

MANAGING BAG SHRINKAGE IN LOW TEMPERATURE FABRIC FILTER PLANTS

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ABSTRACT

Low temperature fabric filter plants normally utilize bags manufactured from Polyacrylonitrile (PAN). Although these bags are cheaper than high temperature bags, manufactured from Polyphenylenesulphide (PPS), they are prone to shrinkage.

Shrinkage in a fabric filter plant is problematic in the sense that it not only affects the performance of the bags, but indeed, of the whole gas cleaning system. Some of the areas affected are permeability, cleanability and strength.

The shrinkage can be chemical of nature. This is related to the cyclisation of the PAN fibers due to heat or chemical attack. The shrinkage could also be physical of nature, which means the shrinkage is caused by the elastic memory of the fibers and stresses induced in the felt during manufacturing.

Heat setting of the fabric is very important and differences of parameters during the heat setting process are responsible for differences in the shrinkage behaviour of adjacent bags in the same bag house, constructed of the same fibre and in the same needling loom.

This paper deals with the reasons for bag shrinkage and how it could be managed.

1. INTRODUCTION

Hendrina power station is situated in Mpumalanga province, South Africa. The power station is a 10x200MW coal fired plant and burns coal from the adjacent Optimum colliery. Due to environmental legislation becoming more stringent, the plant was retrofitted with fabric filter plants (FFP's). The retrofit program was done in two phases, starting in 1995 and continuing to 2004.

The plants are the "Lurgi" rotating manifold design and utilize low temperature bags manufactured from Polyacrylonitrile.

The original electrostatic precipitators were small two and three field precipitators, with design efficiencies of 96% and 98% respectively.

Because the FFP's were retrofitted into the small precipitator casings there was insufficient space to have additional bags, such that on load maintenance could be undertaken. This means that if any of the cells has to be isolated, the unit needs to reduce load to 50% MCR. At the same time the unit cannot do 50% MCR without fuel oil support.

A typical shrinkage induced, rotating manifold trip will take eight hours to repair. Five hours to cool and ventilate the bag house, one hour to do the repair and the rest of the time to de-isolate the bag house and return to full load.

The typical cost for one such incident is R94 000 [approximately USD 15 000]. This figure is made up of fuel oil cost, loss of income, manpower cost and replacement bags/cages. The total cost related to bag shrinkage in 1998 was R13.2M [approximately USD 2M] and in 2000 the figure reached an all time high of R17.5M [approximately USD 2.7M].

When the bag shrinkage first started it was thought that the plant operating conditions were the cause, but the fact that the shrinkage was random, indicated that the problem might be more complex than initially thought.

2. WHY POLYACRYLONITRILE BAGS SHRINK

'All manufactured polymeric fibers are orientated semi-crystalline structures in which the macromolecules are rarely in their equilibrium state. This unstable state result in fibers that are very susceptible to changes in their environment such as heat, tension and pressure'.

(VB Gupta, Department of Textile Technology – India)

Polymers in the form of natural fibers have been used in the clothing industry for many centuries. At the turn of the 20th century an important discovery was made, that is also applicable to man-made thermoplastic based fibers such as Polyacrylonitrile.

The findings were firstly that polymers consist of long chains of covalently bonded molecules and secondly that the fibers contain small crystallites or micelles in an amorphous matrix. It began to be recognized that cohesion, stability, strength and durability were in a large measure provided by the crystals whereas the molecules in the non crystalline regions were mainly responsible for extension ability, pliability and toughness. Further discoveries indicated that the crystalline areas can be determined by heat setting the fiber. This means that if the entire structure were crystalline, the fiber would be inert but brittle and if there were no crystalline areas the fiber would be unstable but flexible. Of course the desired state for bag filters applications would be strong but dimensionally stable fibers.

