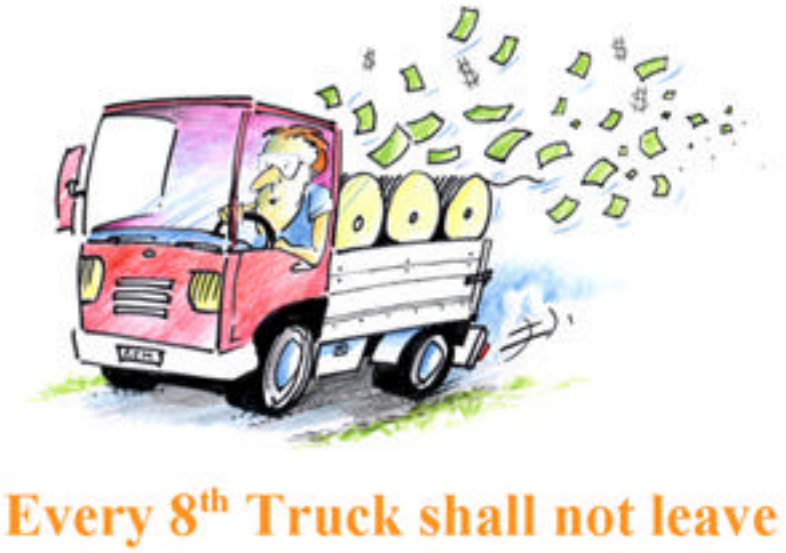
Introduction

The purpose of this study is to ascertain whether replacing extruders in an existing extruder line would improve process variability. The improved process stability would then result in material savings and less production cost. Data from measured values before the change is analyzed and compared with values obtained from the same cable type after the exchange of the extruders.

Conventional measuring methods such as profile projectors or measuring microscopes are inadequate as the inaccuracy of repeatability exceeds the process variations. Therefore, to obtain reliable data of the process variations it is important to use measuring equipment capable of the highest accuracy in absolute value as well as in repeatability. This is possible with the KSM Off Line Measuring System, as described in this presentation.



Manual measuring methods are insufficient due to its wide margin of errors.

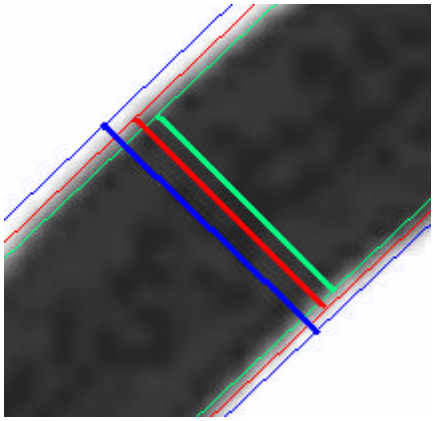
A number of studies have been made using conventional measuring methods such as Shadow Graphs and measuring Micro Scopes.

Photo showing a measuring Micro Scope often used to measure cables

Manual measuring of cable samples is influenced by many things

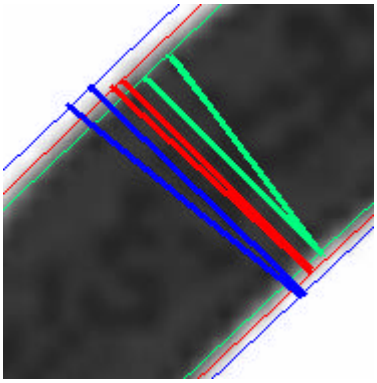
1) It is very difficult to determine where the minimum wall is when taking measurements.

2) Where do the walls start and end?



The blue, red and green lines give very different wall measurements.
Also by simply moving your head you will obtain a different reading.

3) What is the shortest distance between the lines?



4) Errors from how the sample is located on the measuring plate.
5) Errors from reading the micrometer.
6) Errors from recording the readings correctly.

Where are the different minimum walls in this triple layer sample?

