + 50 + $W \cdot \tan\theta$;

b) Multi-ply splice: allowance = ((N-1) × step length) + 50 + $W \cdot \tan\theta$

where

θ is the press bias angle;

W is the belt width;

N is the number of belt plies.

Table 1. List of the minimum splice step lengths per belt class

SANS 484

Reduced splice lengths reduce the vulcanized splice strength proportionally. The reduction in the splice length reduces the dynamic fatigue resistance of the splice and could result in catastrophic failure.

Corrective Actions: Ensure that the minimum splice lengths as detailed in the various SANS specifications, or by the belt manufacturers, are implemented.

3.6 Contamination in the splice

Assembling the splice with contamination can reduce ply and cover adhesion.

Dust and other contaminants decrease the bonding of the rubber to the belt. This also reduces the dynamic fatigue resistance of the splice. The splice area must be kept free of dust.

Corrective Actions: Splice stations need to be assembled over the splice area. Splice stations could be a building, container or even a tent.

Figure 5. Example of a splicing container with temperature control

3.7 The use of expired materials

Using over-age, incorrect, or improperly stored splice materials can significantly reduce ply and cover adhesion.

Over-aged materials have already started vulcanization and the use of this material in a splice will result in a low cross linking density with the belt.

Corrective Actions: NEVER use over-aged materials. Record batch numbers and expiry dates on the job cards.

3.8 The use of incompatible materials

Not all types of rubber can bond to each other!

Incompatible materials result in very low adhesion levels and premature splice failure. Nitrile and EPDM (ethylene propylene diene monomer) rubbers have very poor bonding to SBR (styrene butadiene rubber) and NR (natural rubber).

Corrective Actions: Test material compatibility on the belts to be spliced in advance prior to splicing.

3.9 Off-centre splice alignment

Improper splice alignment can cause off-centre tracking. Misaligned splices run into the structure and damage the splice edges. A centre line must be drawn on both belts. These lines should line up, although a maximum of 5 mm misalignment after vulcanizing is allowed.

Corrective Actions: The splice alignment must be done 2 m either side of the splice.

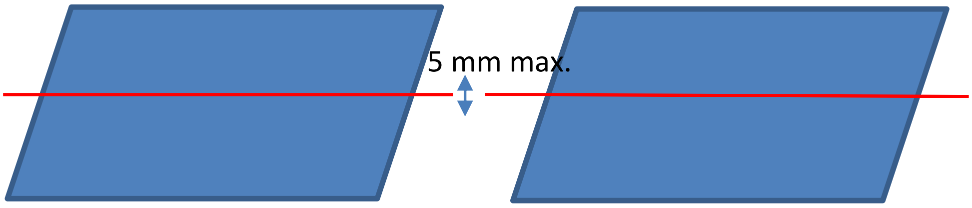

Figure 6. Correct splice alignment

3.10 Insufficient pressure during vulcanization.

Insufficient pressure is generally caused by one of the following factors:

i. Vulcanizing press malfunction resulting in no or low pressure.
ii. Use of edge bars that are too thick. The pressure is then applied to the edge bars and not the splice area.
iii. Under-filling of the bridge sections.

Figure 7. Result of under-filling the rubber

Figure 8. Result of insufficient pressure

Corrective Actions: Always use the correct edge bar thickness. Generally 1,5 mm less than the belt thickness. ALWAYS use the correct curing pressure. Steel cord 200 Psi and fabric 100 Psi.

4. SITUATIONS WHERE SPLICING IS NOT PERMITTED

4.1 When the ambient temperature is less than 5˚C above the dew point.

This could result in dew forming on the belt and materials that will create blows in the splice. Cold splicing cements will also absorb moisture and effect the bonding strength.

4.2 When the difference in the number of plies between two belts is greater than two.

This results in an unacceptable loss in belt strength.

4.3 Use of incompatible splicing materials

Poor bonding occurs that results in splice failure.

4.4 Any loss of 15 per cent or more in pressure during vulcanization.

The loss in pressure reduces the rubber strength and could result in rubber fatigue in the long run.

4.5 Any deviation in the cure time or temperature greater than 5 per cent.

This results in a non-optimal cure state and could also affect the rubber strength.

5. SPLICING TOOLS

The tools used during splicing are specially designed for the job required. The use of incorrect tools is a major contributor to failed splices and injuries during splicing.

Figure 9. A range of splicing tools

The following tools and their use is critical in performing a good splice.

5.1   Hawk bill ply knife

Figure 10. Hawk bill ply knife

This knife is used to cut the steps in fabric belting. The knife is designed to cut only one ply at a time. The use of Stanley knives is not recommended to cut plies.

5.2   Ply lifter

Figure 11. Ply lifter

This is used to ensure that all the strands were cut off with the Hawk bill ply knife. It is supposed to be blunt!

5.3   Sticker rollers

Figure 12. Sticker rollers

These are used to ensure all the air is removed from the splice.

5.4 Stanley knife

Figure 13. Stanley knives

Stanley knives are extremely sharp and used to cut the belt. Most splicing accidents occur due to cuts with Stanley knives. Knee guards should be compulsory when sitting and cutting with a Stanley blade.

There are now mechanized cutters available to reduce the use of Stanley blades. These cutters are safer, faster and more precise.

Figure 14. Steel cord belt cutter

Figure 15. Fabric belt cutter

5.5 Belt Clamps

Figure 16. Belt clamp

During splicing, the belt must be clamped to prevent belt slip. The use of square tubing in place of belt clamps is not recommended.

CONCLUSION

Generally, splice failures occur as a result of poor workmanship, expired or incorrect materials or faulty or incorrect equipment. These failures can be prevented through the correct training of personnel, proper maintenance of the equipment and the use of compatible fresh materials.

ABOUT THE AUTHOR

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Ben-Piet obtained his B.Sc. degree in 1994 at the University of Port Elizabeth. The following year he completed his B.Sc. Honours in polymer chemistry at the University of Port Elizabeth.

In 1996, Ben-Piet started his journey into the wonderful world of rubber, where 17 years later, he still finds himself. On his path he has been a rubber compounder, laboratory technician, quality manager and technical manager.

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