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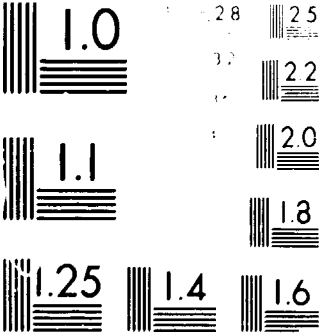
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PRACTICAL APPLICATIONS OF POWDERED RUBBER TECHNOLOGY*

by

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Practical Applications of Powdered Rubber Technology

Natural and synthetic rubber in powder form became commercially available a number of years ago. Bayer manufactures powdered polychloroprene and nitrile rubber materials, the products belonging to the two ranges being supplied under the trade names ®Baypren and ®Perbunan N.

1. The Bayer powdered rubber range

The Baypren powdered rubber range consists of eight materials and includes normal grades having low to medium viscosity values and, correspondingly, slight to medium crystallization tendencies, precrosslinked grades, and sulphur-modified grades. The Baypren powdered rubbers are packed in the same way as the chip materials, i.e. in 25-kg bags, of which there are 40 to a pallet. In general they retain their ability to flow freely for more than six months, provided they are stored in a cool, dry place. This characteristic results from the presence of 5 ± 2 % of an inorganic partitioning agent. Owing to the presence of the partitioning agent the powdered materials have higher Mooney viscosity values than the chip materials, but this has no influence on the vulcanization behaviour.

The Perbunan N powdered rubber range consists of eight materials also and includes a PVC-modified precrosslinked grade in addition to the main and special grades. The Perbunan N powdered rubber grades are packed in 25-kg plastic bags and the pallet weight is 450 kg. These materials also correspond to the polymers on which they are based and contain similar amounts of partitioning agent.

The maximum particle size of all the powdered rubber grades is 1.6 mm; the size of about 80 % of the rubber particles is within the range 0.5 to 1.6 mm.

2. Powdered rubber technology

Our powdered rubber technology embraces the following operations:

- 2.1. Dry blending
- 2.1.1. Processing the powdered dryblend to homogeneous rubber compounds consisting of strips or pellets
- 2.1.2. Direct processing of the dryblend on injection moulding machines
- 2.1.3. Direct processing of the dryblend to extruded finished goods, this technique is still at the experimental production stage.

Dry blending is comparable with internal mixing in conventional rubber processing because it is common to all the processes which have been found suitable for powdered rubber. The subsequent operations represent alternatives to one another. A complete production sequence therefore comprises the basic dryblend operation, followed by one of the other above-mentioned operations.

In developing our powdered rubber technology we have cooperated with five German machinery manufacturers and one German handling equipment manufacturer.

2.1. Dry blending

The production of a dryblend containing all the ingredients belonging to a compound formulation is the foundation of our entire powdered rubber technology.

The purpose of dry blending is to produce a homogeneous powder, representing a mixture of all the ingredients belonging to a rubber compound, in a one step operation, in the shortest possible time, and in such a way that very little energy is consumed and the temperature of the premixed materials therefore increases to only a very small extent.

For this purpose it was necessary to optimize a machine that was already being used at plants which process plastics in powder form, e.g. PVC, in addition to rubber: the turbo-rapid mixer.

In modifying the turbo-rapid mixer to enable it to meet the technical and economic requirements of dry blending in the most satisfactory manner possible we studied a large number of machine parameters.

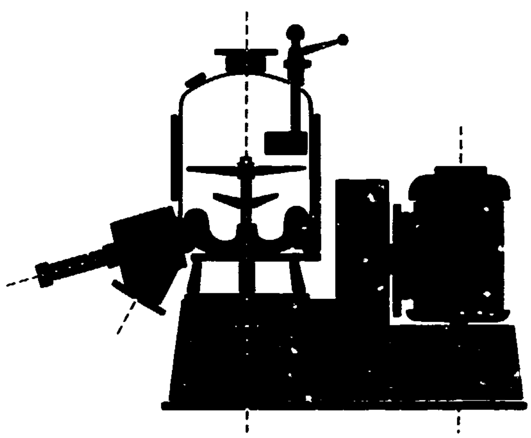


Figure 1: Papenmeier turbo-rapid mixture (cross section)

Figure 1 shows a cross section through a turbo-rapid mixer.

