

A Case Study: Elimination of Batch Variation in Rubber Compounds

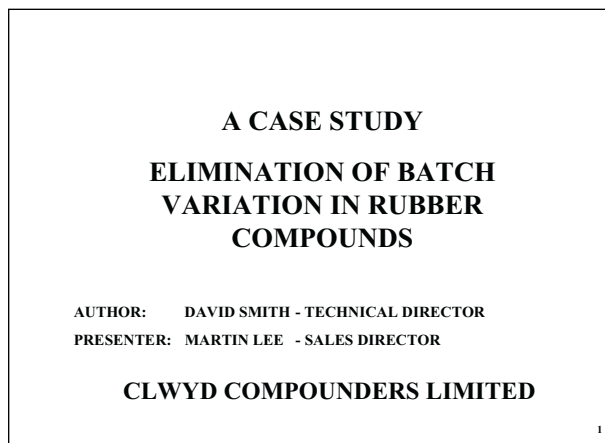
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ABSTRACT

Rubber compound batch variation within a single batch and between batches in any production run has incurred massive costs in rubber component production over the years. High and expected scrap rates and lost production time has always been a feature of our industry.

Clwyd Compounds Limited recognised this problem some 14 years ago in the early stages of the Company's growth, and committed at that time to aim to eliminate batch variation as the Company developed, and so provide an advantage in product quality.



From early 1997 Clwyd have guaranteed compound consistency to a maximum variation of plus/minus 1° hardness point on all runs of compound batches supplied.

This paper was written by our recently retired Technical Director David Smith without whose drive, vision and enthusiasm we would not be able to recount our success in reducing batch variation in rubber compounds.

The essence of the paper is to indicate the measures and decisions that have been taken over the years, which have lead to our achievements in rubber, compound batch consistency control.

12 years ago we set out to eliminate batch to batch variation in all multibatch productions of rubber compound.

This was in recognition that such variation combined with inadequate control in most rubber moulding processes has lead to excessively high operation costs to our industry over the years.

- INTRODUCTION
- BRIEF HISTORY OF COMPOUNDING AT CLWYD
- MAJOR FACTORS CAUSING COMPOUND VARIATION
- THE CLWYD APPROACH TO COMPOUNDING
- PROGRESS AND RESULTS
- CONCLUSIONS AND THE FUTURE

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I have divided the paper into the following sections.

A brief history of Compounding at Clwyd. It is important to look back as operational decisions taken then had a significant effect on the achievements in variation reduction seen today.

A look at the major factors causing compound variation in our particular sector of the compounding industry i.e. where 50% of works schedules are for single batches, multi-batch runs are scheduled as 2 batch to 18 batch production runs with a mean of 5 batches per works order.

The Clwyd approach to compounding covering mixing and weighing, raw material supply and control and environmental control and measurement.

Progress and Results, this will cover the period from 1989 to date and is based on the results achieved during the month of February in each case. The results are shown as histograms of the hardness range. The variation in hardness range are mirrored by MDR rheologic which is our main control criteria but the impact in histogram form is less clear than with hardness.

Conclusions and the future, suggesting the main benefits gained and what can be done in the future towards continuous improvement.

A Brief History of Compounding at Clwyd

- 1979 Formation of Clwyd Compounders Ltd.
Open mill mixing facility incorporating carbon black via bought in polymer master batch.
Mixed compound air cooled for cleanliness.
- 1982 A Barwell Preformer added.
- 1983 Computer aided production control and compound development facility.
- 1985 David Smith joins the company as Technical Director.
- 1986 Quality Control System to BS5750 Part 2.
- 1987 First internal mixer installed.
- 1989 Employee commitment to TQM adoption of Japanese ethos.

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- 1990 Defined improvement objectives to eliminate compound batch variation .
- 1992 Five year plan for variation improvement begun.
- 1994 Second internal mixer with bulk carbon black handling.
Microwave Polymer pre-conditioning.
- 1995 Stockblender installed on dump and finishing mills. New purpose built control lab.
- 1996 Computer controlled scheduling and policed weigh system installed. 3rd internal mixer for masterbatching FKM
- 1997 Guarantee of +/-1° hardness for all multibatch runs.
- 1998 Small powder dispensing system
- 1999 Purpose built silicone compounding plant.
Quality aims redefined.

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The company was formed in 1979 as an open mill mixing facility to supply rubber moulders/ fabricators with a wide range of compound types in single or small batch runs.

