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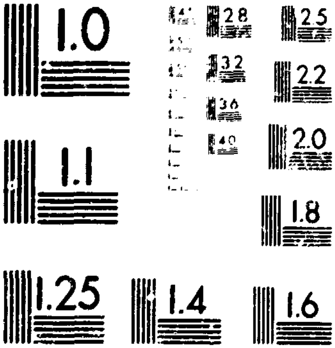

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THE TECHNOLOGICAL AND ECONOMIC STATE AND FUTURE PROSPECTS OF RUBBER MIXING*

by

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1.0 Introduction

1.1. Industries dependent on rubber

Let me start with a brief survey of the industries that are dependent on rubber.

According to the global importance of its end products, the rubber industry belongs to that group of industries whose products are essential to modern technology and which includes the metal, fibre, plastics, and glass industries.

In the world as whole raw rubber is now being produced and consumed at a rate of nearly 12 million tonnes per annum. Roughly 35 % of the world demand is met by natural rubber, which is grown mainly in the plantations of Malaysia, Indonesia, other South-East Asian countries, and Central America.

Roughly 65 % of the world demand is met by synthetic rubber, which is produced in a large number of industrial countries. The raw material of synthetic rubber is oil. The synthetic rubber industry is therefore highly sensitive to oil price increases and to fluctuations in the ability of the oil producing countries to supply. More than half the world's output of natural and synthetic rubber goes into tyres.

The remaining half is accounted for by an enormous variety of consumer goods and goods used in industry. These articles range from dock fenders to penicillin stoppers, from V-belts to water tap washers, and from high pressure seals to membranes for dialysis machines.

Until 1973 the growth rates of rubber consumption throughout the world were satisfactory. The change came with the oil crisis, after which rubber consumption only continued to increase in the COMECON countries and China, in the developing countries of South-East Asia, and in South America. Apart from Japan, the rubber consumption of the western industrial nations approached "zero growth".

1.2. Rubber goods of higher added value need better rubber mixing techniques

A challenge is posed by the difficult economic position in which, on the whole, the rubber industry of the western industrial nations now finds itself: in future the industry will have to produce articles still better suited to their applications, add more value to the raw materials as they are converted into useable products, and employ more economical conversion techniques.

To see what this callenge menas, let us consider briefly the typical property pattern of rubber. The elastic modulus ranges of several materials are listed in Figure 1. The shear modulus of a material can be described as an important fundamental property because it largely determines how the material can be used.

Material	Elastics modulus (MPa)
Steel	10^5
glass	10^4
wood (oak)	10^3
plastics	10_2
rubber	1–10

Elastic modulus ranges of various materials | KA-A

Figure 1: Elastic modulus ranges of several materials

The elastic moduli of plastics are high enough to enable these materials to be substituted for others - iron and other metals, wood, glass etc. - if it is economically advantageous to do so. The property pattern of rubber is such that the applications of this material are limited. Because soft rubber has low shear modulus values - or low hardness values, which amounts to the same thing - it is not intrinsically stiff and therefore cannot be used for large-sized parts that must be self-supporting.

The strength of rubber lies in the characteristics listed in Figure 2, such as the constancy of its elastic modulus, flexibility, and elasticity, the fact that it has little dynamic damping effect, and the fact that it shows little flow under constant load.

1. Hardness:	low (30–90 Shore A)
2. Elastic modulus =	constant (over a wide temperature range)
3. Flexibility*):	excellent
4. Flow under constant load:	slight

*) Deformability under low loads at high deformation amplitude

Typical properties rubber articles — KA-A

Figure 2: Typical properties of rubber goods

This property pattern gives rubber a special position among materials.

These properties are required in numerically limited, but important, specific cases in which the three functions that appear in Figure 3, namely elastic sealing, force transmission, and vibration damping, are fundamentally necessary.

1. Elastic sealing
   - seals of all types
   - pneumatic tires
2. Force transmission
   - pneumatic tires
   - v-belts
   - elastic couplings
   - roll covers
3. Vibration damping
   - springs
   - mountings
   - solid tires

Main functions of rubber articles and chief fields of application	KA-A

Figure 3: Chief functions and fields of application of rubber

Another thing on which the demand for rubber goods depends is the predominantly and characteristically passive dependence of the rubber industry on other industries. In these industries - the motor vehicle, engineering, electrical goods, footwear, mining, construction, and civil engineering industries, for example - rubber goods generally fulfil service functions only.

The rubber industry's principal customers are listed in Figure 4. Being so closely associated with other industries, the rubber industry is relatively unaffected by fluctuations of the economic barometer, except as far as motor vehicles are concerned.

motor vehicle industry
engineering industry
electrical industry
mining industry
construction industry
footwear industry

Main customers of the rubber industry

KA-A

Figure 4: The rubber industry's principal customers

But the relationship has disadvantages too. In recent years most industrial users of rubber have been developing their products in directions that place ever severer demands on rubber goods.

This will suffice, I think, to show how much the output of rubber goods is dependent on the growth of other industries and how forcefully the rubber industry's opportunities for active growth are constrained by the specific characteristics of the industry's products.

In the futue it will be all the more necessary to increase the proportion of our development work that is aimed at improving our processing techniques. The first step should be to optimize the mixing of rubber compounds according to economic criteria and the quality of its results; for an establishment at which rubber is processed can only produce goods of high quality if the rubber mixes that are prepared in the plant's own mixing shop meet exacting demands.

2.0. Technical and economic state of discontinuous rubber mixing

Unlike the plastics industry, the rubber industry is not provided with materials that can be processed immediately (except where silicone rubber is concerned), but, instead, merely with raw materials: rubbers, rubber chemicals, carbon black, and mineral fillers.

Most manufacturers of rubber goods produce their own mixes. So every large, medium, and even small rubber manufacturer normally has to have the chemical and technical know-how needed to convert the raw materials into ready-for-use mixes. Some of the mixes required by smaller manufacturers, however, are obtained from firms that perform mixing under contract. The establishment of a mixing facility entails heavy capital outlay, and this is often beyond the financial means of smallish manufacturers.

