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Description**Field of the Invention**

- 5 The invention relates to a method for comminuting heat-sensitive feedstock, particularly for the fine grinding of thermoplastics, rubber, caoutchouc, and elastomers to a particle size less than 500 μm , preferably less than 425 μm , as claimed in the preamble of claim 1.

Background Art

- 10 During the comminution of feedstock, a substantial part of the energy to be applied for the comminution is converted to heat. This is caused by cutting, frictional, and impact forces to which the feedstock is subjected during the comminution. In the comminution of heat-sensitive feedstock, to prevent thermal damage it is therefore necessary to cool the feedstock and/or to reduce the heat input by decreasing the production output.
- 15 In comminuting devices through which air flows, the feedstock is cooled by the airflow necessary for transporting of the feedstock within the device. This so-called self-generated air can be produced by the device itself and optionally can be supported by a suction fan. If the feedstock is not heat-sensitive, the self-generated air flow inherent in conventional devices is sufficient to cool down the comminuting tools so greatly that any adverse effects on the
- 20 feedstock are eliminated.
- Problems occur on a regular basis when heat-sensitive feedstock is to be comminuted. Especially when materials with a low softening point such as, for example, thermoplastics, are to be comminuted, the operators of conventional devices face a difficult task. In order to achieve the highest possible machine output, grinding of the feedstock is to occur at the
- 25 maximum possible temperature. If in so doing the material-dependent temperature limit is exceeded, the feedstock softens and begins to melt with the result that individual particles agglomerate and thereby the particle size and particle distribution of the comminuted material are no longer within the desired range. Or a thermal decomposition of the feedstock occurs, whereby the particles heated above the temperature limit bake onto the machine parts and
- 30 particularly onto the comminuting tools, so that both the machine output and the quality of the end product suffer as a result.

Reducing the machine output of comminuting devices is a known approach to prevent thermal damage to the feedstock during the comminution thereof. In this way, less comminuting work is done per unit time, thus producing less excess heat. It must be accepted in this regard, however, that the comminuting device is not operated at full capacity, which is contrary to the fundamental requirement of an economic operation of such devices.

This problem is compounded in fine grinding, because it was found that the finer the end product is to be, the more comminuting work has to be done and the greater the heat input into the feedstock.

Increasing the cooling effect by increasing the amount of the self-generated air of a conventional comminuting device, in order to be able to remove the additional heat, is possible only within narrow limits, because the amount of the self-generated air determines the flow velocity and thereby the residence time of the grinding stock in the grinding zone and thereby also the fineness of the end product.

During the fine grinding of certain materials such as, for example, rubber, caoutchouc, and elastomers, there is, moreover, the problem that grinding of the feedstock is not readily possible because of its elastic properties. For this reason, in these cases the transition has already been made to cool the feedstock to temperatures far below the freezing point by adding a coolant. The associated embrittlement of the feedstock then allows comminution of the embrittled particles by means of breaking (cryogenic comminution). Because the cooling of the feedstock to the necessary low temperatures requires considerable amounts of coolant, this type of comminution is very cost-intensive. Moreover, cryogenic comminution produces an end product whose particles are characterized by a cubic shape with a relatively smooth surface. These material properties are disadvantageous, however, for some uses of the end product, particularly if forming a connection with other materials as intimate as possible is a required ability.

DE 197 15 772 C1 discloses a method and a device for preparing plastic waste products. The waste products are first subjected to a precomminution in a shredder and the raw grinding stock obtained thereby is stored temporarily in a storage tank. The raw grinding stock is then fed into an impact mill for further comminution. The different substances present in the grinding stock are separated at subsequent stations and supplied as a secondary raw material for recycling. It has also been recognized here that frictional heat is formed due to the grinding process in the impact mill; such heat is in fact desirable for drying the grinding stock but the grinding air nevertheless should not be too hot. In order to keep the temperature of the grinding air in a range between 70°C and 92°C, it is proposed to supply water to the grinding

air in the feed to the impact mill.