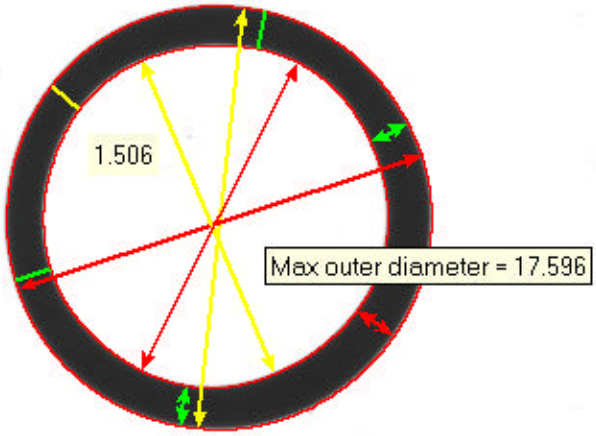
It is difficult to see and difficult to measure manually.
Each time you take a manual reading, you will obtain a different value.

The resulting inaccuracy makes it difficult to arrive at precise conclusions and leading to over dimensioning in the manufacturing of cables. Note that we are discussing measurements of the *wall thickness*, which is of outmost importance in the cable production.
A typical example can be illustrated as follows: Same sample is measured repeatedly, with an intentional time span and by the same person and in addition, sometimes by different persons.
In an experiment in Great Britain, ten different people measured the same sample on a building wire, flat twin and earth, from their own production.
The variation of measured results was a staggering 0.25 mm or 16%!

In an example using a Swedish 1kV under ground Cable-Sample, variation was typically 7% when the same person measured the sample with pause in-between measurements.
In Australia, it was 9 %. In USA from 7% to 10 %. These are only a few examples but it illustrates the danger in drawing conclusions from manual measurements.

Conclusion: Conservatively we can say that spreads in measured values are well over 5% when manual measurements are used. Therefore, such methods cannot be used, as uncertainties of results are too great to draw reliable conclusion of variability in a manufacturing process.

Automatic measuring of cable walls with very high repeat accuracy.



KSM Off line measuring unit *Image of a Cable sample measured as per the European spec*

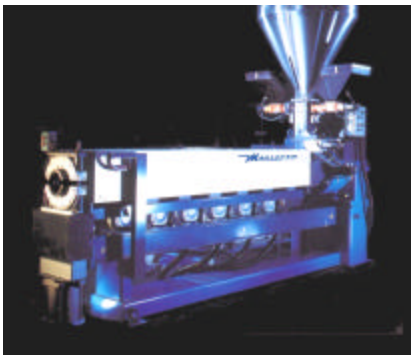
KSM automatic measuring system takes 1 million measurements into its calculations, with a repeat accuracy of typically 0.01 - 0.02 mm (4 - 8 mils). The narrow margin is maintained also, when the same sample is measured several times and when it is relocated on the measuring table between measurements. Therefore, it makes it possible to use the out-put values from KSM for control of the process stability. For example using KSM as an analyzing tool when exchanging Extruders, experimenting with Cross Heads, or running the same product in different extruder lines. Alternatively, when experimenting with various tooling, materials or temperature profiles. Typically, less than 1% spread is possible with the KSM automatic measuring system.

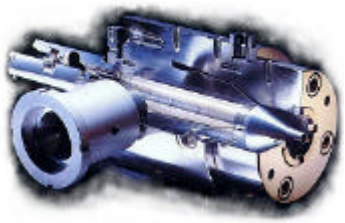
Conclusion: We need an automatic procedure to study process variations.

Extruders used in the case study.

The extruder, the old Maillefer BM120-18 built Year 1983 with head Maillefer 16/30 for the outer jacket, was replaced with a new Maillefer NMC140-24D and crosshead ECH35/45 built year 2001.

Old Maillefer Extruder and Head





New Maillefer Extruder Year 2001
Published with courtesy of Maillefer Extrusion S.A. , Ecublens, Switzerland

Cable type

For this case a typical building wire, 3x1.5 mm^2 with a double outer jacket, was selected. The inner jacket made of PE and the outer made of PVC having a typical minimum wall of 0.6 mm. The investigation was made on the outer PVC jacket in a machine with a new NMC150-24D Extruder.

Comparison method

To compare the study, before and after exchange of extruder, two 50 m coils of the same cable type were randomly selected.
One cable coil was manufactured in May year 2000 and the other in Jan year 2002.
The cable coils were both cut in many locations to get a good selection of samples. Five samples were taken at 1 and 49 m and one sample each at 5, 10, 15, 20, 25, 30, 35, 40 and 45 m.

