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(54) Title: FEEDSTOCK AND METHOD FOR MANUFACTURING THE FEEDSTOCK

(57) Abstract: Feedstock for injection molding, extrusion or additive manufacturing of cemented carbide parts, the feedstock comprising a metal powder, carbides and a binder system, the binder system having polyethylene glycol (PEG) as main constituent, wherein the binder system further comprises a backbone polymer being a polyacrylate, a surface active agent, and a crystallization inhibitor.

Feedstock and method for manufacturing the feedstock

TECHNICAL FIELD

Feedstock for injection molding, extrusion or additive manufacturing of cemented carbide parts, the feedstock comprising a metal powder and a binder system. Method for manufacturing a feedstock.

BACKGROUND

Cemented carbides are composites comprising small grains in the micrometre range of at least one hard phase in a binder phase. The hard phase in cemented carbide is generally tungsten carbide (WC). In addition, other metal carbides, such as metal carbides with the general composition (Ti,Nb,Ta,W,Cr)C may also be included, as well as metal carbonitrides, for example, Ti(C,N). The binder phase usually comprises cobalt (Co) as a main constituent. Other compositions for the binder phase may also be used, for example, combinations of Co, Ni, and Fe, or Ni and Fe. One type of cemented carbide is cermet. Cermets are composites of a mixture comprising hard particles of Ti(C,N) and (Ti,Nb,W)(C,N) and a metallic binder of cobalt.

Industrial production of cemented carbide often includes mixing of given proportion of powders of raw materials and additives in the wet state using a milling liquid. The liquid is often an alcohol, for example, ethanol, or water, or a mixture thereof. The mixture is then milled into a homogeneous slurry. The wet milling operation is made with the purpose of deagglomerating and mixing the raw materials intimately. Individual raw material grains are also disintegrated to some extent. The obtained slurry is then dried and granulated, for example, by means of a spray dryer, and the granulate obtained may be used in uniaxial pressing of green bodies, in extrusion, in injection molding or additive manufacturing.

The handling of the fine metal powders used for the production of cemented carbide are problematic in two ways. Since fine grained powders have large specific surface areas, they are sensitive to reaction with the oxygen in the air. The metal powder oxidation is an exothermal reaction. Also, the oxidation rate increases with the temperature. This means that the oxidation of fine metal powders is an auto accelerating process. Due to this, self-igniting and dust explosions of the metal powders is a serious risk. Further, it has been reported that

the inhalation of most of these metal powders is a serious health risk. These problems are usually solved with a granulation of these powders with an organic binder. The organic binder adheres to the surface of the powders and binds many particles together to a free-flowing granulated powder. Since the organic binder adheres to the metal surfaces, it slows down the oxidation rate of the metal surfaces and decreases the risk of self-ignition and dust explosions. Since the organic binder binds many particles together, it reduces the risk of air borne dust to be inhaled.

In the production of cemented carbide and when the slurry processing is performed in a water-ethanol mixture, metal powders granulated with an organic binder of polyethylene glycol (PEG) are usually used.

Cemented carbide bodies used for cutting members are conventionally manufactured by pressing the granulated powder into a green body followed by sintering at a temperature where the metal binder is in liquid state. The desired form of the sintered body has to be obtained as far as possible before sintering because machining of a sintered body is expensive. Some machining of the body in the as-pressed and/or pre-sintered condition may therefore be done. Thereafter the body is finally sintered. During sintering the body normally shrinks about 17 % linearly. After the final sintering, the body is machined to the final shape, if necessary.

For the manufacturing of parts with complex geometry, injection molding, extrusion or additive manufacturing is preferably used. Injection molding is often referred to as Powder Injection Molding (PIM) when used in powder technology. PIM requires a mold having the specific shape of the part to be manufactured. In injection moulding of cemented carbide based parts, the following four consecutive steps are applied:

1. Mixing of granulated cemented carbide powder with an organic binder system. The binder system acts as a carrier for the powder and constituents 25-60 volume % of the resulting material, which is often referred to as the feedstock. The exact composition of the binder system is dependent on the desired process properties during molding of a part, and on the need to easily remove part of the binder system from the part before sintering, as well as on giving the part sufficient strength before sintering. The mixing is made by adding all the constituents into a mixer heated to a temperature above the

melting temperature of the organic binders. The resulting feedstock is obtained as pellets of approximate size 4x4 mm.

2. Performing injection molding of a part using the mixed feedstock. The material is heated to 100-240°C, forced into a cavity with the desired shape, cooled and then removed from the cavity.
3. Removing some parts of the binder from the obtained part. The removal can be obtained by extraction in a suitable solvent and/or by heating in a furnace with a suitable atmosphere. This step is often referred to as the debinding step.
4. Sintering of the parts. Common sintering procedures for cemented carbides are applied. During sintering of a powder injection molded part the remaining organic binder constituents are removed. The parts normally shrink about 20% linearly during the sintering operation.

The solids loading, ϕ, of the feedstock is the volumetric amount of hard constituents, compared to the organic constituents. ϕ can be calculated using the following equation:

$$\phi = \frac{\rho_f - \rho_v}{\rho_s - \rho_v}$$

where ρ_s is the density of the cemented carbide as sintered, ρ_v is the mean density of the organic constituents and ρ_f is the density of the feedstock, measured with a helium pycnometer.

