WHITEPAPER

HOW AGRICULTURAL ENGINEERING CAN MASTER THE CURRENT CHALLENGES

Rubber and plastics in modern agricultural technology

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According to the German government's agricultural policy report, the central task of modern agriculture is to produce safe, affordable and healthy food in order to contribute to feeding the world's population. Against the background of a rapidly growing world population of now 7.86 billion people in 2021, this is no easy task. In order to guarantee the supply, modern agriculture must overcome the problems that arise, such as a shortage of arable land or an increase in extreme weather conditions, and also satisfy the constantly rising quality demands of industry, trade and consumers in order to generate consistently high or increasing yields. In addition to economic success, ecological aspects and the political framework conditions must be taken into account in order to be able to produce sustainably. The problems faced by farmers are confronted with growing demands on agricultural technology producers.

Farmers expect producers to ensure that the technology they use has a long service life and requires little maintenance. At the same time, repairs should be easy and quick to carry out and should be possible directly in the field during the harvest period. Lightweight construction should increase the efficiency of the machines and at the same time reduce the stress on the soil. The digitalization of processes and the associated automation in operations is also an important issue in growing farms that producers must address in order to remain successful.

On the following pages, we would like to show you how rubber and plastics can contribute to solving these problems. Among other things, you will learn:

1. What demands are being placed on today's agriculture.
2. How to meet the increasing demands of trade and consumers and what role components made of rubber and plastics play in the following points:
   - weight reduction
   - individualization in production
   - reduction of development time
   - increasing quality requirements
3. Which advantages result from a changed material selection, which also considers regional application conditions.

1 PROBLEMS OF TODAY'S AGRICULTURE

Shortage of available farmland

Agriculture competes with several players in terms of available usable land. Residential and road construction, as well as industrial and commercial construction, require buildable land. New construction projects and local bypasses, as well as the construction of industrial facilities, reduce the amount of available land and provide landowners with a profitable alternative to leasing it to farms. In addition, environmental protection projects, environmental regulations and forestry contribute to a reduction in available land.

The resulting increase in the cost of leasing and buying land is forcing farmers to become more efficient in order to remain economically successful. This is putting increased pressure on agricultural technology producers to develop particularly efficient machines. Ever larger vehicles are expected to provide the necessary area performance in order to obtain the maximum yield from the farmed area. At the same time, the machines are expected to be durable and highly flexible under a wide range of operating conditions.

Increasing demands on the quality of produced goods

The quality awareness of consumers and the requirements of the trade are constantly increasing. Foodstuffs with visual defects can no longer be marketed directly and consequently fetch lower prices. The technology used must ensure that the products produced are handled as gently as possible in order to guarantee the quality of the crop.