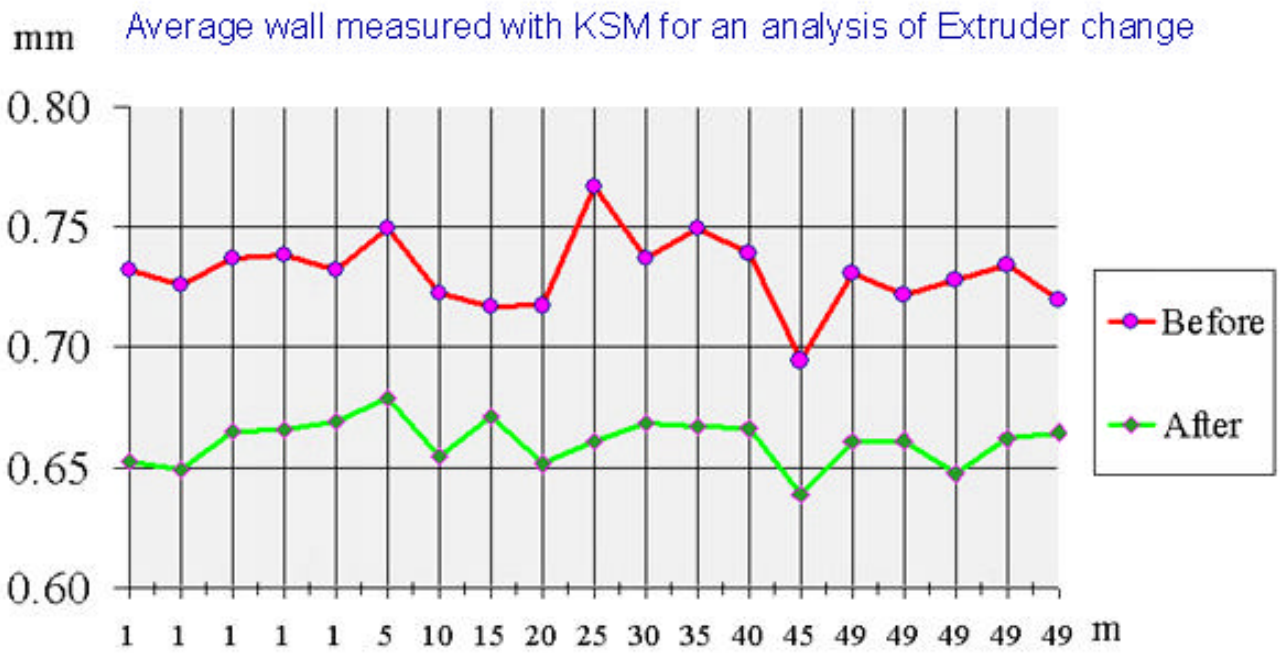
Tool type AM102 was used to slice the samples (please see picture above). The tool ensures accuracy of the samples since poorly cut samples can give incorrect measuring results in manual as well as automatic measuring methods. All samples were sliced to the same 0.4 mm (15 mils) thickness.