Fibers based on polymers are extensively used as commodity textile fibers and also as industrial fibers. In the as-manufactured state, the macromolecules in the fiber structure are rarely in their equilibrium state. As a result, they are susceptible to dimensional instabilities caused by application, load, temperature or solvent. When the fibers are converted to yarns and the yarns to fabrics, further instabilities are imparted to these structures. It is important then to rid these fibers of the instabilities. If the instabilities are not sufficiently removed there may be considerable thermal shrinkage or permanent deformation. The heat setting of fibers and fabrics aim to do this. Thermoplastic fibers such as Polyacrylonitrile can be made dimensionally stable to a significant extent by heat treatment, often aided by moisture and tension. The heat setting increases the amount of crystalline areas thus making the fiber more stable.

Case Study

To illustrate the above, an actual case study will be used. The following tests were done by Eskom's Consulting, Research and Development (C, R&D) Department to determine the reason for random shrinkage.

Samples of shrunk and non-shrunk fabric from Hendrina power station unit 10 were used.

As bag shrinkage is often random, comparative tests were done on shrunk and non-shrunk bags removed from the same FFP. The main culprit for Polyacrylonitrile bag shrinkage is normally indicated as the process conditions, for instance, heat excursions, moisture carry over etc. This does not however explain why shrinkage is random. Plant processes should have the same effect on all the bags in a FFP.

Test Method

Three shrunk and three non-shrunk bags were removed from Hendrina unit 10 fabric filter plant. Samples cut from the bags were analysed with a differential scanning calorimeter (DSC) in order to measure the temperatures and heat flows associated with molecular transitions in the material as a function of time and temperature. The shrunk samples were compared with the non-shrunk samples after similar operating hours.

Visual Appearance

There was no visual difference between the shrunk and non-shrunk samples. All the samples were slightly discolored as is normally the case with Polyacrylonitrile, as it ages in a flue gas environment. The ash on the samples was washed in warm water and the samples were dried in an oven at 60°C for 30 minutes.

Results

The heat flow curves show no significant differences, indicating that the amount of exothermic heat given off by each sample is similar. The cyclisation of the shrunk and non-shrunk samples is therefore the same. The melting point temperature of the involved fabric samples is different. Higher melting point peaks were observed for the shrunk samples.

Discussion Of Results

Polyacrylonitrile (PAN) fibers undergo cyclisation reactions when exposed to heat, causing discoloration of the fabric. The degree of cyclisation is therefore directly related to the heat to which the fibers were exposed and can be measured by a differential scanning calorimeter (DSC). The DSC heats the fiber further at a controlled rate and measures any heat flow that occurs in the fiber whilst being heated. The cyclisation reactions are exothermic and can be detected by a DSC.

The degree of cyclisation for PAN fibers in a controlled environment depends on its previous thermal history (temperature and time). Cyclisation is a slow process, which takes place during operation, by fabric exposure to bag house temperatures.

During the heat setting process the fabric is exposed to specific temperatures for a very short period in comparison to the very long duration of fabric exposure to the actual plant conditions and thus, the cyclisation related to heat setting is minimal and can not be detected.

The shrunk and non-shrunk samples revealed similar amounts of exothermic heat indicating that these samples were exposed to the same temperatures for the same periods. The cause of shrinkage cannot be related to the conditions in the bag house because the shrunk bags were sampled adjacent to other non-shrunk bags. This means that the bags were exposed to the same process conditions.

The shrunk and non-shrunk samples were also analyzed with the DSC for their melting point peaks. This was achieved by a heating rate of 90°C per minute. If a slower heating rate is used, the degradation reactions will overshadow the melting point onset and peak. The melting points for the shrunk samples were higher than the non-shrunk samples indicating that the former had a more compact molecular rearrangement that requires more energy to melt it.

When non-crystalline polymers are stretched, they undergo some molecular orientation. With increasing stretch and temperature, the molecules begin to slide past one another and assume a more ordered configuration, which they will retain when cooled. The fibers will retract to their non-stretched form when they are heated again.