2.1. Production processes

Roughly half of the world's total raw rubber output is used by thousands of firms which produce technical rubber goods. The other half is used by the considerably smaller number of tyre manufacturers. As technical rubber goods are used for a vast number of purposes, a very wide range of differently formulated mixes - much wider than the range produced in the tyre industry - is produced by manufacturers of these goods. Thus, to meet the demands of the daily production programme, mixing plants at tyre factories have to produce large numbers of batches of identical mixes, whereas the mixing rooms at other rubber factories produce, every day, a much greater number of mixes - in considerably smaller quantities, however.

The two most widely used procedures for arriving at processable rubber mixes are largely specific to the tyre industry in the one case and to the production of technical goods in the other.

The machine and plant combination represented by the flow sheet in Figure 5 consists of an internal mixer, a mixing mill, and a batch-off unit.

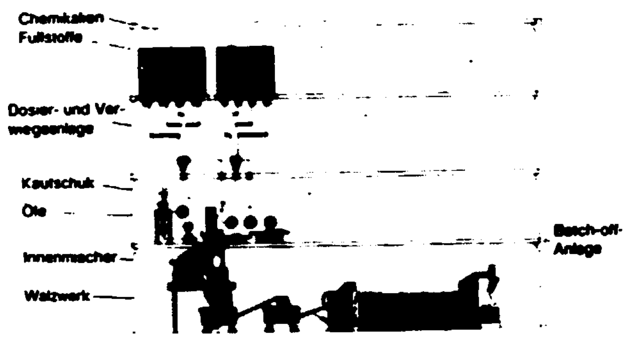


Figure 5: Discontinuous mixing: internal mixer - mixing mill - batch-off unit

This basic mixing room arrangement is typical of the technical rubber goods industry and meets the requirement that the adaptation of one's total equipment to a new compound formulation must be accomplished quickly and without technical difficulty.

Large internal mixers are used in the tyre industry because the quantities of compound required here are enormous; in this industry they can only be used economically if they are supplemented by special extruders, these being installed beneath them.

A mixing procedure involving the use of an internal mixer, a special extruder, and a cooling unit is represented schematically in Figure 6. The batch weights are so high - up to 500 kg - that mixing mills can-

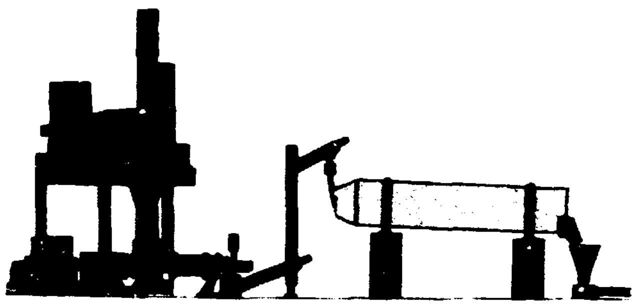


Figure 6: Discontinuous mixing: internal mixer-special extruder - cooling unit

not handle these quantities of materials within the required short mixing times; in addition, mixing mills cannot be joined up with internal mixers with the aid of auxiliary devices in such a way that continuous operation becomes possible.

2.2. Internal mixing

Each mixing line at a tyre factory is centered on the internal mixer, into which all the compounding ingredients - rubber, carbon black, mineral fillers, rubber chemicals, plasticizers, and so on - are introduced manually from bins or automatically or semi-automatically through metering devices.

The principal features of an internal mixer are shown by the section drawing in Figure 7.

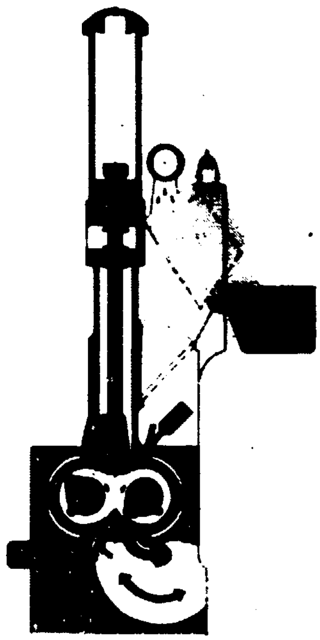


Figure 7: Ram-type internal mixer, with hinged door and bin feeding

The two horizontal rotors are enclosed by the mixing chamber, which is formed by a block divided vertically into several parts. The machine support also serves as the side walls of the chamber. Together with the two centre pieces, they form a complete block, whose individual parts are held together by powerful screw connections, by force exercised by a feather key, and also by means of a self-locking mechanism. In all modern internal mixers the chamber has a hinged door. The entrance to the chamber is exactly above the gap between the rotors and sufficiently large to enable even bulky pieces of rubber to be drawn in without difficulty. This opening is closed by the ram after the chamber has been charged. The rotors themselves and the entire working surface of the chamber are served by a powerful temperature control system.

This is fundamentally important because the quality of a mix depends partly on the temperature progression during the mixing operation. The rotor surfaces are hard-faced as a protection against wear. All the other surfaces which come into contact with the mix are partly protected in the same way.

The chamber is sealed very effectively by sliding rings in annular slots. It is therefore impossible even for dust from fillers and chemicals to escape.

The rubber mix is produced by the action of the two horizontal rotors in the mixing chamber, which is kept closed by the ram and hinged door. The effectiveness and economy of the mixing operation depend not only on the output of the machine, i.e. the size of the machine, and on the specified mixing sequence, but also, and to a large extent, on the design of the rotor system.

A tangential rotor system with four blades is shown in Figure 8.