Carbon black was added to compounds via bought in polymer masterbatch for optimum dispersion and process cleanliness. Mixed compound was sheeted, template cut and air cooled on metal racks to avoid wet antitack contaminants.

In 1982 Barwell preformer was added – and

In 1983 a computer aided production control and compound development system was installed.

This next mile stone is an addition to the paper as David Smith was far too modest to include it in the original paper. In 1985 David joined as Technical Director bringing with him 30 years of experience in the rubber industry.

In 1986 quality control procedures were established which lead to approval to BS 5750 part 2.

1987 saw the installation of the first internal mixer to pre mix polymer/carbon black masterbatch to feed the open mill mixing operation.

1989 employee commitment to TQM and the adoption of the Japanese quality improvement ethos.

In 1990, we defined the improvement objectives to eliminate compound batch variation.

1992 saw the beginning of the 5 year plan for improvement in batch variation.

In 1994 the second internal mixer was installed together with bulk black handling and a polymer conditioning system.

1995 saw the addition of stock blenders and a new purpose built control laboratory was opened.

1996 computer controlled scheduling and policed weighing system installed and a 3rd internal mixer for masterbatching FKM.

1997 we announced to our customers we would guarantee that all batches of rubber compound within any production run would fall within the hardness range +/- minus 1°.

1998 Small powder dispensing system installed and in 1999 we opened our purpose built silicone compounding plant.

Major Factors Causing Compound Variation

- Internal Mixers
- Cross Contamination batch to batch
- Other contamination

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Little has changed in basic equipment design for the rubber compounding process since the development of the Banbury drop door and the introduction of the stock blender some 30 years ago.

Rubber compound batch production through out the world is largely from various types of internal mixer.

The wide variation in processing properties within rubber compound batches and between batches in any production run has incurred massive costs in our industry with high reject rates, lost production hours and under utilisation of resources. The causes of high levels of inconsistency in rubber compound batches are numerous and often complex, but most are attributed to control of the process and environment.

We believe that internal mixers are generally unsuitable for production schedules of the kind mentioned in the introduction incurring excessive levels of variation in single and multibatch compound runs.

This belief is based on three measured observations.

1. The mixing profile of the first batch bears little resemblance to the remaining batches in the run. This is usually seen in rheologic property differences of the first batch and is often rejected or blended away.
2. Cross contamination from batch to batch by residual compound in the chamber (hang up) this is almost unavoidable and occurs by varying degrees in over 90% of batches mixed.
3. Discharge from the enclosed mixing chamber is restricted and offers sites for entrapment of residual compound and ingredients for example on conveyor belts, ledges, protruding bolt-heads etc.

The internal mixer is more suited to multibatch runs over say 20 batches, as the longer the run the less the effect of cross contamination from the previous batch. Also curatives

addition delayed to the second stage (on a mill) can reduce batch to batch variation to some degree.

The overriding positive attribute of internal mixers is however its ability to thoroughly disperse carbon black and other reinforcing filler into the polymer.

The Clwyd Approach to Compounding

- Elimination of Batch Variation
- Mixing and weighing
- Raw material supply and control
- Environmental control and measurement

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The Clwyd Approach to Compounding

To overcome these factors we have adopted a combined mixing approach whereby we mix rubber compounds on two roll mills incorporating carbon black via a masterbatch with polymer premixed in an internal mixer. This process provides the benefits of optimum dispersion of the internal mixer without the problems of cross contamination, and thus eliminating one of the main causes of batch to batch variation. Typically our mixer features a variable speed DC drive for better mixing control, batch dump into a bucket conveyor for mill transfer avoiding conveyor belt cross contamination. The milled sheet being air cooled on racks to avoid wet antitack coolant contamination. The mixer also utilises tempered water cooling and time/temp mixing profile control.

Before embarking on our mission to eliminate batch variation it was felt that the right level of employee commitment and focus was required. To this end we adopted some of the Japanese improvement ethics to establish a heightened level of awareness, motivation and commitment.

Various practices and incentives under familiar names such as a TQ and Total Quality Management were introduced which lead to the removal of lateness, absenteeism and almost completely eliminated labour turnover.

Elimination of Batch Variation

With these systems in place our five year plan to achieve these objectives was published, setting out how we would reach these objectives by improvements in:

Mixing and raw material weighing.