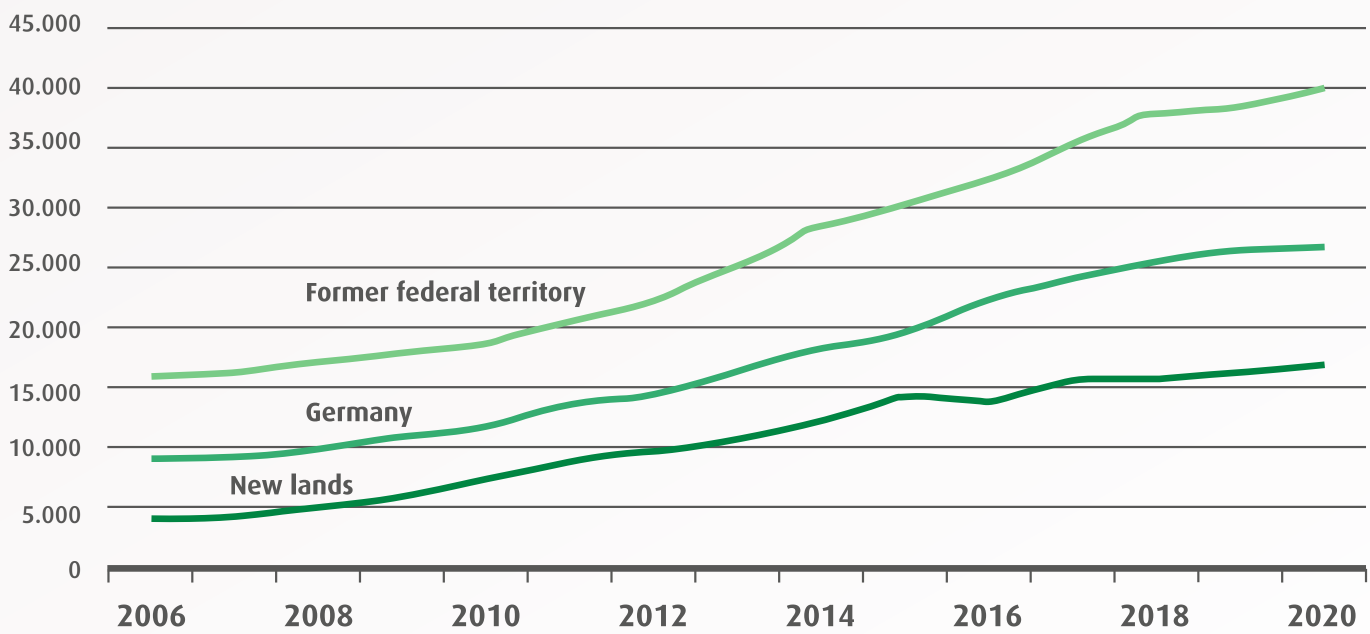

Figure 1: Development of price and area of cultivated land managed by German agriculture in the period from 2004 to 2016.

Source reference:
Statistisches Bundesamt, reference series 3, series 2.4, 2016.
Statistisches Bundesamt, reference series 3, series 3.1.2., 2005-2016

Careful use of available resources

The rising prices for raw materials and the shortage of fossil fuels expected in the long term call into question the techniques used to date and demand optimization of efficiency in production and over the entire service life of agricultural technology. Here, it is the task of the agricultural technology industry to increase the proportion of recyclable materials as well as to continuously optimize the weight of vehicles to reduce fuel consumption. At the same time, the selection of raw materials from renewable sources can contribute to resource efficiency and thus improve the sustainability of agriculture as a whole.

Increase in extreme weather conditions as climate change progresses

Rising temperatures on average and an increase in extreme weather conditions are leading to significantly more difficult conditions for farmers. Failure to produce yields is a constant threat that poses difficult challenges, especially for small farms. The agricultural machinery industry has a responsibility to reduce emissions of climate-damaging gases and thus play its part in mitigating climate change.

Motivation for agricultural technology producers

Increasing demands for resource efficiency, durability, flexibility and crop quality are creating high development pressure in the agricultural technology industry. However, they also offer the opportunity to successfully compete globally in the long term through new, innovative products. Efficiently operating commercial vehicles and machines with longer durability and reliability make an important contribution to securing the profitability of agricultural businesses. At the same time, the provision of individualized machinery adapted to the specific application ensures a continuous increase in yields per area of land. This paves the way for meeting the nutritional needs of a steadily growing world population.

Current demands on agricultural technology

- Digitalization/automation
- Increased service life with low maintenance and repair costs
- Individual design of flexibly usable aggregates
- Reduction of emissions
- Satisfaction of increasing quality requirements

2 NEW SOLUTIONS FOR THE AGRICULTURAL INDUSTRY

In order for companies in the agricultural industry to be able to provide future-proof technology, they must take into account a number of essential points. In the following, the technical challenges facing modern agricultural technology are outlined, along with suitable approaches to solving them.

Weight reduction to increase resource efficiency

What is the challenge?

In order to provide for a steady increase in area output (efficiency per area farmed), the dimensions of modern agricultural machinery are increasing. The design of wider harvesting headers and increased capacity in storage bunkers allows a machine to harvest a larger area in a shorter time. On the other hand, this positive effect leads to increased weight and requires heavy and powerful tractors. Due to the high weight, the harvesters cause a higher consumption of resources and burden the worked soil by a higher compaction.

It is necessary to differentiate between the equipment that must have a necessary high weight and those for which it is rather disadvantageous. If a high pressure on the soil is necessary for harvesting success or if stability must be ensured by a heavy construction of the machine, a reduction of the weight is not useful. However, it is usually advantageous to reduce the weight. A reduced weight requires less power from the tractor, which in turn is reflected in fuel consumption. This protects the environment and saves the farmer money.

What solutions are there?

One way to maintain functionality while reducing weight is to use plastics and elastomers instead of metallic materials. If we look at the average density of common metals, apart from lightweight materials such as aluminum or magnesium, most metallic materials have a value of over 7 g/cm^3. In the case of plastics and elastomers, we generally have a density of well below 2 g/cm^3, in many cases even below 1 g/cm^3.

Not only in terms of weight, but also in terms of other properties, polymers prove to be equivalent or even superior to metallic materials such as steel. Thermoplastics in particular are not susceptible to corrosion or aging. They are impact resistant and can be shaped in almost any way during production. There is no need for energy-intensive forming processes such as those used in metal foundries. This reduces system costs. Elastomers, on the other hand, are interesting for many applications in agricultural engineering due to their good elasticity and ductility.

Figure 2: Support roller made of glass fiber reinforced plastic with a rubber tread.