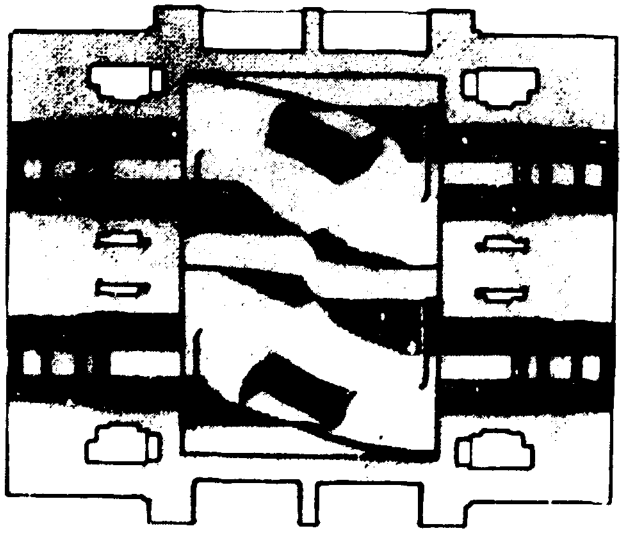


Figure 8: Tangential rotor system with four blades

With this system most of the mixing work is done between the rotors themselves and between the rotor blades and chamber wall. The high degree of efficiency which characterizes this system depends decisively on the maintenance of a high pressure in the mixing chamber. The ram is capable of exerting heavy pressures, but the machine must also be adequately charged. Assuming that the rotor speed is infinitely variable, maximum efficiency is obtained at the highest rotor speed at which the mix in question does not become too hot, and at which it can therefore be produced in the shortest possible time. Irrespective of the size of the internal mixer, the kneading effect is additionally improved if the rotors rotate tangentially at a friction ratio of approximately 1 : 1.1. The rotor speed range itself becomes narrower as the size of the machine increases. In the case of an internal mixer with a batch weight of 60 kg it is 30 to 90 r.p.m.; large internal mixers with a batch weight of 550 kg have a rotor speed range of 15 to 55 r.p.m.

The Intermix has interlocking rotors, as may be seen in Figure 9.

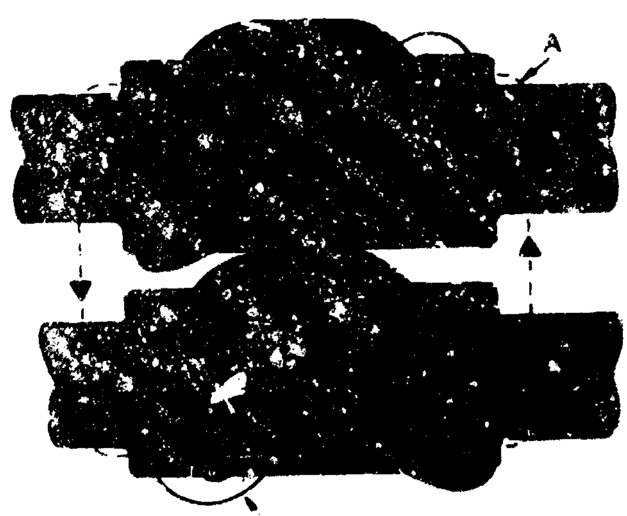


Figure 9: Interlocking rotors of the Intermix

Each rotor has two large and two small block-shaped spiral protrusions. The mixing effect results from the interlocking of these spiral blocks; here, understandably, the rotors are run without friction. The mixing of the rubber with the other ingredients takes place mainly between the surfaces of the spiral blocks and the rotor cores, between which there is friction in consequence of the different peripheral speeds.

Now that roughly a decade has passed since this internal mixer, with its interlocking rotors, was introduced in Europe it can be said that no other mixer is equally economical or gives an equally good result.

2.3. Prospects for discontinuous mixing techniques

Many medium-sized and small companies have recently become aware that their ability to survive will depend to a large extent on their ability to produce rubber mixes of high quality at reasonable cost on their own premises. It is no longer true, as it was in former years, that such companies are keeping their investment in mixing plant to the bare minimum.

In view of this trend, relatively confident forecasts concerning the future of discontinuous internal mixing can be made in accordance with Figure 10.

1. Processing machinery

No spectacular new developments, but improvements in the performance of existing machine parts (e.g. mixer rotors).

2. Process control

Functional improvement and continous control of mixing through the use of microelectronic devices.

	Prospects fot the discontinous internal mixing technique	KA-A

Figure 10: Prospects for discontinuous internal mixing

- Spectacular development of the machinery that is now used for discontinuous rubber mixing is unlikely. But small improvements in parts of this machinery - rotors, for example - are probable.

- It is all the more likely that efforts will be made to improve the mixing procedure through the use of microelectronics. A fuller study of the relationships between the parameters on which the effectiveness and economy of mixing depends, i.e. the batch size, rotor speed, mixing time, ram pressure, and temperature control, will lead to experimentation with process-dependent internal mixer control with a view to improving the quality of mixes itself and enabling the mixes to be produced to closer tolerances.

Figure 11 is a schematic representation of a computerized process control system for a Werner and Pfleiderer high-capacity internal mixer.

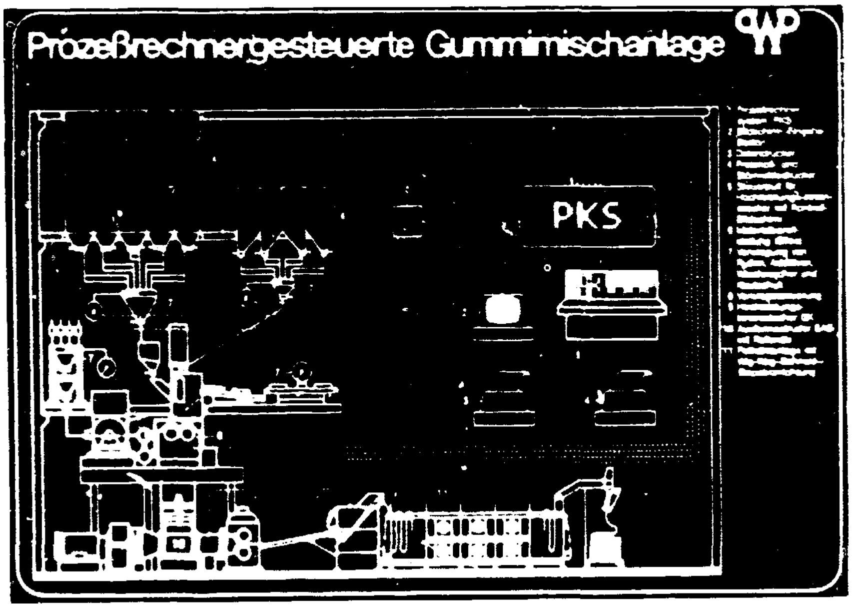


Figure 11: Computerized control system for a WP high-capacity internal mixer

3.0. State and prospects of continuous rubber mixing

For years the rubber industry has hoped that it would one day be possible to convert the raw materials of rubber into processable mixes in an uninterrupted sequence of continuous mixing operations; in general the industry's hopes have remained a dream. Nevertheless, several continuous mixing lines have been in use in Europe for a short while. They show that there is a trend in favour of two different production procedures.