Raw material supply and supplier control.

Process and storage environment control

We were not certain how far we would progress towards the total elimination of variation but we felt that within 5 years we should remove the 24% tail of wider range hardness that existed in 1989. (see slide 6)

Mixing and Weighing

Our mixing process, provided the foundation on which we could progress towards greater batch consistency, and all new plant additions were carefully considered with this in mind.

The second internal mixer was installed in 1994, primarily for the production of polymer/carbon black masterbatch, had new features incorporated to minimise process batch variation, these were:

1. Segregated bulk carbon black handling system with computer policed manual weighing in a minimum dust environment.
2. Variable speed DC drive with total energy consumed recording.
3. Sensors in the mixing chamber to detect residual compound 'hang-up'.
4. Video camera beneath the drop door to view rotors during discharge.

Further modifications to the mixing process were made by the installation of stockblenders on internal mixer dump and finishing mills during 1995. This investment had a significant effect on improving consistency within each batch, particularly with high heat generation and peroxide cured compounds, where curatives are added at a second stage.

The computer controlled scheduling and policed weigh system, played a major part in the final achievement of our batch variation reduction objectives.

Our already low scrap and return rates were halved to 0.2% and 0.3% respectively, within weeks of installation.

In any manual polymer bale weighing operation - where a process operator is armed with a machete, Stanley knife, Fogg and Young bale cutter, and a set of weigh scales - you would be lucky throughout any day to control weighments within + or - 2.0%. A 4% spread in weight of the prime constituent in a rubber compound will produce significant variance in hardness and rheologic data.

Our weighing system presents to the operator, via a screen, one recipe ingredient at a time with the target weight required for each ingredient. When the delivered weight lies within + or - 1.0% of the target weight the operator can accept and move on to the next ingredient in the mix.

This system ensures all constituents are present within + or - 1.0% of the target weight in any compound and the precise

weight of each ingredient is recorded against the batch number, operator, and time/date, for traceability.

We cannot, therefore, omit any ingredient from a mix and are assured that all constituents are present within $\pm 1.0\%$ of expected weight. However, we could, and occasionally have, weighed the wrong material, but this possibility was removed by the installation of a small powder weighing dispensing system a year later in 1997.

Raw Material Supply and Control

In 1992 we notified suppliers of our 5 year plan to eliminate variation from all compound batches as measured by rheologic and hardness range.

We asked them to identify any properties of their product likely to affect the achievement of our objectives and to take the necessary steps to remove significant factors, and then redefine specification range limits to support their actions.

Many of our polymers and key raw materials are now purchased to redefined specifications with reduced ranges for critical properties. This was achieved over several years by pursuing a supplier development programme with performance improvement measures communicated annually.

Initially we adopted a single sourcing policy for raw materials, to eliminate variation between dual sources of the same product although today we have dual sourcing to the same standard for good commercial reasons.

We operate a very strict goods received and approval regime where all materials are tested, aligned to certificates of analysis from source, and certified to revised specification before acceptance.

The process does not permit sub-standard materials to enter our manufacturing operation.

Environment Control and Measurement

The ideal storage conditions for rubber compound are standard to low relative humidity, absence of direct sunlight and a temperature below 10°C. At temperatures above 10°C, structural and chemical changes occur within the compound, which are detectable by rheologic changes in a matter of days. Below 10°C these changes are arrested and little change can be detected over a 6 month period.

We do not heat our factory storage and processing areas, but constantly monitor daily temperature and relative humidity for batch process tracability at a future date.

To even out seasonal differences we installed a second roof layer over the entire factory and storage areas. Insulation between the roof layers effectively reduced the maximum to minimum temperature range over a year by 12°C.

We installed a microwave bale heating unit, initially for thawing frozen natural rubber. This was so effective compared with a traditional hot room, and with a potential capacity of up to 10 tonnes per day, presented us with the opportunity of preconditioning all polymers prior to mixing, to standardise on bale breakdown energy consumption, irrespective of season.