The properties of plastics and elastomers must be taken into account in design development. A simple substitution of the metallic materials by a plastic is not reasonable, because the manufacturing processes and also the stability of the components often require a new design according to the requirements and the production. The use of simulation techniques such as the finite element method (FEM) is a proven way for the rubber and plastics industry to reduce the effort involved in prototype production and subsequent tool design.

Replacing metallic materials

A successful example of substituting a heavy metal part with a rubber-plastic compound is the idler roller for conveyor and screen belts. The component, which was formerly made entirely of metal, was replaced by a fiberglass-reinforced plastic that offers high stability. The running surface is made of a rubber compound that is adapted as required. This rubber coating ensures smooth running and gives the element the required elasticity. Only the ball bearing is still made of a metallic material. With up to 160 idlers on a modern harvester and a weight saving of just over half a kilogram per idler, the contribution to weight reduction is clearly measurable.

Another example of the successful use of an elastomer are the drive belts of screen rod conveyor belts. Compared to metal drive chains, the belts do not show any elongation; they are extremely smooth-running and exhibit a long service life. As a result, the driver is less stressed due to the low noise level and there is no need for tiresome chain retensioning.

This is also evident in the feed channels of combine harvesters, through which the crop is conveyed from the cutting attachment to the threshing units. In conventional design, steel bars bolted to a steel roller chain convey the crop at high speed into the interior of the combine. This has the disadvantage that the chain links cause a high noise level when passing through the metal conveyor shaft. Due to the need for regular retensioning and the high wear of the chain and sprockets, maintenance is high.

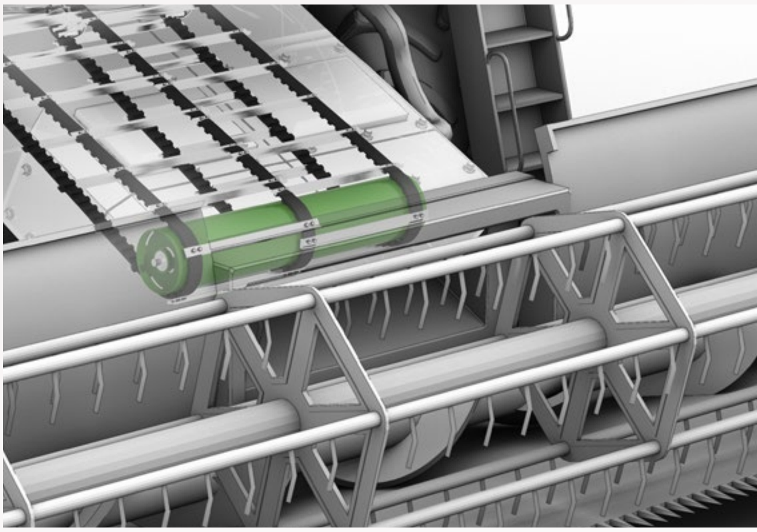

Figure 3: Silentium Drive with parabolic rubber-fabric cam belts

Replacing the conveyor chain with a parabolic rubber-fabric cam belt, which is routed over virtually wear-free idlers, allows smooth running to be increased and maintenance to be reduced. Fastening screws for the steel bars vulcanized directly into the belt round off this solution. The use of the belts relieves the operator by creating a more pleasant working atmosphere and at the same time protects the environment. In addition, the system costs for the operations are reduced.

Individualization in the production of flexible agricultural machinery

What is the challenge?

The diversity in modern cultivation includes the classic cereal varieties, numerous vegetable and fruit variants, fodder crops for livestock and an increasing proportion of energy-rich crops for fuel or raw material production. This requires an increasing diversity of varieties in the farmer's machinery. In addition, machinery must be adapted to local soil conditions and specific climatic conditions. The challenge is to offer a suitable range in the portfolio for every application without accepting an explosion in development and production costs. To do this, agricultural technology companies need to make their manufacturing processes more efficient.

What solutions are there?

One way to ensure this is the modular design variant familiar from the automotive sector. Several machine types can be built modularly on a uniform design. This saves development time and reduces costs.

For the suppliers of components, this modular production method offers the possibility of producing their add-on parts in assemblies and thus supporting the modular construction method. Several individual components, which together form a unit, are installed in the machines as required. This saves additional time in production and enables the supplier to add more value by selling several components at the same time.

In addition to the possibility of using subassemblies, the machines can be converted more easily and quickly for different uses. This increases flexibility and makes it easier for farmers or contractors to justify the high investment. An important criterion of such a unit is the uncomplicated conversion, which can best be done directly on site, during operation.