Acrylic fibers behave in this manner when heated and stretched, but they also have a portion of well-ordered crystalline regions. These regions act as anchor points for the molecules, preventing plastic flow (irreversible flow) from taking place and ensuring the molecules return to their original positions when the stretched fiber is heated again. This shrinkage memory of acrylic fibers may be lost with correct heat setting by persistent stretching at high temperatures or by annealing the fiber at constant length.

Excessive shrinkage can thus only occur if a large portion of the fiber's shrinkage memory is retained. The higher melting point peaks for the shrunk samples can be related to a more ordered molecular configuration achieved by shrinkage.

The bag shrinkage in this case is associated with physical shrinkage, which means shrinkage memory of the fibres is retained, and is therefore related to manufacturing conditions. [The fibre structure differs from bag to bag].

The shrunk samples had the same thermal exposure in the plant as the non-shrunk samples,

indicating that the difference between them can only be related to the manufacturing process. Heat setting of the fabric is very important and differences of parameters during the heat setting process are responsible for differences in the shrinkage memory of adjacent bags in the same bag house, constructed of the same fibre and in the same needling loom.

3.MANAGING BAG SHRINKAGE.

It is clear that PAN bag shrinkage is a general problem and is normally random of nature in the early stages of operation. Once bag shrinkage occurs, it is irreversible and the shrinkage needs to be managed in a cost effective manner, or the set of bags need to be replaced.

Bag life is normally determined by either bag leakage that causes higher emissions or by high pressure drop which affects the ability of the induced draught fans to cope. Both of these factors are influenced by bag shrinkage.

Increased Emissions

Bag shrinkage could cause high emissions because the bag pushes the cage up, and the seal between the tube plate and the bag is lost. The dust then leak between the bag and the tube plate. The bags are also not cleaned as effectively as they should be and this could cause bleed through of dust.

High Pressure Drop

Bag shrinkage affects the pressure drop in various ways.

When shrinkage takes place the fiber structure is more compact and the denser structure reduces the permeability.

The shrinkage also causes the bags to shrink around the support cage preventing the bag from flexing when pulsed. The cleaning efficiency is therefore reduced.

When the rotating manifolds are lifted out of the way of the cages, the pulse jet of cleaning air is not as effective as it was designed to be. This allows a thicker ash cake on the bags and thus reduces permeability. Eventually the unit cannot do full load anymore because of induced draught fans that are unable to cope. The bags then need to be replaced while they could still be in good condition in terms of ph and strength.

Increased Cost

As indicated previously the financial impact of bag shrinkage can be huge. It is not only the cost of managing the shrinkage but also the reduced bag life, inability to do full load and the resultant loss of production that increase cost.

4.HOW TO LIMIT THE RISK OF BAG SHRINKAGE OCCURING

Fabric Selection

Specification

PAN normally operates at 125 deg C. It is important that the bag house operator recognize this. As previously mention Polyacrylonitrile is unstable and any temperature excursions will increase the risk of shrinkage drastically.

All plant parameters that could influence the bag performance must be indicated to the bag manufacturer. It is good practice to not only give the design parameters to the bag supplier but the actual conditions as well. Important information that should be given to the bag manufacturer is FFP inlet temperature, stratification, desired pressure drop, results of acid

dew point tests that was done, coal composition etc. If the bag house operator have special requirements such as higher than normal fabric strength etc. it should be specified.

Unsuitable Fabric

It might be that the plant specifications are correct but that an incorrect fabric has been selected. Ensure that the plant operating conditions are within the operating zone of PAN. In borderline cases the option to revert to another type of needlefelt should be investigated. The increased cost of a superior needlefelt can easily be justified, if bag shrinkage causes production losses in a specific plant.

Trial Bags

It is good practice to have a trial bag program in place where unique bags could be tested in the main plant and the performance of the bags evaluated against the performance of the installed set of bags. Preferably trial bags must be fitted with a new set of bags to ensure similar operating conditions. It is also good practice to fit at least ten bags of a type randomly in the plant. This ensures representable results.

Bag Manufacturing

Not Manufactured To Specification.