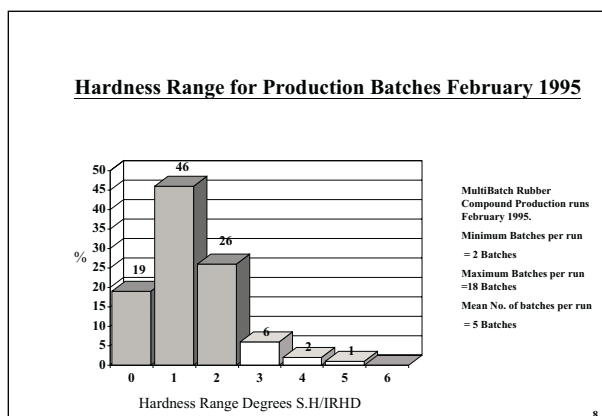
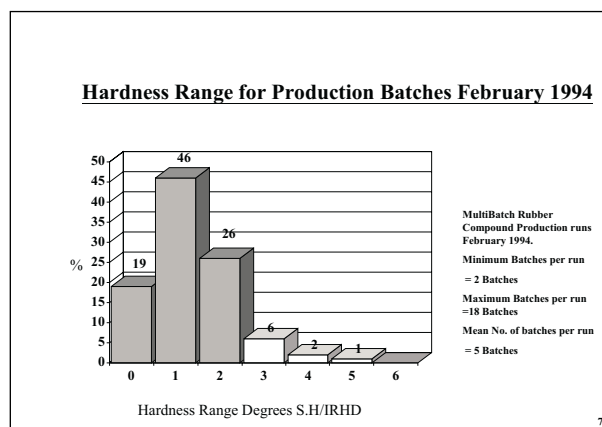
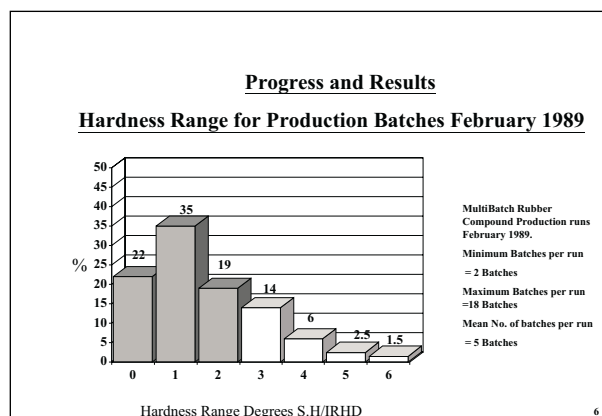
We realised that as we progressed towards better batch consistency actual measurement of improvement would become increasingly difficult, given the variation in testing conditions and differences between operators.

To overcome this a new control laboratory was built with full air conditioning to provide a stable and controlled testing environment all year round.

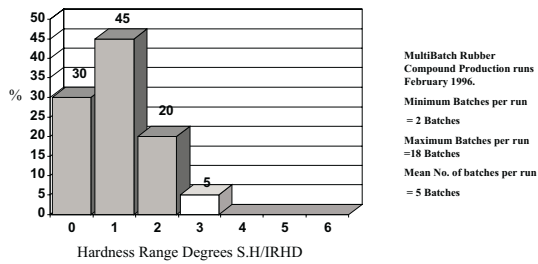
Batch control release employs two MDR 2000E rheometers both with computer limit setting, recording, and auto approval within defined limits. Specific rheometers are dedicated to particular mix types to avoid inter machine discrepancies.

Specimens for hardness testing are cured at optimum, on presses with platen control within a 1° temperature range. Cured samples are environmentally conditioned for a minimum of 15 hours prior to testing for hardness the following day.

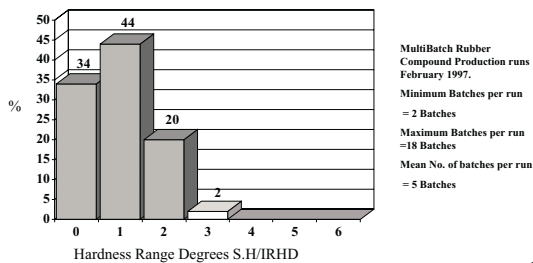
Both IRHD and Shore A instruments are jig mounted with digital display hardness readings, after a fixed time dwell, to eliminate operator recording errors. Differences in hardness measurement are the single greatest cause of dispute within our industry.