In recent years it has become clear that continuous mixing is technically impossible, and certain to be uneconomical, unless the raw materials meet the fundamental requirements listed in Figure 12.

Fundamental raw material criteria:

1. Meterable physical form
2. Free flowing material (no caking)

Continous rubber mixing | KA-A

Figure 12: Fundamental prerequisites of continuous mixing

If continuously operating machinery is to be used in rubber mixing, all the raw materials must be meterable and free-flowing. Having recognized this, the raw material industry is now in a position to supply a whole series of different raw materials in flowable and meterable forms - as powders, crumb, spherical or cubic granules, chips etc.

All the continuously operating machines that have been used so far can be classed as "special extruders", despite the fact that in some cases their manufacturers have, for various reasons, used other terms to describe them.

The considerations which led to the development of continuously operating rubber mixing machines and to dryblend or premix metering, on the one hand, and separate metering of each individual raw material, on the other, are of great importance, however.

3.1. Continuous mixing, preceded by dryblend feeding

The criteria listed in Figure 13, which favour dryblend feeding rather than separate metering, are all applicable to the circumstances of many manufacturers of technical rubber goods. At these establishments many different recipes comprising more than ten compounding ingredients per recipe are in use and the batch sizes, i.e. the required quantities of compound, are relatively small.

Criteria for dryblend metering

1. Many different formulations
2. Compounding ingredients per recipe >10
3. Small quantities (amount of compound) per recipe

Continous rubber mixing technique | KA-A

Figure 13: Continuous rubber mixing - criteria favourable to dryblend feeding

To ensure that the ingredients of the homogeneous dryblend which emerges from the turbo-rapid mixer are not separated in the next part of the plant, i.e. in the silo storage, conveying, and feeding system which serves the special extruders, the rubber should be supplied as a powder having the ideal particle size of not more than 1.6 mm, as may be seen in Figure 14. Provided the particle size does not exceed 2-3 mm, the granules are still just small enough to be processed satisfactorily, though this may depend on the type of elastomer.

Fundamental requirements for a homogeneous, stable dryblend:

1. physical rubber form: ideal particle size of max. 1.6 mm (powder); granules of particle size 2–3 mm are usually still processable
2. Physical rubber chemical form: particles as small as possible and physical forms geometrically similar

Continous rubber mixing technique | KA-A

Figure 14: Continuous rubber mixing - prerequisites of a homogeneous and stable dryblend

The rubber chemicals should have the smallest possible particle size and the forms in which they are supplied should be similar.

Continuous rubber mixing, proceded by the production of a dryblend, clearly entails the use of powdered rubber technology. This explains why dryblend production is fundamental to the powdered rubber technology which has been developed by Bayer and several makers of processing machinery.

The dryblend is supplied by a suitable conveying and metering system to the special extruders, either immediately or after intermediate storage.

Special extruders that convert the powder-rubber-based dryblend into homogeneous feeding strip or granules that can be processed without any additional treatment are supplied by Werner & Pfleiderer and also by Berstorff.

3.11. WP special extruders

Figure 15 is a schematic drawing of the Werner & Pfleiderer EVK compounding extruder. The intake zone consists of a short twin-screw passage

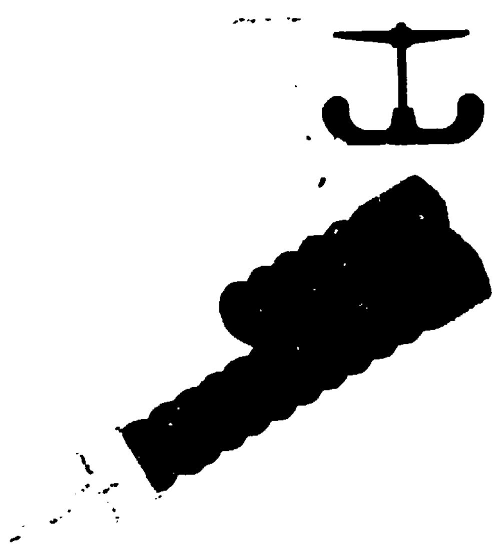


Figure 15: The Werner & Pfleiderer EVK compounding extruder

in which a high conveying pressure is built up. On leaving this part of the extruder, in which it is compacted, the dryblend enters a single-screw section. This part of the extruder, which embodies a suitable EVK mixing principle, serves to disperse the ingredients very evenly among one another. Depending on what kind of die is fitted, strip or granules are obtained; in both cases they are ready for processing. The WP machines are available with screws having diameters of 90, 120, and 150 mm for outputs ranging from 200 to 1000 kg/n.

The mixing procedure from the raw materials to the homogeneous granules is represented in Figure 16.

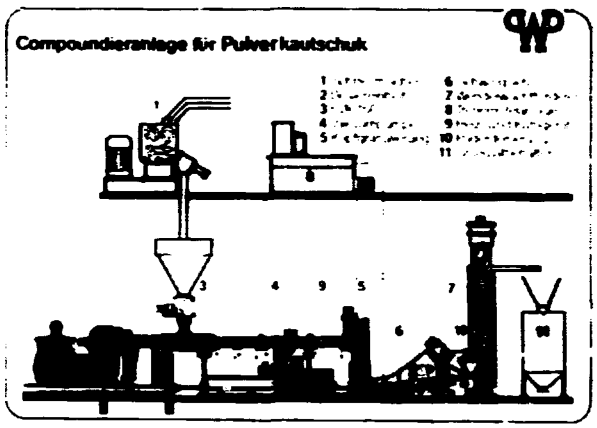


Figure 16: Dryblend processing on a WP 150-mm special extruder

A WP special extruder which has been in use for more than three years converts Baypren powdered rubber dryblends into granules at rate of up to 1000 kg/h.