It is important to put proper quality control measures in place to ensure that the bags comply with the specifications. As indicated previously it is not a simple matter to manufacture stable fibers or fabric and it can only be to the bag house operators benefit if he is involved in the quality control process.

Review the bag manufacturer's quality procedures and indicate hold and witness points. Samples of the needlefelt could be tested by an independent laboratory to ensure compliance to user specification. Once the bags are manufactured and installed, it is difficult to rectify the situation.

Process Control

Plant Control Philosophy

It is good practice to periodically review the plant operating philosophy. Items that should receive specific attention are temperature control, sootblowing, prevention of moisture carry-over etc. Ensure that the control philosophy is optimal and suitable for the operating conditions. One heat excursion can drastically increase the risk of shrinkage.

5.HOW TO LIMIT THE EFFECTS OF BAG SHRINKAGE

The effects of bag shrinkage is, reduced cleaning efficiency, leaks between the tube plate and the bag cuff, and the most significant, lifted support cages that interfere with the pulse cleaning system.

Hendrina power station managed its bag shrinkage in the following manner:

Short Term Solution

At the time that the shrinkage first started there was no ready made solution. The bags were still fairly new and could not be replaced. The effects of bag shrinkage were managed by means of the following:

Lift Manifolds By Lifting Arms Only.

Initially when we experienced shrinkage, there was no indication of how much the bags would shrink. The rotating manifold is approximately 40mm above the tube plate and

therefore there was place for the cage to lift 40mm. At approximately 12500 hours the cages were starting to interfere with the rotation of the manifolds. The manifold arms were then lifted by slotting the bolt holes where the manifold attaches to the center pipe and new support brackets were fitted. This allowed an additional 10mm lift which proved to be sufficient for another 1000 operating hours.

Lift Manifolds By Lifting The Drive Unit.

It was found that the manifolds could be lifted another 15mm by lifting the drive gearbox and putting a suitable spacer under the support bearing. This gave us another 1000 hours. At this stage there was no significant change in pulse air usage.

Lift Manifolds By Cutting The Center Pipe.

When the manifolds started tripping again, the center pipe was cut and the manifold lifted another 80mm. The bags were now shrinking at a faster rate and the lifted manifolds helped for approximately 4000 hours. Of course the lifted manifolds resulted in less pulse cleaning efficiency and this caused the units to experience high FFP pressure drop. After the 4000 hours the manifolds started tripping again and this was managed by replacing the offending bags periodically, until the set of bags could be changed.



Figure 1: In the above photo the two types of cages can be seen. The highest telescopic cage (MK1) in this photo is 42mm above the tube plate and the highest normal cage is 97mm, although the bag shrinkage is virtually the same.

Result of Short Term Solutions

➤ Limited incidents of stuck manifolds once manifolds are lifted.

But:

➤ Bag failure mode is blinding.

- Lifting the manifolds decrease pulse efficiency and therefore decrease the bag life.
- Insufficient ID fan power cause load losses toward the end of bag life.
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Long Term Solution

Together with all the actions and control measures that were put in place to minimize the risk of bag shrinkage, the following was done.

While the first sets of bags were still installed and it was clear that the solutions implemented could only be temporarily, another solution had to be found urgently.

It was accepted that shrinkage would still persist with future sets of bags and therefore the permanent solution had to cater for this.

Telescopic Support Cage

A new cage was designed that could absorb the longitudinal shrinkage without the cage protruding above the tube plate. This cage in MK1 version could compensate for 50mm of bag shrinkage before the cage wires started protruding over the top of the cage. The cage was further improved and the MK2 version has a longer extruded metal sleeve at the top. The bags can now shrink for 90mm before the wires start protruding over the top. This allows Hendrina Power Station to operate with the pulse manifolds at normal height for the duration of the bag life, which is expected to be 32 000 hours. The added advantage of these cages is that the seal part of the cage stays intact at all times.