The finished mixture is a free-flowing powder with a mean bulk density of 0.5 $\pm$ 0.1 g/cm^3.

Extensive development work resulted in machines with the sizes 100, 160, 250 and 400, these figures represent the maximum volume of the chamber in litres, for which the following additional data can be given (Figure 2):

Mixer size (litres)	Average batch weight (kg)	Maximum drive capacity (kW)
100	30	30
160	50	37
250	80	55
400	120	75

Figure 2: Machine data - turbo-rapid mixers

The turbo-rapid mixers of these sizes give batches with average weights of 30, 50, 80 and 120 kg after net mixing times of 2 to 3 minutes. 1 to 1 1/2 minutes must be allowed for the manual loading operation. The emptying time is negligibly short.

If the net mixing time is 2 to 2 1/2 minutes the final temperature of a dryblend for vulcanizates with a hardness of 20 to 40 Shore A is 60 to 80°C. If the Shore A hardness is to be above 40 the net mixing time is about 3 minutes. In such cases the mixture contains a relatively small amount of plasticizer; it therefore absorbes less energy, with the result that the final temperature of the homogeneous powdery material is between 35 and 45°C. While the mixture is being produced the motor capacities of the machines just referred to are used to the extent of 60 to 70 %.

2.1.1. Production of homogeneous rubber compounds from the dryblend powder

Especially where the production of mechanical rubber goods is concerned there are plants whose compounding capacity is inadequate and which therefore have to buy compounded stock from other firms. If it is intended to enlarge the existing capacity of a plant there are two alternatives:

One can install either an additional internal mixing line or a powdered rubber processing line. In the case of the first alternative both the capital outlay and operating costs will be high. If a decision is taken in favour of powdered rubber technology the cost of investment will be considerably lower, less personnel will be needed to operate the machines, and energy will be saved. In view of these advantages we will first describe the processes by which the dryblend can be transformed into a homogeneous compound, which, like any other compound, can be converted into finished goods on all the rubber-processing machinery and equipment which happens to be available.

2.1.1.1. Production of processable feed strip or pellets

Feed strip or pellets can now be produced by three different machinery set ups.

a) Dryblend-processing on special extruders

Special extruders which directly transform the dryblend into homogenous feed strip or pellets are now supplied by the firms of Werner & Pfleiderer and Berstorff.

The dryblend is conveyed to the special extruder by a suitable metering unit either directly or from a silo in which it has been stored.

Werner & Pfleiderer special extruder

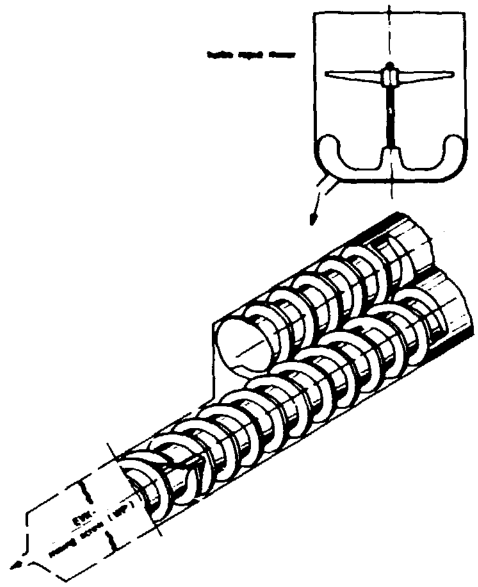


Figure 3: EVK compounding extruder, Werner & Pfleiderer system

The twin-screw section is relatively short, the pitch of the screws being such as to give a powerful feed effect. The free-flowing powder is compacted in this part of the extruder and fed to the longer single-screw section, where it is subjected to an EVK mixing section which improves the dispersion of the ingredients to the standard required for final processing.

Depending on the type of extruder head in use, the material emerges as strip or pellets.

The Werner & Pfleiderer machines are available in sizes of 90, 120, and 150 mm for outputs ranging from 200 to 1000 kg/h.