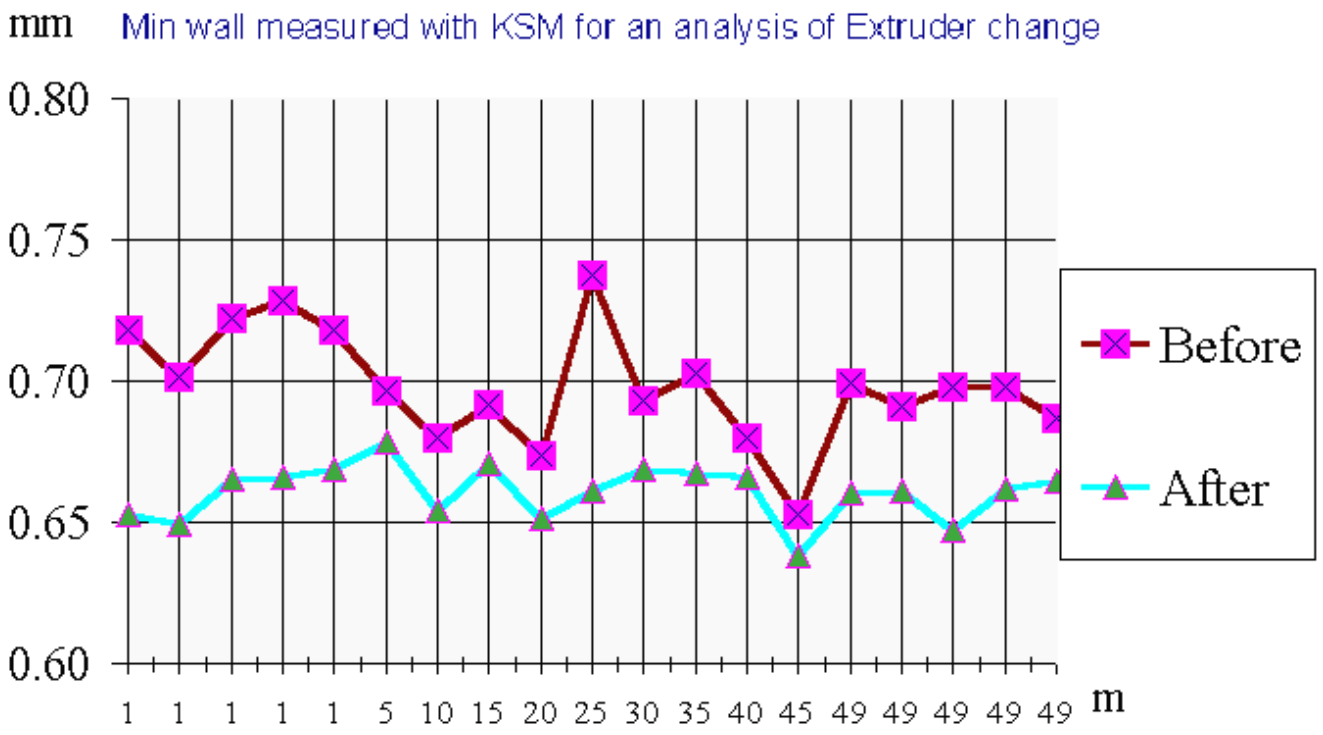
Measuring unit type KSM30F, having a maximum measuring field of 30 mm (1.100 mils), was used. Three samples were measured repeatedly. The repeat accuracy was better than 0.02 mm (0.8 mils).

Microsoft Excel was used to construct the graphs, shown below, with two curves in the same diagram. One graph shows measurements taken before and one after changing extruders. .

Measuring Results before and after extruder change

Walls measured with KSM for an analysis of an Extruder Change





Comments to the diagrams

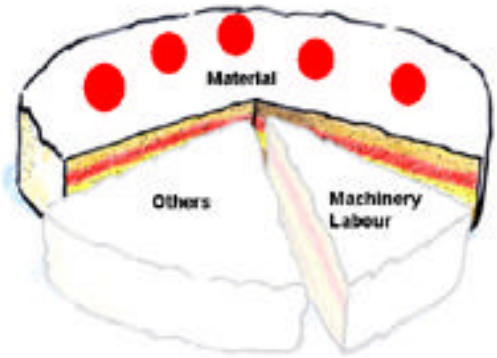
1) The five values measured at 1m and 49 m show in principal the repeat accuracy since we can assume that the values for the walls within 5 x 0.4 mm cable = 2 mm are the same.
   We can therefore conclude that this is the same 0.02 mm (0.8 mils) value as mentioned earlier.
2) The different levels of the curves before and after exchange of extruders are due to improvements made already before the extruder change. This factory has been using KSM for a long time to measure and record accurate data.
3) The values for Average and Minimum walls give an indication of a savings of at least 0.1 mm (40 mils) of the diameter.
4) Other measuring values obtained from the production line since the above study have also confirmed the case that at least 0.1 mm reduction of the diameter is possible.

Cost savings

? It is well known that the material costs are the dominate cost in a cable.

? Material cost for building wire can be up to 80% of total.
   - The metal part is approx. 2/3 and the insulation part 1/3.

? An Extruder consumes insulation material of US$1 - 2.Million per year making the potential savings considerable.