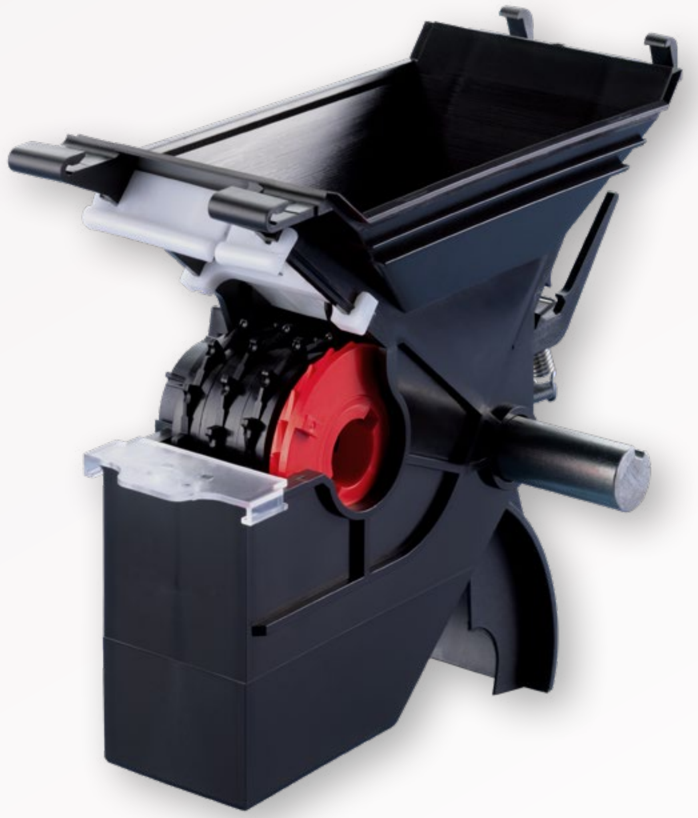

Figure 4:
Seeding housing made of polyoxymethylene (POM) as an example of an assembly of several individual components.

Flexible replacement of components

An example of the flexible exchange of components are the rotors of a metering unit for seed placement. In the unit, the seeds are metered via rotors and passed on from the supply in a controlled manner. The individual rotors are optimized for different seeds. They all have the same internal structure, via which the connection to the drive shaft is made. On the outside, they are specifically adapted in shape and size to the respective seed. This means that several types of seed for cereals and grasses can be spread in the field with a single seed unit. At the same time, the manufacturer can adapt the materials of the rotors to the respective chemical and climatic requirements. Particularly in the case of simultaneous metering of fertilizers, attention to resistance is of enormous importance.

In addition to the diversity of the range and the flexibility of the components, it is just as important for the parts suppliers to support the individualization strategy of the manufacturers. Customized production, which is adapted to the wishes of farmers and contractors, also requires the supply of add-on parts in small batch sizes. In particular, the requirements of contractors, who have to maintain a large fleet of vehicles and therefore represent an increasing purchasing power vis-à-vis the manufacturers, are better met with this strategy. The manufacturers' demands on the suppliers go as far as batch sizes with a quantity of 1, which is to be requested and delivered at short notice if required. This requires flexible production with well-structured logistics.

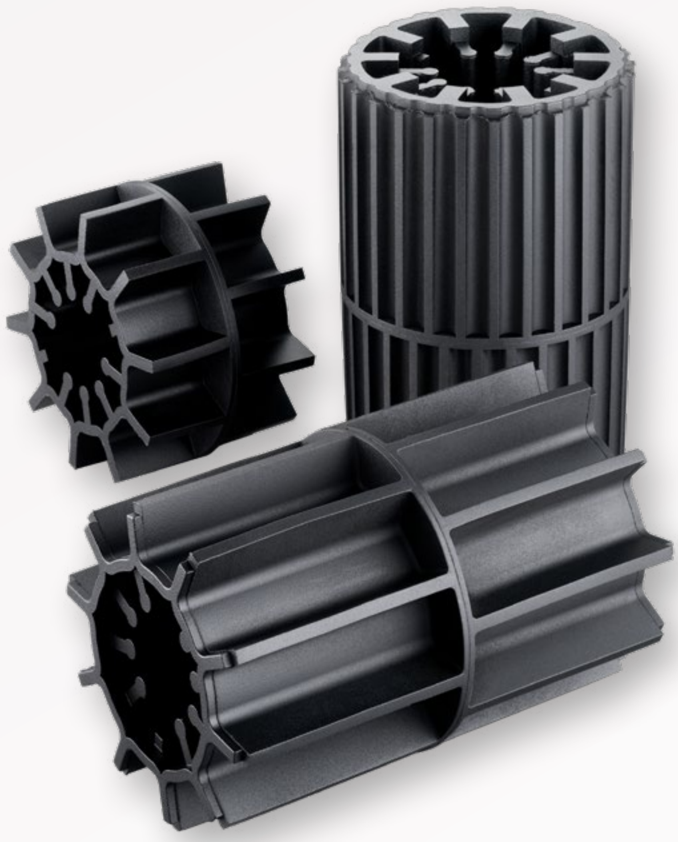

Figure 5: Interchangeable rubber inserts for the automatic metering unit for seed placement.