At the end of the paper a film demonstrates a powdered rubber mill-room line in operation. This line consists of a 300 litres turbo rapid mixer in combination with a Werner & Pfleiderer 150 mm special extruder. For this production Bayer polychloroprene powdered rubber is used to produce a final mix in pellet-form.

Berstorff special extruder

The Berstorff special extruder represents a cascade consisting of two machines, a planetary extruder part and a separate final product warm-feed extruder.

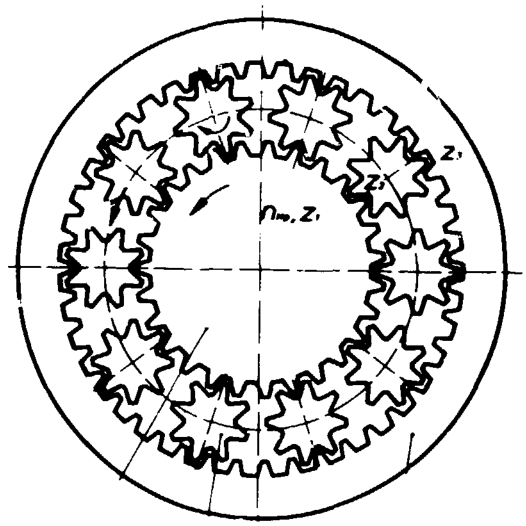


Figure 4: Planetary extruder, Berstorff system

The dryblend is compacted and homogenized exclusively in the planetary part of the extruder - see Fig. 4 -, which consists of a stationary cylinder and a driven main spindle surrounded by eight to ten independent planetary spindles. The rotation of the main spindle forces the planetary spindles to rotate also. The planetary spindles are held in place by a special ring at the end of the cylinder. On entering the space between the main and planetary spindles the mixture of the ingredients is subjected to an intensive kneading action.

The Berstorff combination, which had been used for several years in the processing of plastics in powder form, expecially of PVC, was modified to meet the requirements of powdered rubber technology. The type known as WE 140 has been used successfully for a large number of different rubber compounds. Depending on which of the types is used, the machine gives a throughput of 250 to 500 kg/h. The manufacturer intend to introduce additional types, which are to be known as WE 190 and WE 240. The type number indicates, not the screw diameter, but the distance in millimetres between opposite planetary spindles; This distance is thus 140 mm in the case of the WE 140 machine.

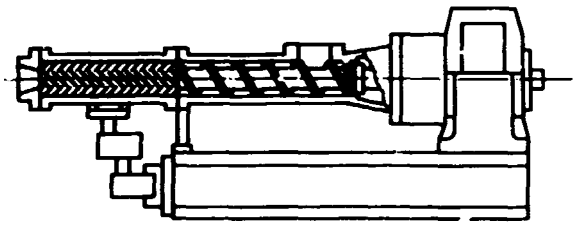


Figure 5: Dryblend processing on a Berstorff WE unit

Figure 5 shows as a schematic drawing how the dryblend is processed on a Berstorff planetary extruder unit.

b) Dryblend processing on mills fed by a single-screw compactor

Though less rational than the alternative procedures, dryblend processing on mixing mills to which the material is supplied by single-screw compactors minimizes the fundamental capital investment necessitated by the introduction of powdered rubber.

For this procedure - irrespective of whether it is operated continuously or interruptedly - the existing mill must be supplemented by a turbo-rapid mixer and a single-screw compactor. The existing mill serves to improve the dispersion of the compound to the standard required for final processing. To enable the work to proceed without interruption the mill should be divided into two zones and provided with a stockblender. The fully mixed strip leaving the mill should be passed through a cooling unit and deposited wig-wag-wise in open containers in readiness for final processing. If it is decided to operate the process continuously, as described before, it is important to adjust the throughputs of the machines to one another.

The sequence of operations embracing the turbo-rapid mixer, a single-screw compactor and a mixing mill, is shown in Figure 6.