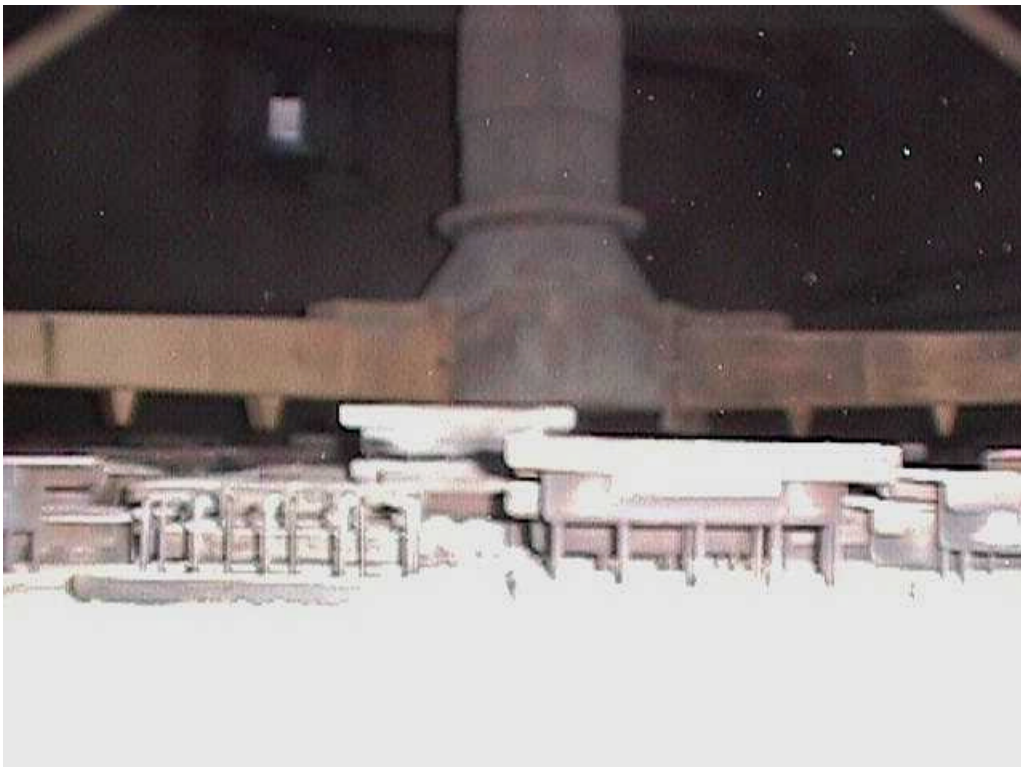


Figure 2: The two bags closest to the camera in the photo are shrunk exactly the same height but the cage height differs by 51mm.

Manifold Distance Piece

In the past the raising of the manifolds required a three-day outage.

The manifolds were subsequently fitted with a flanged distance piece that can be removed in the event that shrinkage is so excessive that the telescopic cages cannot cope. The flanged distance pieces allow us to raise the manifold in a matter of hours.

6.CONCLUSION

Although shrinkage can be caused by various factors, the biggest cause for random bag shrinkage is the heat treatment of Polyacrylonitrile fibers and needlefelt. The manner in which Polyacrylonitrile fibers are produced influences shrinkage, and this process should be evaluated and optimized.

The process of heat setting and the effects it has on Polyacrylonitrile is well understood, but the application of heat setting still needs improvement. The various production processes are all moving toward higher and higher speeds as superior control systems become available, time, temperature, twist and tension in texturing of multifilament yarns are all happening faster. Texturing machines capable of achieving speeds in excess of 1500m/min with short heaters of 0,6m, capable of operating at temperatures of 600 deg C are already in use at various manufacturers. This makes it necessary to study and develop heat transfer at such high heating rates.

There are methods of limiting bag shrinkage such as stringent specification, trial bag testing proper quality control and process control. If these are applied the risk of bag shrinkage are significantly reduced.

The effects of bag shrinkage once it has occurred can be effectively managed. Although permeability will be affected, the protruding cages can be managed by means of telescopic cages.

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