A 90-mm WP special extruder for throughputs of up to about 200 kg/h can be seen in Figure 17.

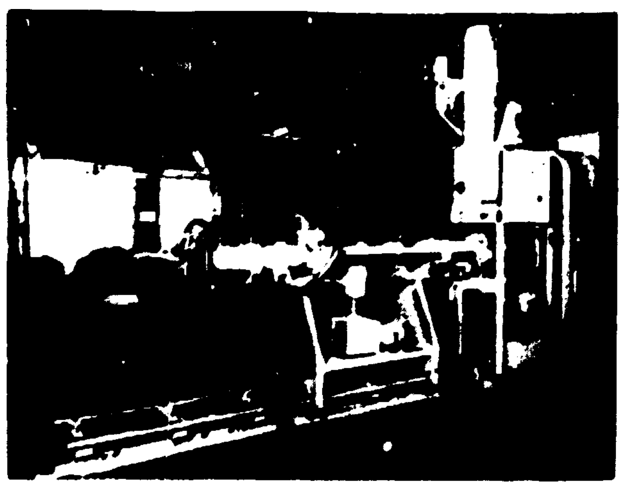
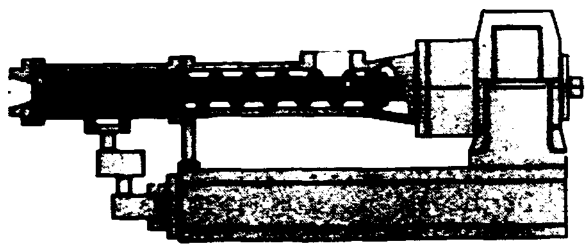


Figure 17: WP 90-mm special extruder with pneumatic conveyance and mechanical dryblend metering

The dryblend is introduced into the hopper funnel by a mechanical device, after which it is conveyed pneumatically.

3.12. Berstorff special extruder

As can be seen in Figure 18, the Berstorff special extruder is a cascade combination of two machines. It consists of a planetary roller extruder, followed by a separate output extruder.



WE - Extruder Fa Berstorff

Figure 18: The Berstorff planetary roller extruder

The dryblend is compacted and homogenized exclusively in that part of the machine which consists of the planetary roller extruder, as may be seen in Figure 19. This consists of a stationary cylinder, a driven main spindle, and eight to ten freely mobile planetary spindles.

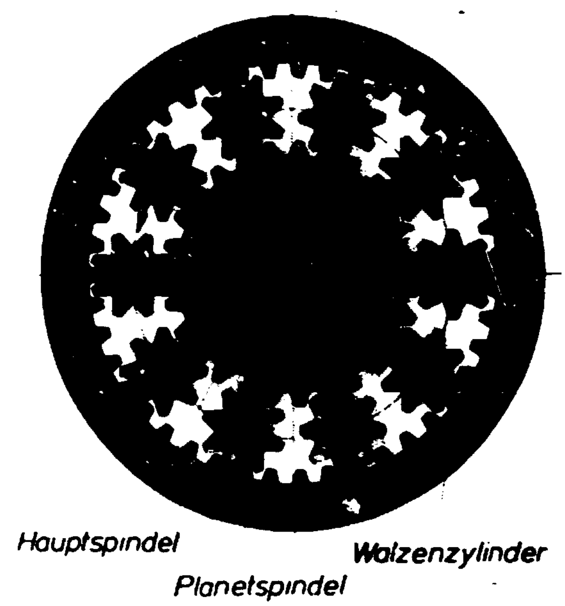


Figure 19: Section through the planetary roller extruder of the Berstorff machine

The rotation of the main spindle makes the planetary spindles rotate also. The planetary spindles are held in place because their axes run in a ring-shaped slot at the end of the cylinder. The continuous motion of the main spindle relative to the planetary spindles gives an intensive mixing action. The Berstorff combination, which has been used for several years in the processing of plastics in powder form, especially of PVC, has been modified to meet the requirements of powdered rubber technology. The machine known as WE 140, which is shown in Figure 20, has been used successfully for a large number of rubber mixes.

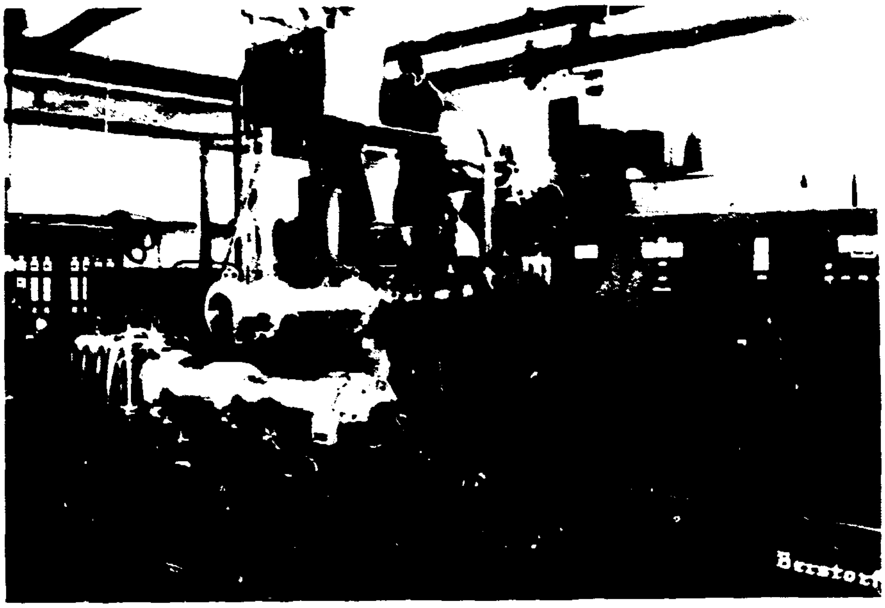


Figure 20: A 140-mm planetary roll extruder in the Berstorff Machine Testing Department

Throughputs of 250 to 500 kg/h are obtained, depending on the type of mix concerned. The manufacturers plan to introduce additional machines, to be known as WE 190 and WE 250. The type number indicates not the screw diameter, but the distance in millimetres between the central points of opposite planetary spindles, this being 140 mm in the case of the WE 140 machine.