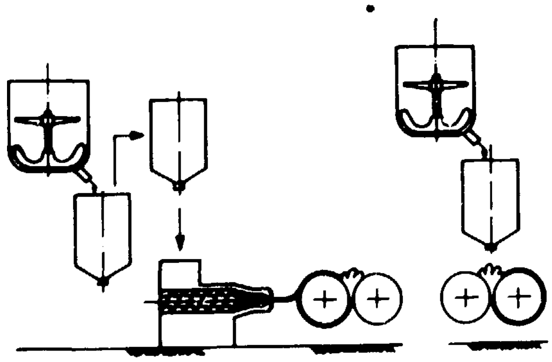


Figure 6: Turbo-rapid mixer - single-screw compactor - mill processing sequence

If, for reasons of cost, it is decided to use an existing mill, the dryblend must nevertheless be compacted. If the dryblend were compacted on the mill itself this would create dust on a scale which would be hazardous to the personnel and would make it impossible to keep the mixing room clean.

The purpose of compacting, which is a new operation in rubber processing, is to compress the free-flowing dryblend, which has a mean bulk density of 0.5 $\pm$ 0.1 g/cm^3, until it has approximately the specific gravity of the compound required. This operation gives an inhomogeneous, but compact and continuous strip, which is afterwards homogenized on a mill. The strip is produced in a very inexpensive machine, which also requires very little energy, cooling water, and installation space. This machine, by which the dryblend is compacted, though not yet rendered homogeneous, was developed by Sikoplast, of Siegburg, in cooperation with us. It has a horizontal compacting screw with a special conical part and is available in two sizes with rated motor capacities of 11 and 35 kW for mean throughputs of 250 and 600 kg/h.

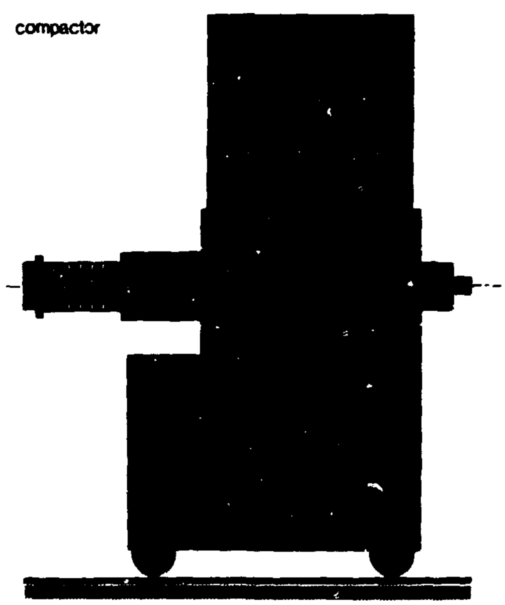


Figure 7: Sikoplast single screw compactor

Figure 7 shows the a cross section of a single-screw compactor.

The turbo-rapid mixer empties its contents batchwise into the feed hopper of the compactor, which is located at a lower level. The compactor can, however, be operated continuously if the outputs of the two machines are adjusted to one another.

c) Processing of dryblends in internal mixers or on mills

Mills and internal mixers, which belong to the conventional equipment of rubber plants, are particularly suitable for soft compounds intended for soft printing rolls or use on coating machines when dryblends are processed by the direct method.

When such compounds are produced in the conventional way, i.e. in internal mixers, several stages or long compounding times are necessary because of the need to disperse the large amount of plasticizer homogeneously.

If the ingredients of a compound are introduced into an internal mixer in the form of a dryblend, the number of internal mixing stages can be reduced to one or two, with a resultant considerable increase in the output of the internal mixing line. The savings that can be achieved in this way depend on the formulation of the compound, on how the compound of this type is normally produced at the present time, and on how modern the internal mixer is. It is difficult to give a specific figure for the reason that, when the rubber is introduced into an internal mixer in the form of bales, the individual compounding stages are not of equally long duration. Nevertheless we know from practical experience that the capacity of an internal mixing line can be increased by about 20 to 40 % by the interposition of dryblending.

A dryblend powder containing a high proportion of plasticizer is able to flow freely but does not form dust. If the ingredients of a compound are finally mixed, i.e. homogenized, on a mixing mill onto which they are introduced in the form of a dryblend, the total compounding time can be reduced, the quality of the product can be improved, and dust formation by compounding ingredients can be entirely prevented.

In the manufacture of soft printing roll covers the use of powdered rubber together with the use of a new and inexpensive machine, the turbo-rapid mixer, in conjunction with an existing mill, simplifies and reduces the cost of producing a processable compound.