Further, DE 37 08 914 A1 discloses an impact mill for comminuting grinding stock with a rotor, equipped with impact tools and disposed within a housing. The grinding stock is supplied to the rotor via a supply opening and after it is comminuted, it is fed into a separating
5 device. The metered addition of grinding stock to the impact mill occurs depending on the power consumption of the drive for the rotor by scaling back the feed when the drive's current consumption is too high.

Summary of the Invention

10 It is therefore an object of the invention to provide an option for comminuting heat-sensitive feedstock to a diameter of at most 500 μm , preferably at most 425 μm , without having to cool the feedstock below the freezing point.

This object is solved by a method with the features of claim 1.

Advantageous embodiments emerge from the dependent claims.

15 The starting point for the present invention is methods on the basis of cryogenic comminution of feedstock, because hitherto experts have held the unanimous view that comminution of particles to a diameter less than 500 μm , preferably less than 425 μm , is not possible in some other way. It is the merit of the invention to have departed from this idea and to have developed a method that allows fine grinding of heat-sensitive materials at temperatures far
20 above 0°C. A cryogenic comminution and thereby the cost-intensive use of special coolants such as, for example, liquid nitrogen, are unnecessary as a result, which entails a substantial economic advantage.

A further advantage over a cryogenic comminution is based on the different mode of action of the inventive type of comminution. Whereas in the cryogenic comminution by embrittlement
25 of the feedstock, breaking of the material particles is achieved under the effect of impact energy, the material particles in the method of the invention are comminuted substantially by tearing. The result is an irregular form of the comminuted material particles with a rough surface, which during further use of these particles enormously improves the bonding properties thereof with other materials.

30 According to an embodiment of the invention, continuous cooling of the feedstock occurs in each case via the constant product gas stream PG₁, or PG₂, which is quantitatively dependent on the self-generated air of the comminuting device or fine grinding device and is usually obtained from the ambient air. On the one hand, however, its cooling capacity is not sufficient to cool heat-sensitive feedstock sufficiently; on the other, its cooling capacity varies

depending on air humidity and air temperature. For this reason, the solution of the invention in each case provides for a dynamic supplementation of the cooling performance by the selective addition of a coolant to the comminution or fine grinding process with the simultaneous monitoring of the temperature before and/or during and/or after the precomminution or fine grinding. For example, water can be used as the cooling medium, which is supplied to the material stream as a mist, spray mist, or stream.

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If these two measures for temperature regulation still would not be sufficient, thus it is provided according to the invention to slow down the machine output of the precomminution and/or fine grinding. For this purpose, the maximum energy consumption of the comminuting device or fine grinding device is reduced, which is used as a reference variable in a control circuit for determining the amount of the feedstock to be metered. The amount of the supplied feedstock is reduced in this way and heat development is thus counteracted.

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Suction is provided according to an exemplary embodiment to remove the feedstock from the precomminution and/or fine grinding. The suction is produced substantially by suction lines which are supplied with a low pressure and connect to the material outlet of the particular machine and in which the feedstock is transported away. In this process, water can be supplied additionally to the material stream, with the advantage that an unwanted rise in temperature is prevented. It can be achieved at the same time that the particles are coated with a water film, which counteracts the tendency of material particles to agglomerate. It turned out that this entails enormous advantages in transport, storage, screening, and bagging of the feedstock or the end product.

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Description of the Embodiments

The invention is illustrated below with reference to an embodiment, wherein additional features and advantages of the method are disclosed. The embodiment relates to the processing of rubber recyclate into fine rubber powder, which is fed back into the production cycle.

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The course of the method of the invention emerges from the flowchart shown in the Figure. The starting material for the method of the invention in the present exemplary embodiment is rubber waste, for example, peeled rubber as it accumulates during used tire processing, with pieces about 10 mm to 20 mm in size. This feedstock is supplied to precomminution via a metering station, where the feedstock is precomminuted to a particle size of at most 4 mm, preferably at most 2 mm. The precomminution preferably occurs in a knife mill or cutting mill whose electrically driven rotor is equipped with blades. The rotor is surrounded by a

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screen basket, which keeps the feedstock within the active zone of the blades until comminution to below the hole diameter of the screen has occurred. After sufficient comminution of the feedstock, the material particles in process gas stream PG_1 are removed from the precomminution. During the comminution, only part of the driving power is used for material comminution; the remaining part is converted to heat energy, which is the cause of the rise in the feedstock temperature.