If it would be possible to reduce the diameter by 0.1mm (or the wall by 0.05 mm) the cost saving could amount to 0.05/0.7 x 1-2.000.000 = **US$ 70,000 - 140,000 annually per extruder line!**

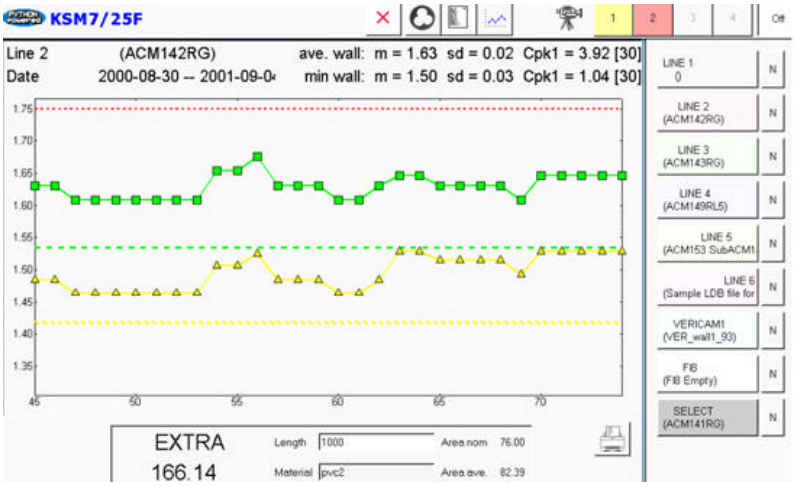
This saving was verified from the actual production line where the saving for the measured product alone was confirmed to be US$ 40,000 annually.

Paralleling the cable production with the Airline Industry, which changes aircrafts to reduce fuel consumption the cable industry, must drive at less material waste. Airlines cannot stay competitive if they do not invest in new improved cost saving technology. The cable industry is no different. The problem with the cable Industry used to be lack of competition so price pressure was never an issue.

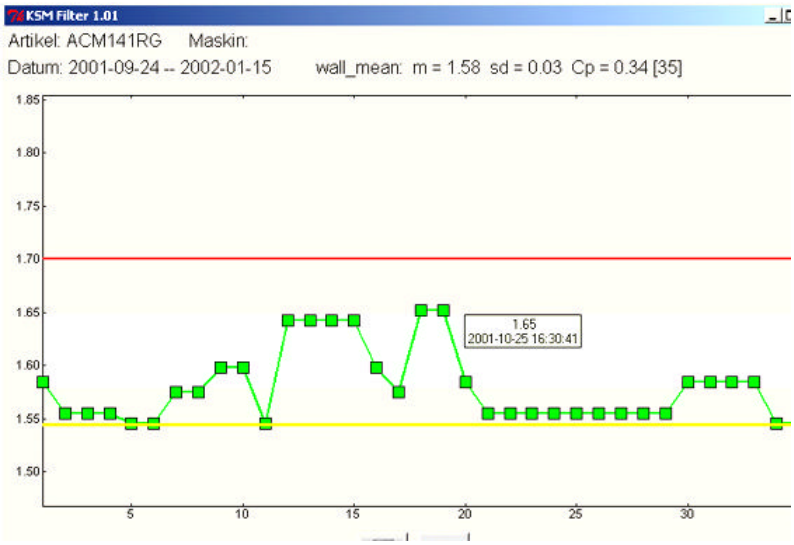
Today we see a situation where the cable manufacturing industry must become more cost efficient to stay competitive.

Analyzing Tools for the measured results.

KSM do not only measure with a very high repeat accuracy but also present costing information to the machine operator. A trend curve with costs due to material over dimension is presented automatically after measuring.



Programs such as Microsoft Excel or **KSM Filter** can be used to select and study measured data on the Office PC. The system facilitates detailed analysis on the production line using different tooling, materials etc.



Conclusion

The off-line measuring system KSM for automatic and accurate measuring in the manufacturing process of cables is an excellent tool, but it provides only accurate facts. Using this knowledge will present an advantage by a) Reducing material waste b) Improving production stability.
Adding to this your tenacity in continues improvement will eventually achieve your goal as the lowest cost producer.