3.2. Continuous mixing with separate raw material metering

Even if the raw materials are supplied to the continuous mixing machinery separately, they must be available in meterable and free-flowing forms; this applies particularly to the polymers.

From Figure 21 it is clear that, if the raw materials are metered separately, the factors on which the successful introduction of continuous mixing depends are opposite to those that operate when the raw materials are supplied as a dryblend. Here there should be a small number of recipes, consisting of less than ten ingredients each, and the number of batches of one recipe should be as large as possible.

Criteria for separate metering:

1. Small number of different recipes
2. Compounding ingredients per recipe < 10
3. Large quantities (amount of compound) per recipe

Continous rubber mixing technique

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Figure 21: Continuous rubber mixing - criteria for separate meetering

These conditions exist in the manufacture of certain parts of tyres, conveyor belts, hydraulic hoses and cables, i.e. such parts as tyre treads and sidewalls, conveyor belt and hydraulic hose covers, and cable jackets, for all of which only a few recipes, but very large amounts of compound, are used. In such cases the recipe is not often changed; if it were, a lot of time would have to be spent on cleaning operations, especially in as far as the raw materials are supplied separately to the continuous mixing machinery.

3.2.1. Importance of metering technology

Where rubber mixes are produced in internal mixers by the conventional discontinuous methods, special raw material metering technology is not essential. With continuous mixing processes, however, the need for suitable metering techniques is inescapable.

But for the development of system technology and the availability of highly developed programmable control systems, continuous processing procedures would never have become technically and economically possible. It is not by chance that metering devices are of central importance in continuous mixing, for a given recipe must be maintained very accurately throughout the production of the article in question.

If the widely differing weight inputs in unit time that are specified by a recipe are to be maintained without variation, the metering devices must be highly accurate and reliable. Without attempting to describe the present state of metering technology, I would like to mention that two types of metering device have established themselves: the differential metering balance and the conveyor type weigher.

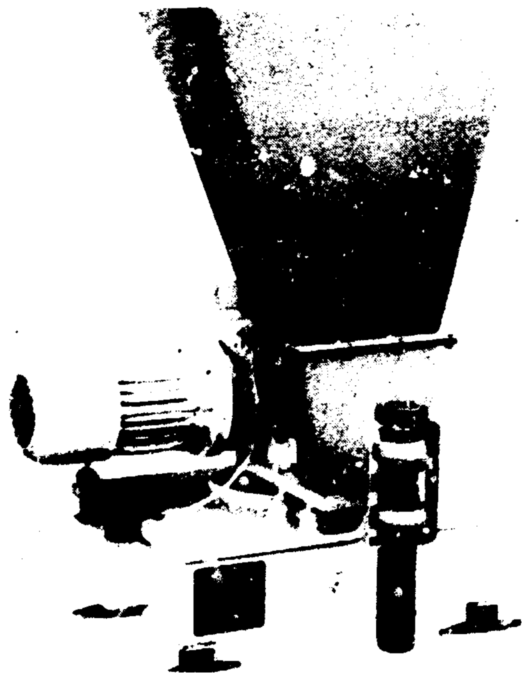

Figure 22: Differential metering balance by K'tron-Soder

Figure 22 shows a differential metering balance, whose storage compartment and funnel rest on a balance. The control device determines the speed of the screw drive in such a way that the weight output of the entire system in unit time corresponds exactly to the kg/h setting. With metering machines of this type the control device responds only to the actually delivered mass. If the material should adhere to any of the surfaces of the machine, the metering nevertheless remains correct. The conveying parts of the machine are absolutely separate from the balance, i.e. the measuring device. Differential weighing balances are therefore particularly advantageous if the materials to be metered are dust-forming, since they require practically no cleaning.

A conveyor type weigher can be seen in Figure 23.

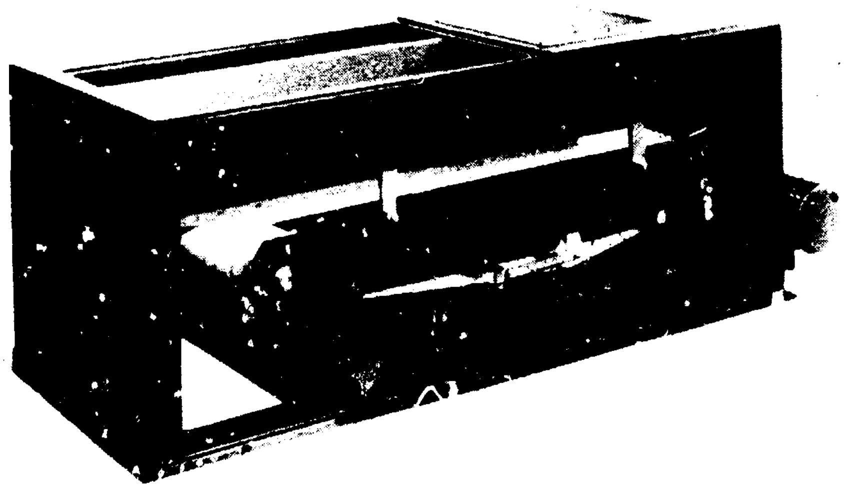

Figure 23: Conveyor type weigher by K'tron-Soder

The machine consists of a conveyor belt with drive and of a weighing table connected with the belt machinery, which moves without bearings or joints. The balance is generally placed below the storage container, from which it always takes the material at the required rate. The control device compares the actual performance, that is to say the product of the load acting on the belt and the belt velocity, with the required performance, and if the two values are not exactly the same it alters the velocity of the belt accordingly.