According to the invention, in this case thermal damage of the feedstock is prevented by the combined cooling measures. A portion of the excess heat energy is removed by the constant-volume process gas stream PG_1 , whose primary task is to provide for the transport of the feedstock to and from the comminution zone. The temperature T_1 of the feedstock at the exit from the precomminution is monitored via a temperature sensor disposed downstream of the precomminution.

If the cooling effect of the self-generated air at the given load of the comminuting device is not sufficient, which can be determined by a rise in the temperature T_1 , water, which removes heat from the feedstock by evaporation, is then added as a coolant to the material stream before and/or during the precomminution. The amount of coolant is regulated via a first control circuit R_1 , so that the temperature T_1 remains below a predefined setpoint, for example, below 70°C , preferably below 65°C , most preferably below 55°C . The material stream in the outlet from the precomminution in this case has an inherent moisture content of about 3% to 5%.

If these measures are not sufficient to maintain the temperature T_1 , then the metering of the comminuting device is regulated in a control circuit R_3 as a function of the electrical current consumption. Reducing the setpoint for the maximum current consumption A_1 of the comminuting device results in a limitation of the feedstock amount supplied to the precomminution and thereby also in a limitation of the heat development.

The precomminuted feedstock is removed via suction from the precomminution and is supplied to a silo for temporary storage. In terms of plant layout, the suction is connected to the material outlet of the comminuting device. Water is again supplied in the suction area to reduce the feedstock temperature further to a value T_3 . The amount of supplied water is determined in a control circuit R_5 , in which the present material temperature in the suction area is compared with the temperature T_3 and if there is a deviation a control signal is output. The temperature of the precomminuted feedstock before its intermediate storage is at most 45°C , preferably at most 40°C , and is preferably between 20°C and 35°C . The inherent moisture content is 10% to 15%.

As a safety measure to prevent a smoldering fire, it is possible to add water again during the intermediate storage of the precomminuted feedstock in the silo or to flood the silo. To this end, the temperature of the precomminuted feedstock is monitored in a control circuit R₇ and water is supplied if a limit value T₅ is exceeded. The limit value T₅ is, for example, at most 75°C, preferably at most 60°C.

The precomminuted feedstock is supplied from the silo to fine grinding by means of a second metering station. The feedstock in this case has a temperature of about 20°C to 30°C at an inherent moisture content of 5% to 10%.

The subsequent fine grinding can occur, for example, in a turbo mill whose rotating impact plates produce a highly turbulent vortex field in which the material particles are exposed to high acceleration and impact forces bringing about the comminution. Here as well, the self-generated air of the mill, which flows through the comminution chamber as a constant-volume process gas stream PG₂, contributes a first portion for cooling the feedstock.

If the material temperature exceeds a limit value T₂, which is monitored downstream of the grinding zone at the exit from the fine grinding, then water is supplied as a coolant to the feedstock before the fine grinding, for example, in the feed to the mill, and/or during the fine grinding, for example, in the grinding zone of the mill, and/or after the fine grinding, for example, in the outlet from the mill, in a control circuit R₂ until the temperature T₂ is reached. The temperature T₂ is, for example, at most 70°C, preferably at most 65°C, most preferably at most 55°C.

If this measure is not sufficient, thus slowing down the metering can further affect the temperature development. To this end, the maximum current consumption A₂ of the mill is limited and monitored in a control circuit R₄, as has already been described during the precomminution.

After the fine grinding, a predominant portion of about 90% to 99% of the end product has a particle size of at most 500 μm, preferably at most 425 μm, at a temperature below T₂ and an inherent moisture content preferably in the range of 0.5% to 2%.