If the dryblend has only a low plasticizer content, final compounding takes longer and dust formation is indevitable.

2.1.2. Direct processing of the dryblend on injection moulding machines

In connection with the direct processing of dryblends to moulded technical goods, which is also known as "one-step moulding", we have been cooperating with Werner & Pfleiderer in the development of horizontal and vertical injection moulding machines. In connection with horizontal machines we are also cooperating with GKN Windsor, of Bischofsheim; the plasticizing units used with these machines are supplied by Berstorff, of Hannover.

The sequence of operations involved in the direct injection moulding of dryblends is shown in Figure 8.

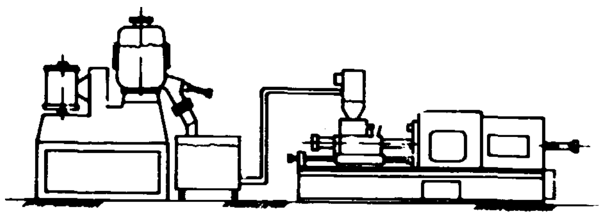


Figure 8: Dryblend processing line (schematic drawing): one-step moulding on horizontal injection moulding machines

We have developed this two-stage procedure - production of a compound in a turbo-rapid mixer, followed by the final processing operation - mainly for use in the production of technical mouldings on horizontal and vertical injection moulding machines. The screw throughputs of rubber injection moulding machines are considerable smaller than those of extruders. The throughputs for screw diameters of 50 to 80 mm range from 20 to 80 kg per hour.

If it would not be acceptable to increase the familiar plasticizing times the entire free volume of the feed zone must be enlarged, and a suitable mixing and shearing screw fitted, so that direct feeding with dryblend is possible.

In this two-step procedure the kneading or mixing effects of internal mixers and mills have to be dispensed with. The screws of the plasticizing units of the injection moulding machines therefore have to provide the mixing and shearing effects needed to incorporate fillers and rubber chemicals into the powdered rubber particles and disperse them evenly.

The handling of the dryblend powder after it has left the turbo-rapid mixer and before it is fed to the injection moulding machine is most important to the success of the whole procedure. It would be unreasonable to expect the machine operators to feed the material by hand and, in any case, this would make it impossible to keep the building clean. A handling system has therefore been developed by Meyer, of Hennef, in cooperation with Bayer, in which the dryblend is fed by suction from a silo to a metering screw located above the feed opening of the injection moulding machine's plasticizing unit.

Disturbance-free handling is also fundamental to the entirely automatic operation of injection moulding machines without machine operators.

Practically speaking, every manufacturer of rubber goods would like to know whether existing rubber injection moulding machines can be modified so as to be suitable for this procedure, which is undoubtedly the most economical powdered rubber processing technique. In every case the circumstances must be carefully investigated. According to our experience machines with sufficient screw lengths and adequately powered plasticizing units can be modified if they are single-station machines. But the screw length should be at least 15 x D and not more than 20 x D, and the screw diameter D itself should not exceed 80 mm. As the drive motors of many existing rubber injection moulding machines are only just adequate to the demands made on them at present, one should be hesitant to assume that the drive motor will be adequate in any particular case.

2.1.3. Direct processing of the dryblend to extruded goods, techniques still at the experimental production stage

If the direct processing of a dryblend on extruders is found to be practical it will, like one-step moulding, be an elegant one-step manufacturing procedure which permits correspondingly large savings. But the direct extrusion of a dryblend is considerably more difficult than the direct injection is considerably more difficult than the direct injection moulding of such a material. In this case the output and homogeneity of the mixture, the temperature of the material, and the dimensional stability of the extrudate must all be optimized at the same time; in other words a well dispersed compound must be produced at the highest possible rate, while remaining at the lowest possible temperature, and the dimensional stability of the extrudate must be extremely good.

This procedure, which was envisaged as the final goal of our powdered rubber technology, is now being operated experimentally on industrial extruders.

All the familiar types of extruders are either entirely unsuitable for direct feeoing with a dryblend powder or suitable only if the output is reduced to such an extent that the procedure becomes uneconomical.