Time to market - reduction of development time

What is the challenge?

The development of new machine types requires conscientious testing of all components. Nothing is worse for the farmer than if a faulty component causes the entire machine to fail during the short harvesting period, so that the harvest cannot be brought in on time. In the same way, contractors who take over the harvesting process for several farmers on a contract basis are dependent on the reliability of their machines in operation.

In order to be able to guarantee this expected reliability and stability of the products, the manufacturers rely on lengthy tests under real harvesting conditions. In some cases, the machines are tested on in-house test fields over a full harvesting period and examined for weak points in the design and choice of materials. In total, this can add up to several years over the entire development period of a machine type.

What solutions are there?

Reducing development time is an important issue in agricultural engineering. One tried-and-tested means of achieving this is computer-aided calculation of components using simulation techniques such as the finite element method. Complex prototypes can thus be manufactured using the knowledge gained. This reduces the number of iteration loops in development until the release of a series article.

In order to reduce the overall effort up to the field test via the simulation, it is advantageous if the components are analyzed from the material side with regard to their physical and chemical properties. Here, the supplier can participate through its own laboratory tests and deliver components that can ideally be inserted into the overall system without further testing. The construction of special test rigs is another means of carrying out preliminary checks on materials and assemblies, but also of monitoring series production in the long term.

In this way, the supplier can support the manufacturer, make a decisive contribution to the quality of the agricultural technology, and at the same time reduce development time.

Thanks to its extensive experience with materials and rapid selection of rubber or plastic compounds, the supplier can contribute existing material expertise and respond quickly to manufacturers' requests. Ready-made standard compounds for known applications simplify the selection process. At the same time, the agricultural technology manufacturer is able to strengthen its competencies and expand them externally to include rubber and plastics.

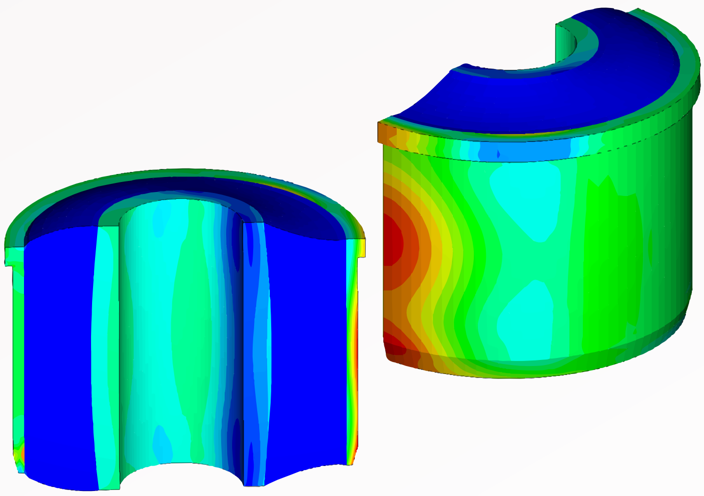

Figure 6:
Example of a simulation for component design using the finite element method.

Increasing quality requirements for the crop

What is the challenge?

Consumers' demands for perfect produce are constantly increasing. Apples with bruises are abandoned in stores, as are potatoes that are too small or too large. For many consumers, these visual requirements are on a par with the demands for hygienic standards in processing and the quality of the goods themselves. Today, products with visual defects are also no longer accepted by retail chains. Even in the case of feed for livestock, this is now an important criterion. Accordingly, the pressure on producers to get their goods from the field to the warehouse as undamaged as possible is increasing.

What solutions are there?

In order to maintain the quality of the harvested goods and to avoid pressure marks, damage to the husk and the like, the use of sieve bar belts with rubberized flights is effective. The elastic properties of the rubber material enable the crops to be transported more gently than it is the case when metallic materials (for example, steel) are used. As a result, the harvested crop shows fewer pressure marks. Particularly in the case of sensitive fruits such as tomatoes, this is a decisive factor in improving both appearance and shelf life.