The removal of the sufficiently refined material from the fine grinding occurs again actively via suction, which in terms of plant layout is connected to the material outlet of the fine grinding device. Water is again supplied in the suction area to reduce the material temperature to a value T₄. The amount of supplied water is determined in a control circuit R₆, in which the present material temperature in the suction area is compared with the temperature T₄ and if there is a deviation a control signal is output. The temperature T₄, which in the present exemplary embodiment is at most 45°C, preferably at most 40°C, for example, between 20°C

and 35°C, is therefore used as a reference variable for control circuit R₆. Optionally, an inherent moisture content of at most 1% is achieved by secondary drying of the material in the suction air stream.

In the subsequent process step, the material leaving the mill is screened, whereby particles
5 larger than 500 µm, preferably larger than 425 µm, are returned to the fine grinding and the sufficiently refined end product is packaged.

Patentkrav

1. Fremgangsmåde til formaling af varmfølsomme emner, især af termoplast, gummi, kautsjuk og elastomerer, til en partikelstørrelse på mindre end 500 μm **kendetegnet ved**

5 følgende trin:

a) Indledende formaling af emnerne til en størrelse, der er mindre end 4 mm i en roterende formalingsindretning, som gennemstrømmes af en første procesgas PG_1 , hvor temperaturen T_1 på de indledende formalede emner i udløbet fra den indledende formaling reguleres i et første reguleringskredsløb R_1 , idet emnerne før og/eller under

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og/eller efter den indledende formaling tilsættes vand, og
b) Finformaling af de indledende formalede emner til en størrelse, der er mindre end 500 μm i en roterende finformalingsindretning, som gennemstrømmes af en anden procesgas PG_2 ,

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hvor temperaturen T_2 på de indledende formalede emner i udløbet fra finformalingsindretningen reguleres i et andet reguleringskredsløb R_2 , idet de indledende formalede emner før og/eller under og/eller efter finformalingsindretningen tilsættes vand, og

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** doseringen af emnerne til

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formalingsindretningen reguleres afhængigt af formalingsindretningens energioptagelse A_1 i et tredje reguleringskredsløb R_3 .

3. Fremgangsmåde ifølge krav 1 eller 2, **kendetegnet ved, at** doseringen af de indledende formalede emner til finformalingsindretningen reguleres afhængigt af

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finformalingsindretningens energioptagelse A_2 i et fjerde reguleringskredsløb R_4 .

4. Fremgangsmåde ifølge et af kravene 1 til 3, **kendetegnet ved, at** de formalede emner suges ud af formalingsindretningen, hvor temperaturen T_3 i udsugningsområdet reguleres i et femte reguleringskredsløb R_5 gennem tilsætning af vand i udsugningsområdet og/eller i

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formalingsindretningens emneudløb.

5. Fremgangsmåde ifølge et af kravene 1 til 4, **kendetegnet ved, at** de formalede emner suges ud af finformalingsindretningen, hvor temperaturen T_4 i udsugningsområdet reguleres i et

sjette reguleringskredsløb R_6 gennem tilsætning af vand i udsugningsområdet og/eller i finformalingsindretningens emneudløb.

5 **6.** Fremgangsmåde ifølge et af kravene 1 til 5, **kendetegnet ved, at** de formalede emner mellemlagres før finformalingsindretningen, hvor temperaturen T_5 overvåges i mellemlageret i et syvende reguleringskredsløb R_7 .

10 **7.** Fremgangsmåde ifølge et af kravene 1 til 6, **kendetegnet ved, at** temperaturen T_1 og/eller temperaturen T_2 er maksimalt 70°C , foretrukket maksimalt 65°C , mest foretrukket maksimalt 55°C .

15 **8.** Fremgangsmåde ifølge et af kravene 4 til 7, **kendetegnet ved, at** temperaturen T_3 og/eller temperaturen T_4 er maksimalt 45°C , foretrukket maksimalt 40°C , mest foretrukket maksimalt 35°C .

9. Fremgangsmåde ifølge et af kravene 6 til 8, **kendetegnet ved, at** temperaturen T_5 er maksimalt 75°C , foretrukket maksimalt 60°C .

20 **10.** Fremgangsmåde ifølge et af kravene 1 til 9, **kendetegnet ved, at** den første procesgasstrøm PG_1 og/eller den anden procesgasstrøm PG_2 er volumenkonstante.