With a view to enabling the use of modern cold-feed venting extruders which have already been installed to continue we are cooperating with Troester, of Hannover, in experiments under conditions similar to those of practice. It has already been found that the desired effect cannot be achieved simply by modifying an extruder of this type by, for example, fitting a mixing and shearing screw and extending the cylinder. The feed systems available at present are not able to achieve the required output of strips or pellets when the extruder is fed with free-flowing dryblend. The concept which we are examining jointly with Troester represents a cascade system in which the feeding and compacting are separated from the homogenizing operations.

This cascade system is represented schematically in Figure 9.

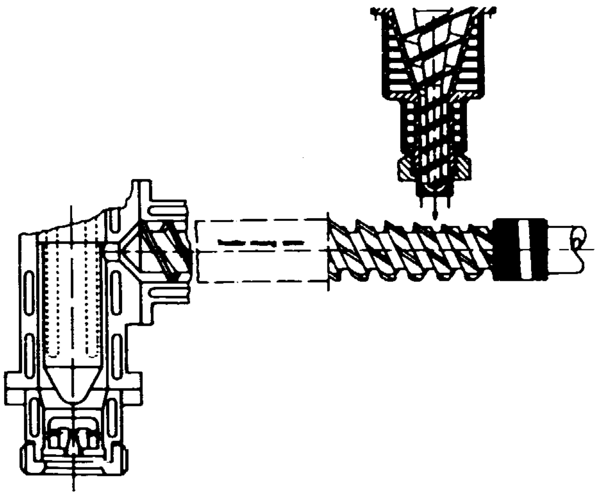


Figure 9: Mixing extruder with shear-head in combination with a single-screw compactor, Troester system

The concept just referred to envisages the use of a single-screw compactor with separate drive as an additional unit situated above the feed opening of the extruder. The purpose of this unit is to draw in the dryblend, compact it, and feed it as an inhomogeneous, but continuous feed strip to the mixing extruder located below. The modern cold-feed venting extruder which is the next machine in the extrusion line must in all cases have a mixing and shearing screw and its length may have to be increased. This single-screw mixing extruder is connected with a shear-head. The rubber material coming out of the cold feed vented extruder is fed into this shear head at a temperature of approx. 110°C and is sheared in an annular gap. This annular gap is composed of a fixed cylinder and a rotating mandrel the speed can be regulated precisely.

Due to the internal friction the temperature of the rubber compound is raised to the vulcanizing temperature. The temperature range is approx. 170 till 200°C. Finally the hot compound is shaped by the extrusion die and vulcanized in a curing equipment.

We are not yet in a position to comment on the overall technological and economic potentialities of this concept.

3. Economic aspects of the new technology

The purchase of the plant needed for a conventional mixing room, and even the installation of an additional internal mixing line, entails such heavy capital expenditure that the burden is bound to be felt, even by a large firm, for a number of years. Such an investment may provide the production capacity that has been lacking hitherto, but the firm concerned is unlikely to be in a position to buy new processing machinery, such as extruders and injection moulding machines, at the same time.

The new powdered rubber technology provides a real alternative to such an investment. The plant's compounding capacity can be increased at very little cost, and, at the same time, the existing processing machinery can be modified very inexpensively or new equipment can be bought. In addition the new powdered rubber technology can be introduced in a number of stages, whereas a new mixing room must be provided, or an existing one enlarged, all at once.

The economic factors that must be taken into consideration differ considerable according to the country in which the factory is located or, in the case of a particular factory, according to the type, location and size of the undertaking. The conditions on which such calculations are based have been averaged from those which existed in the Federal Republic of Germany in 1981. Assuming the validity of these figures, which cover such factors as the interest on capital, the depreciation period, maintenance costs, space requirements, energy consumption, and wages costs, two examples of the savings permitted by the new technology will now be given.