Metering devices are widely used as control balances because only then can the composition of the mixture and the mixture's throughput rate be kept uniform when the ingredients are metered continuously. Generally the metering device for the most important and critical ingredient of the mix is made to serve as the control balance.

Figure 24 is a flow sheet for the continuous production of a special mix, consisting of rubber, carbon black and antioxidant, for cables.

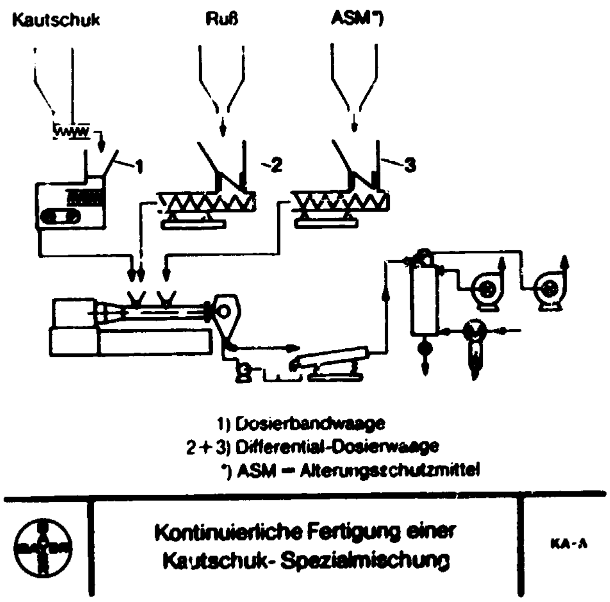

Figure 24: Continuous production of a special rubber mix

The rubber weighing conveyor is a computer-controlled guide balance, whose performance is predetermined by means of kg/h settings. The performances of the subsequent balances, however, are expressed as percentages of that of the guide balance. The set ratios remain constant, even if the performance of the guide balance is altered. It is therefore easy to start up and shut down a continuous mixing line without having to scrap some of the material. The sequential balances can of course be controlled independently of one another.

In the present state of metering technology it is technically possible and also economical to meter up to six solid and two liquid raw material ingredients separately into a continuously operating mixing machine. If the number of raw material ingredients exceeds ten, it is always preferable to meter some of them as a ready-mixed batch. For economic reasons it is also generally advisable to deal with minor ingredients - those that represent less than 1 % by weight of the total formulation - as a batch, this likewise being supplied to the mixing machine via a metering device. Thus the lowest rate at which ingredients are supplied individually is now between 1 and 5 kg/h.

I have been talking about modern metering techniques because I thought that it ought to be said clearly that the perfect functioning of the two high-performance extruder-type machines just referred to depends substantially on the precision with which the ingredients are metered and supplied. The degree of precision shown by the combined functioning of all the elements belonging to a metering system has a decisive influence on the quality of the end product.

3.22. Continuously operating mixing extruders

May I remind you, before going any further, that we are concerned here with recipes consisting of relatively few ingredients, e.g. not more than six solid and two liquid materials, a condition under which the separate metering of each individual ingredient may undoubtedly be both technically and economically appropriate. For purposes of this sort several plants have been installed within the last two to three years by European cable manufacturers; they are being used successfully in cases where the manufacturing programmes seldom change - in cases, that is where the individual formulations have long runs.

The machines that have been used so far or are suitable for this purpose are the Ko-kneader by Buss, of Basle, Switzerland, and the twin-screw kneaders made by Werner & Pfleiderer, of Stuttgart, and by Berstorff, of Hannover.

Buss Ko-kneaders

Buss Ko-kneaders are supplied with throughputs of up to 7 tonnes/h for PVC granules, up to 8 tonnes/h for food doughs, and up to 33 tonnes/h for carbon electrodes and compositions for aluminium melt flow electrolysis.

The principle of the Buss Ko-kneader can be explained, with the aid of Figure 25, as follows:

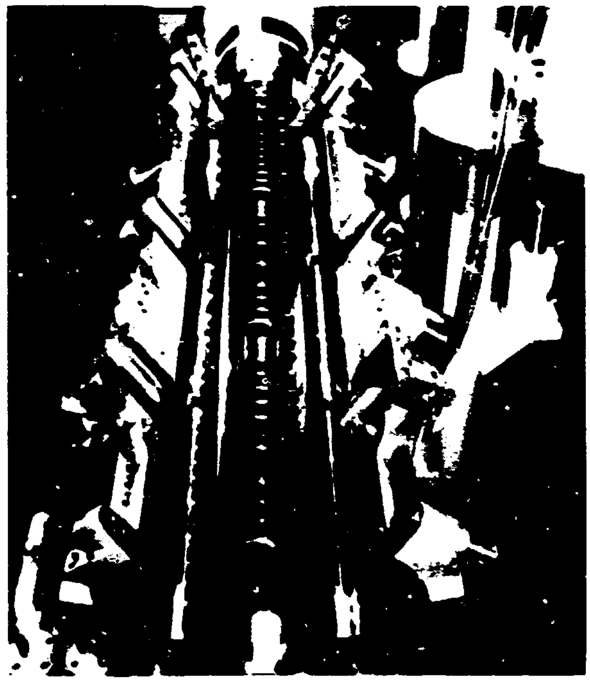

Figure 25: Buss Ko-kneader with opened-up cylinder

The Buss Ko-kneader is fundamentally a single-screw extruder, but it differs from others both in detail and in the way in which it works. The screws of normal single-screw machines have a continuous flight and perform simple rotary motion. The flight of the Buss Ko-kneader screw, however, has three gaps for every rotation. The screw therefore has kneading blades, as it were. In addition the screw performs one axial stroke every time it rotates.