Another example of the use of elastomers for gentle processing of the crop is the roller conditioner for processing green forage. Immediately after the mowing process, the green forage is conveyed in it through rollers interlocked in a spiral or V-shape. In the process, the stems of the forage plants are crushed, but the nutrient-rich leaves are spared. Processing takes place over the entire working width of the mower, which ensures a high and uniform throughput. A large roller diameter guarantees low energy consumption. The result is effective drying of the green waste at a high operating speed.

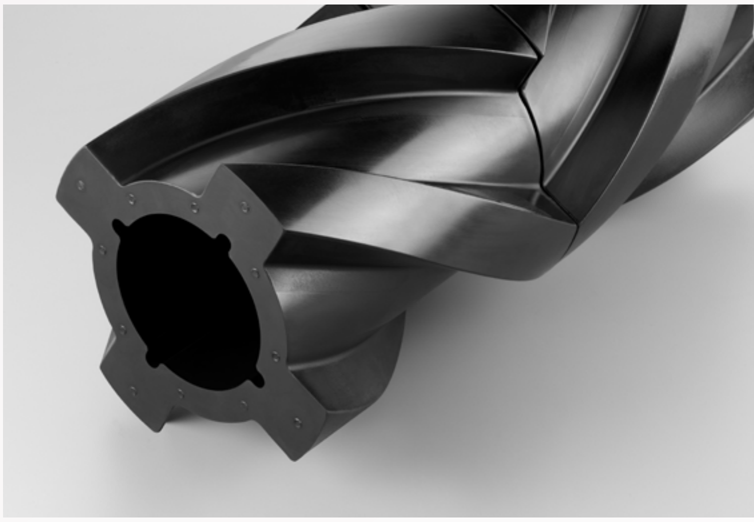

Figure 7: Rubber roller conditioner for conditioning green forage with a high leaf content.

Rubber roller conditioners are particularly suitable for processing leafy legumes such as alfalfa. Metal rollers or rollers made of hard plastics would crush the leaves and the nutrients they contain could be spoiled in the silage process or during storage. Roller conditioners made of polyurethane, on the other hand, show poorer long-term resistance to the acids escaping from the crop here compared to rubber.

3 MATERIAL COMPETENCE

The German agricultural engineering industry generates three-quarters of its annual revenues by exporting goods to other European and global countries. This means that, in addition to their function, the machines and parts produced must also be resistant to regional climatic conditions. In addition, the chemical influences from the crop or seed and factors such as soil conditions must be taken into account.

With a broad knowledge of the materials used and a targeted selection of rubber or plastic compounds, the supplier can contribute existing material expertise and respond quickly to manufacturers' requests. Particularly in the area of rubber goods, this requires close interlinking of compound development, compound production and subsequent analysis of the physical properties in the laboratory. Ready-made standard compounds for known applications, as well as knowledge of the qualitative requirements placed on the materials, facilitate the selection process. This gives the agricultural machinery manufacturer the opportunity to benefit from the supplier's know-how in the field of rubber and plastics.

What is important in the selection of materials?

The selection of materials is one of the first steps in the development of a new component. The first step is to define the general requirements. General specifications such as hardness, color or the question of which media the material must be resistant to play just as important a role as the expected application. Knowing the requirements of different applications can speed up the process enormously. Standard mixtures for the various applications, which only need to be adapted to the special requirements, are just as much a part of the material development tasks as the redesign of formulations.

In addition to general knowledge of the resistance of materials to certain media, it is advantageous to know or be able to determine the specific requirements for resistance. A swelling test helps in this respect after the materials have been selected. For this purpose, the materials are placed in the appropriate medium and observed over a longer period of time. By storing the sample vessel in a convection oven, temperature stability in the swelling medium can be mapped.

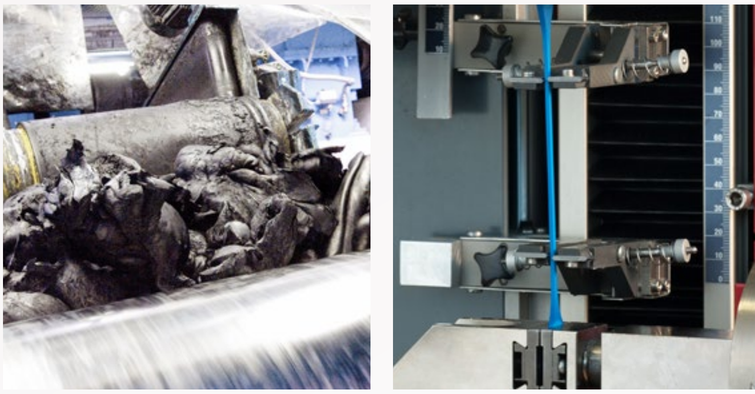

Figure 8: Preparation and testing of the compounds in the mixing room and laboratory.