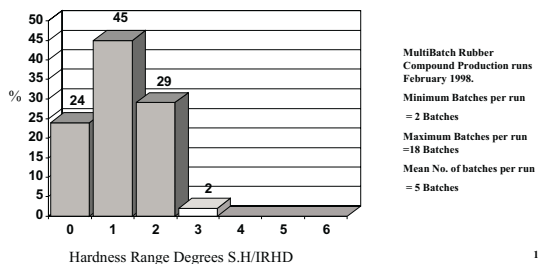
Hardness Range for Production Batches February 1996



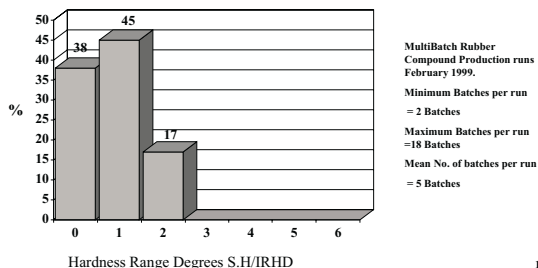
Hardness Range for Production Batches February 1997



Hardness Range for Production Batches February 1998



Hardness Range for Production Batches February 1999



Progress and Results

As stated earlier we felt in 1989 we were at the industry standard on control of hardness with 76% within the range +/- 1° with the tail of 24% extending to 6°.

The combined effect of all this initiatives started to show results in 1994 with 9% of production batches falling outside a plus/minus 1° range. This was improved slightly in 1995 with the drop of a further 1% down to 8% falling outside a plus/minus 1° range.

1996 saw this fall by a further 3% leaving only 5% falling outside a plus/minus 1° range.

The results for February 1997 shows the percentage of production batches falling outside the plus/minus 1° range was only 2%. 98% of production batches were produced within the range in any multi-batch run. 34% of production runs showing zero variation.

We were now confident that we had made sufficient impact on batch variation control that we could now offer our customers a guarantee that all batches of rubber compound within any production run would fall within the hardness range of plus/minus 1°.

From that time and today we supply and guarantee all compound to be within this range, we will accept rejection and will replace free of charge any batches supplied outside these limits.

1998 showed that progress is not always consistent but still 98% of batches meet the criteria.

1999 It is now 2 years since we were able to offer our guarantee and the final histogram shows that 100% of February 1999 production was within our limits and 38% had zero variation 45% a range of 1° and 17% a range of 2°.

CONCLUSIONS & FUTURE

- What difference will two or three hardness points make
- Benefits
 - Process Efficiency
 - Reduced Scrap
 - Machine Down Time
 - Faster Cure Systems
- Future
 - Improved cleanliness
 - Improved dispersion

CONCLUSIONS AND THE FUTURE

We were fortunate in having the opportunity, or foresight, in defining quality excellence objectives in the early stages of the Company's growth. As we developed the business to the usual parameters of sales growth, return on investment and net margin, we also were able to develop and invest in delivering excellence in product consistency.

I will conclude with a comment made to David Smith by one of our customers on hearing of our claims and guarantees of control to a narrow hardness range. His reaction was "So what! What difference will two or three hardness points make to a dog chewing on a rubber play ball?"

None whatsoever, unless the dogs teeth are not too good. The difference lies in the level of control of the process for producing the play ball.

In this case the process included a very recent model of injection moulding machine with a well engineered mould tool and close tolerance temperature control.

This process was capable of producing a perfect lift and with ultimate batch consistency in compound feed giving zero defects and optimum press utilisation.

For compression and transfer moulding of rubber parts there is scope for significant improvements in process efficiency by using batch consistent compounds.

Benefits may be maximised by controlling the storage and usage of our rubber compounds and, with variation taken out of the compound, attention may be focused on reducing variation in press and mould surface temperatures with scope to reduce scrap, machine down-time, and provide significant cost savings.

Our process of mixing rubber compound is more temperature forgiving than in single stage internal mixing, we are able to use more adventurous and faster cure systems in injection

moulding compounds, providing real opportunities in reducing cycle times and operating costs.

Finally what of the future, progress must be continuous. To date we are now focusing on ways of improving dispersion and reducing the chances of contamination by improved cleanliness.

BIOGRAPHICAL NOTES

David Smith AIRI

44 years technical capacity in the Rubber Industry, the last 24 years of which as a Technical Director. Recently retired after 14 years as the Technical Director of Clwyd Compounders. Worked widely in the rubber industry for ITS Redfern Rubber Vol-Crepe and Charles Weston Oilseals.

Martin Lee BSc CEng

25 years in sales and marketing in the rubber industry currently Sales Director of Clwyd Compounders. Previously with 3M UK Plc, RAPRA and in the aircraft industry with the Bristol Aeroplane Co and British Aerospace.