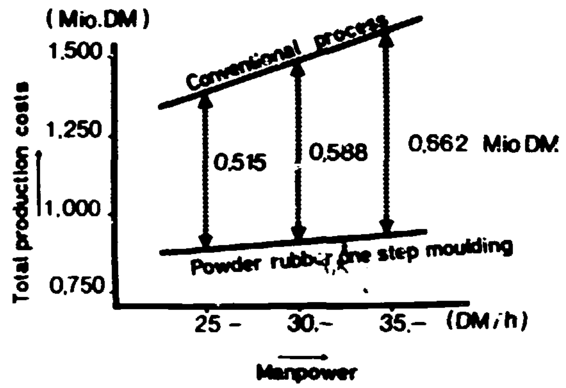
To start with we will compare a conventional internal mixing line, consisting of a 60-litre internal mixer, two 84" mills, and a batch-off unit with strip cutting device, with a dryblend compounding line, consisting of a 160-litre Papenmeier turbo-rapid mixer and a 150-mm Werner & Pfleiderer EVK extruder with twin-screw feed zone and strip extruding head. At an annual output of approximately 2,500 tonnes, produced on a two-shift basis, the saving permitted by the powdered rubber technology after allowance has been made for the fact that, at present, powdered rubber is more expensive than conventional rubber forms is about 340,000 DM. Under the same conditions it will still be possible to save 170,000 DM a year after the conventional internal mixing line has been entirely written off.

The purpose of the second example is to indicate the considerably greater economic advantages which are possible when the powdered rubber is processed directly. I will assume that a technical moulding shop, equipped with 30 injection moulding machines, is supplied with conventionally produced compound strip in one case and with freeflowing dryblends in the other, and that the other factors are the same as those on which our first example was based. Here again the amount of compound required annually is 2,500 tonnes and there are two shifts a day. The compound strip is produced conventionally on the plant belonging to the internal mixing line. The production of a compound according to the powdered rubber technology is confined to the dryblending process, for which, again, a 160-litre Papenmeier turbo-rapid mixer is used. In the case of the powdered rubber technology one has to take into account the fact that the raw material is more expensive than conventional rubber and the capital outlay for new machinery or, in the case of modified machinery, for a new plasticizing units with mixing screws and dryblend feeding devices. At interest rates of 8 and 16 % the use of powdered rubber in this example permits annual savings of 540,000 and 510,000 DM. Even if the internal mixing line with which a comparison is made has been entirely written off, an annual saving of about 300,000 DM is still possible.

Cable Belt Ltd in Marlow was one of the first rubber processing companies in Great Britain starting compounding its own materials from powder 3 years ago. The compounding line, including ancillaries, cost about £ 300.000 and has a capacity between 750 and 1000 kg/hour. In terms of compound cost alone the company saved this capital in two years.

This company manufactured a 7.8 kilometres of belting for an Austrialian mining company using Bayer s Baypren 220 powdered chloroprene rubber. The curved overland conveyor is used by Coal and Allied Operation to transport coal from Hunter Valley mine, New South Wales, to the rail loading bay.

Finally, Figure 10 shows the future cost trends of a technical moulding shop with thirty rubber injection moulding machines as operated conventionally, in the one case, and according to the powdered rubber technology, in the other.



Future trend
Comparsion conventional process vs.
One step moulding
Moulded goods production with 30 injection - moulding machines

Figure 10: Future trends of total production costs

This figure shows the trends of the costs of the two production processes as functions of the expected increases in the average wage of a skilled rubber worker. At the present average hourly wage of DM 25,-- it is clear that the total cost of production is likely to increase considerably more in the case of the conventional process than in that of the new process. Several factors favourable to the powdered rubber technology have been disregarded, however. These are the expected future increases in the cost of energy, the opportunities provided by the powdered rubber technology for reductions in curing times, and the fact that the prospect of operating injection moulding machines entirely automatically, i.e. without personell, is considerably better when the machines are fed with dryblend than when they are fed with conventional compound strips.

4. Powdered rubber in production

The first film shows the powdered rubber millroom of the above mentioned British rubber company, which is producing on a two-shift basis an output of 2.500 tons per year.

A German moulded goods company can be recognized in the second film. The manufacturing method used is the powdered rubber one step moulding process. These machines are producing automatically without operators.

Literature

J.P. Lehnen "Powdered rubber proved as production cost cutter", European Rubber Journal, Nov. 1977

P. Grange "Powder pay off", British Plastics and Rubber, Nov. 1980

J.P. Lehnen "Cut costs with powder", European Rubber Journal, Febr. 1982