The results of a swelling experiment at room temperature are shown below. For this purpose, test specimens of various vulcanized rubber compounds were shown in an aqueous solution of a calcium ammonium nitrate fertilizer, or KAS. At several intervals, the test specimens were removed from the medium, the volume or mass determined, and then placed back into the swelling medium. In the example shown, the observation was carried out over a period of three weeks.

The compounds used are based on natural rubber (NR), butadiene rubber (BR), ethylene-propylene-diene rubber (EPDM) and hydrogenated acrylonitrile-butadiene rubber (HNBR). The series of tests shows that all the selected compounds exhibit only minimal absorption of the swelling medium.

At the same time, the hardness before and after the swelling experiment is at a uniform level within the error tolerance. Thus, the suitability of the material-active ingredient combination can be demonstrated via the swelling measurement. Unsuitable materials show a strong change in the swelling media. This can manifest itself in strong swelling, which in the extreme value leads to dissolution of the material. Other combinations result in embrittlement or crumbling as plasticizers transfer from the rubber to the swelling medium. In both cases, the materials lose their required property and are no longer suitable as seals or dampers, for example.

Typical materials for agricultural engineering

Two of the materials frequently used in agricultural engineering are natural rubber (NR) and polyurethane (PUR). Both materials are characterized by high strength and good elasticity. They exhibit high ductility and have good (NR) or very good (PUR) abrasion behavior. →