This double motion of the screw shaft, i.e. the simultaneously occurring rotary and oscillating motion, is supplemented by the action of stationary teeth located on the cylinder wall; excellent and highly efficient mixing and kneading is therefore obtained. In addition the materials are subjected to very mild treatment and the energy consumption is low. The residence time can be varied from a few seconds to several minutes in accordance with the procedure as a whole. The Buss Ko-kneader is absolutely self-cleaning because, despite the oscillating motion of the screw, the material is constantly in motion towards the front of the screw. The forward stroke of the screw is more effective than the backward stroke. The principle can be compared with a procession in celebration of spring in which the walkers take two steps forward and one backward. A further contribution to the screw's self-cleaning action is made by the lack of any dead spaces in the screw-cylinder system.

The outside appearance of a Ko-kneader is shown in Figure 26.

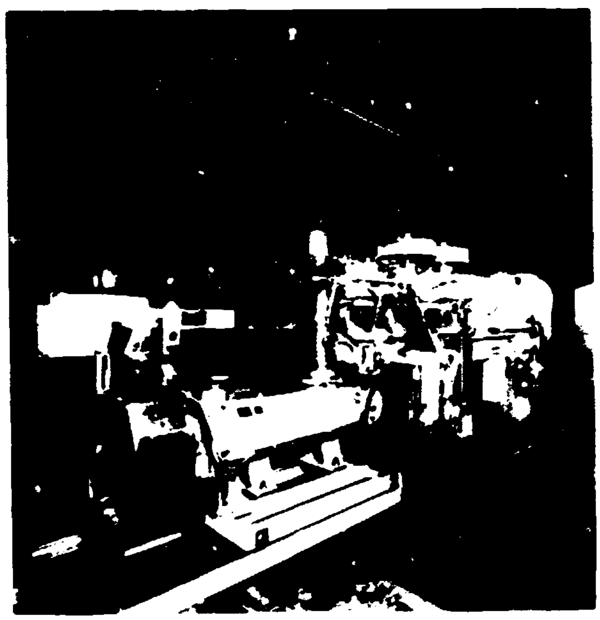

Figure 26: A Buss Ko-kneader

Twin-screw kneaders

For the purpose under consideration the German machine makers Werner & Pfleiderer, of Stuttgart, and Berstorff, of Hannover, supply twin-screw kneaders. These are two-step machines with separate mixing and output parts. The twin-screw unit and the extruder part of a Werner & Pfleiderer machine can be seen in Figure 27.

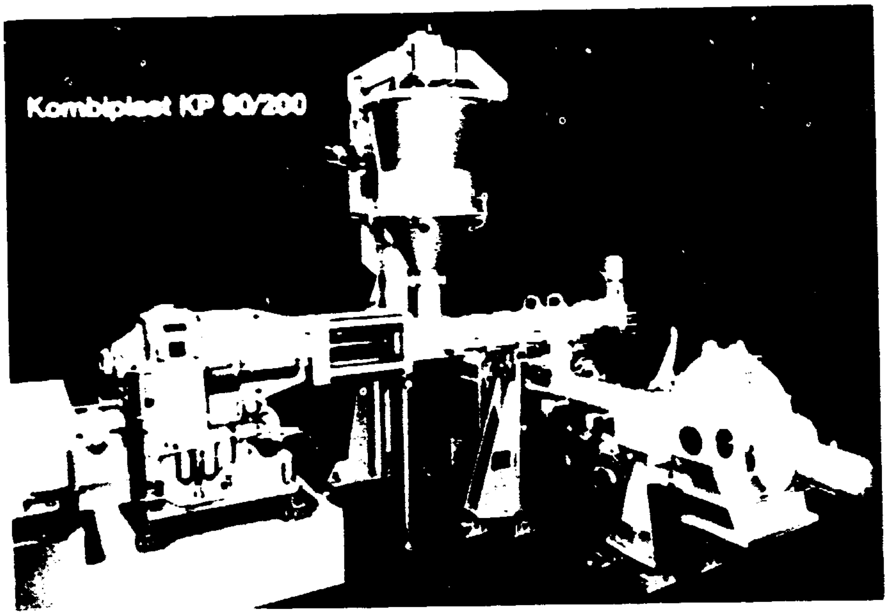

Figure 27: Twin-screw kneader (ZSK) with output extruder, by Werner & Pfleiderer

The materials are softened and then made into a homogeneous mixture in the first part of the machine, whose screws both rotate in the same direction. The screw geometry can be varied substantially by sliding additional kneading elements onto the screws. As no axial pressure is built up in the first part of the machine, an output extruder is needed to create the pressure required for the extrusion of strip or granules.

Kneading and mixing elements used by Berstorff can be seen in Figure 28. The use of kneading blocks (see left half of figure) gives good dispersion and enables heavy shear stresses to be introduced. Special mixing elements (at front on right side) constantly divide and reunite the material current; they are very effective despite a low energy input and therefore permit mixing under mild conditions.

Figure 28: Berstorff kneading and mixing elements

4.0 Prospects

For example, it took almost two decades for radial tyres to establish themselves on the market, and - because radials last twice as long as cross-ply tyres - the change led to a drastic reduction in the rate at which rubber was consumed by the individual motor vehicle. In the Federal Republic of Germany the introduction of steel-reinforced elastomer bearings substantially increased the demand for rubber, but this change has likewise taken almost two decades. With machinery-development it's the same story. The introduction of the cold-fed extruder has taken a comparably long time.

In the 1960s and 1970s the tyre industry provided itself with new mixing rooms of the conventional type, equipped mainly with large-sized internal mixers, mill-room extruders, and automatic raw material feeding devices. During the same period the many smaller firms that made technical rubber goods repeatedly put off equivalent investment in their own mixing rooms, restricting themselves to only the bare minimum. Thus, in the near future and medium term, in particular, the mixing rooms of these firms will be more than usually in need of modernization, expansion, or replanning.

In view of what I have just said it is likely that the most up-to-date internal mixing technique will be preferred in most cases, this technology having proved itself over many years. Nevertheless, continuous mixing plant will be chosen increasingly for special mixes and types of mixes, or for special finished articles, particularly in as far as internal mixing is less economical and less satisfactory as regards quality. Higher growth rates and government investment incentives will greatly benefit the overall development.

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