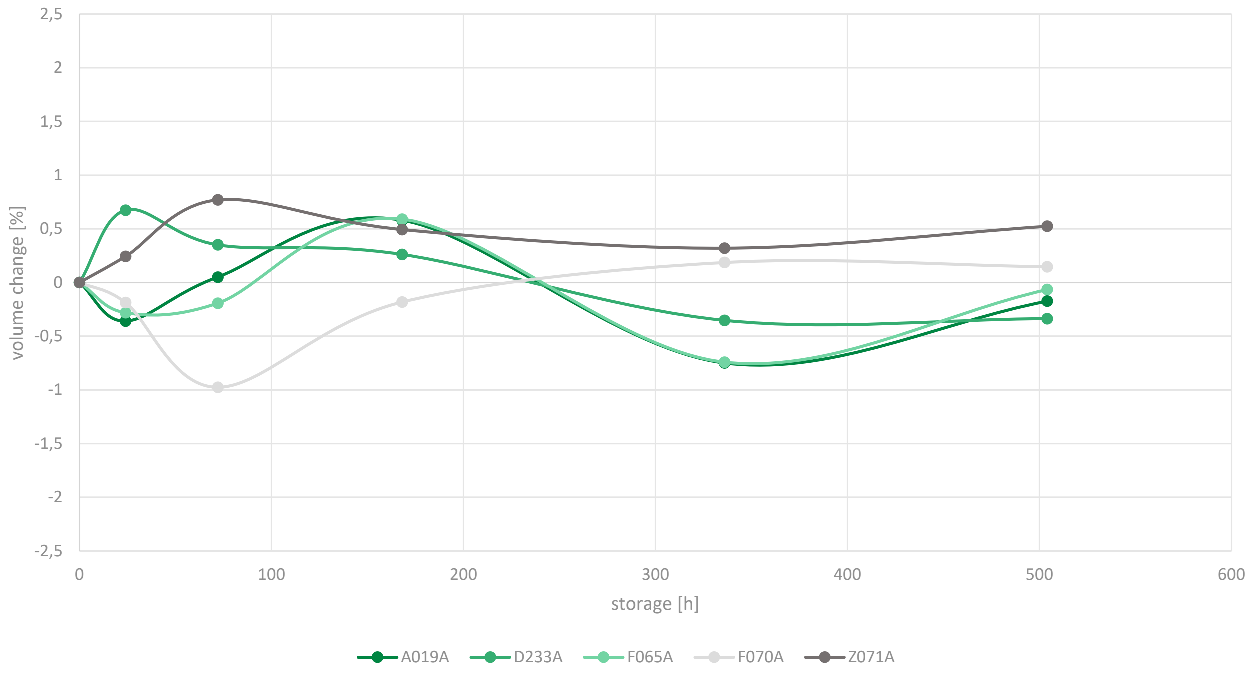

Figure 8: Volume change of the specimens during the source experiment

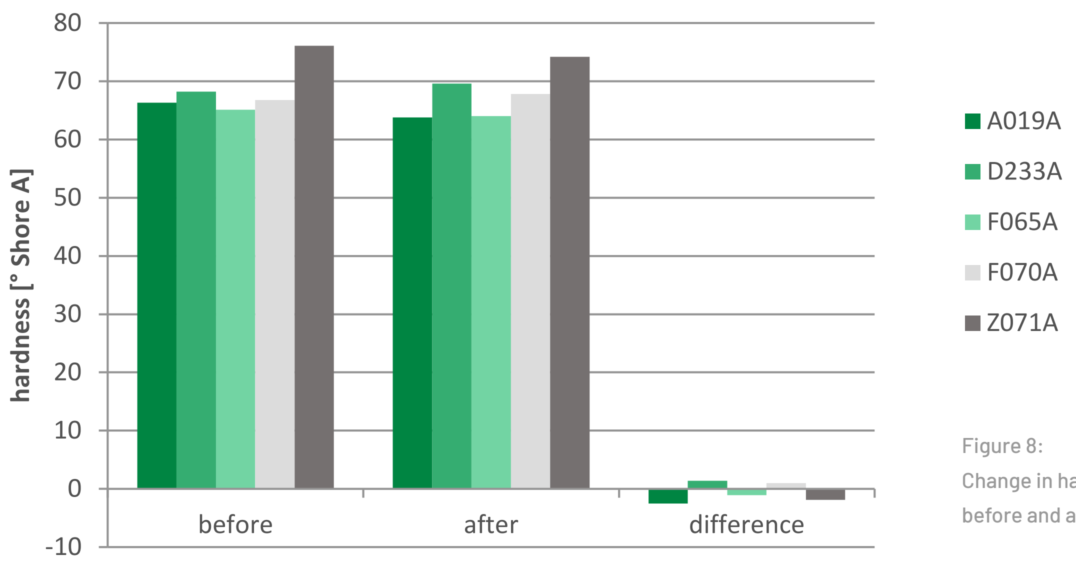

Figure 8:
Change in hardness
before and after the experiment.

However, too good abrasion behavior is a disadvantage in some applications. Using the example of an idler on which a belt runs, a PUR coating ensures that the rubber of the running belts wears out more quickly than a rubber coating. In contrast, the combination of comparable rubber compounds made of natural rubber exhibits high durability. Abrasion on the roller and belt is low.

Another advantage of natural rubber is its flexibility at very low temperatures. Even at -50 °C, natural rubber can still be used. Polyurethanes, on the other hand, show embrittlement here and are no longer usable. One advantage of polyurethanes is their good resistance to aging and ozone, which natural rubber does not have.

If we look at resistance to various media, polyurethanes have an advantage when it comes to use in combination with oils and greases. Here, components made of natural rubber show high swelling and can fail in the worst case. In contact with water, especially at elevated temperatures, the behavior is exactly the opposite. Here it is the polyurethanes that exhibit only low resistance to water.

By varying the composition within the polyurethane, this behavior can be counteracted somewhat. For this purpose, the soft component of the polyurethanes must be selected on an ether basis instead of an ester basis, which leads to a slight deterioration in the mechanical properties. The main properties of natural rubber and polyurethanes are compared in Figure 10.

Another advantage compared to steels is the relatively low price of plastics. Manufactured on a large scale, they thus offer a good alternative and prove to be equal or even superior in most applications.

Property/Polymer	Natural rubber	Polyurethane
Hardness range (Shore A)	30 to 100	10 to 100
Application temperature (°C)	-55 to +100	-20 to +80
Rebound	very high	moderate
Tensile strength	high	very high
Elasticity	high	high
Abrasion resistance	good	very good
Compression set resistance	very good	moderate
Oil resistance	bad	good
Water resistance	very good	bad to moderate
Aging behavior	bad	very good
Ozone resistance	bad	very good
Flame resistance	bad	moderate
Price	low	moderate

CONCLUSION

The use of rubber and plastics enables manufacturers of agricultural equipment to master the increasing demands on quality and reliability. In the process, resource efficiency is increased and sustainable tillage is made possible. Particularly in lightweight construction, current plastics are an important contribution to reducing weight, and when combined with rubber, a sensible design results in a symbiosis of rigidity and elasticity in one component.

The fears of many farmers that plastics mean a loss of quality compared to steel can be dispelled by modern polymers. Many disadvantages of metallic materials, such as susceptibility to corrosion, are eliminated. In cooperation with suppliers, manufacturers have the opportunity to expand their own knowledge and advance the design of new agricultural machinery more quickly and effectively. Simulations and calculations save time. Analyses in the laboratory and on test rigs reduce the need for time-consuming field trials.

The proportion of polymer materials in agricultural technology is steadily increasing. The machines used to be made mostly of steel; the trend is now toward a combination of many different materials. Only if these are combined sensibly and the advantages of all materials are played off against each other can agricultural technology producers be successful in the long term and produce cost-effectively and conserve resources. This is how manufacturers meet the political, economic and ecological challenges of our time.

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