The viscosity of the feedstock is affected by the viscosity of the organic binder. The viscosity of the organic binder is related to the green strength of the injection molded part. A low green strength can cause the parts to crack during debinding, where the expansion of some organic constituents during melting causes stresses in the part. Another drawback with a low green strength is that the parts may be damaged during the handling of the parts before sintering. A high green strength of the injection molded part usually means that he viscosity of the organic binder is high.

In the case of having a feedstock with high viscosity, problems with mold filling, extended mold wear, weld lines, which may open during sintering, forming cracks and surface defects, as well as mold release problems, may occur.

SUMMARY

It is an object of the disclosure to provide a homogenous feedstock having suitable rheological properties for powder injection molding, extrusion, or additive manufacturing and where one of the components in the feedstock is metal powders granulated with polyethylene glycol. The above object is achieved by a device as defined in claim 1 and by the method of claim 14.

The disclosure provides a feedstock for injection molding, extrusion or additive manufacturing of cemented carbide parts, the feedstock comprising a metal powder, carbides and a binder system, the binder system having polyethylene glycol (PEG) as main constituent, and wherein the binder system further comprises

- a backbone polymer being a polyacrylate (PA),
- 1-20 vol% of a surface active agent, and
- 5-15 vol% of a crystallization inhibitor.

By this combination of components, a feedstock having suitable rheological properties and a high degree of chemical and physical stability for powder injection molding, extrusion or additive manufacturing is achieved. Polyethylene glycol gives the feedstock a suitable viscosity and it is easily extracted during solvent or low-temperature thermal debinding of the produced cemented carbide parts. Polyethylene glycol also provides a decrease in the dusting of cobalt in cemented carbide. Polyacrylate as a backbone polymer in combination with polyethylene glycol provides the feedstock with a viscosity that is suitable for powder injection molding, extrusion or additive manufacturing of cemented carbide parts. Additionally, polyacrylate as a backbone polymer in combination with polyethylene glycol gives the produced parts good green strength.

According to some aspects the binder system comprises an antioxidant. The addition of the antioxidant prevents polyethylene glycol from oxidation and degradation at elevated temperature.

According to some aspects the content of the antioxidant is 1-10 vol%, preferably 1-5 vol%, of the total content of the binder system.

According to some aspects the antioxidant is tert-butylhydroquinone (TBHQ). The addition of tert-butylhydroquinone prevents polyethylene glycol from oxidation and degradation at elevated temperature.

According to some aspects the content of polyacrylate is 2-30 vol%, preferably 2-20 vol%, most preferably 2-15 vol% of the total content of the binder system.

According to some aspects the feedstock has a viscosity below 1000Pa*s at 5000 s^{-1}.

According to some aspects the polyacrylate is polymethyl methacrylate (PMMA). Polymethyl methacrylate as backbone polymer contributes to holding the green body together after injection molding and during removal of the organic compound in the feedstock.

According to some aspects the content of said crystallization inhibitor is 8-12 vol% of the total content of the binder system.

According to some aspects the crystallization inhibitor is at least one of the following: polyvinylpyrrolidone (PVP) and hydroxypropyl methylcellulose (HPMC). The addition of at least one of polyvinylpyrrolidone and hydroxypropyl methylcellulose inhibits the crystallisation of polyethylene glycol.

According to some aspects the content of said surface active agent is 1-15 vol%, preferably 2-10 vol%, of the total content of the binder system.

According to some aspects to one embodiment said surface active agent is at least one of the following: stearic acid and oleic acid. This improves the wettability of the metal powder and additives and reduces the viscosity of the feedstock.

According to some aspects the content of the polyethylene glycol is 53-85 vol%, preferably 55-80 vol%, most preferably 60-75 vol% of the total content of the binder system.

According to some aspects the solid loading, ϕ, of the metal powder and carbides is 48-60 vol%, preferably 50-58 vol% of the total content of the feedstock.

According to some aspects the binder system comprises a wax. According to one embodiment the wax is a paraffin wax.

According to some aspects the content of the wax is 1-10 vol%, preferably 1-5 vol%, of the total content of the binder system.

The disclosure provides a method for manufacturing a feedstock for injection molding, extrusion or additive manufacturing of cemented carbide parts,
the method comprises the following steps:
- wet milling of metal powder and carbides in a slurry comprising polyethylene glycol and at least one of the following: water and alcohol,
- drying of the slurry formed during the wet milling process step,
- mixing the dried powder with a binder system comprising a backbone polymer in the form of polyacrylate, a surface active agent, and a crystallization inhibitor to form the feedstock.

According to some aspects additional polyethylene glycol is added during the mixing step.

According to some aspects an antioxidant is added during the mixing step.

The disclosure provides use of a feedstock according to any of the above embodiments for powder injection molding, extrusion or additive manufacturing of cemented carbide parts. The cemented carbide parts may be cutting members such as any of the following: cutting inserts, solid end mills and drills.

DETAILED DESCRIPTION

Aspects of the present disclosure will be described hereinafter. However, the device and method disclosed herein may be realized in many different forms and should not be construed as being limited to the aspects disclosed herein.

The viscosity measurements in this disclosure were carried out using a Malvern Panalytical Rosand RH10 capillary rheometer at 160°C, using two dies, one with diameter 1.0 mm and length 16.0 mm, and one with diameter 1.0 mm and length 0.25 mm, and two pressure transducers, one 30 000 psi or 10 000 psi transducer, hereinafter named a first transducer, and one 1 500 psi transducer, hereinafter named a second transducer. After loading the rheometer

with the feedstock, the sample was first compacted at 10 mm/min until 1.0MPa pressure was achieved in the first transducer and 0.3MPa in the second transducer. Thereafter the sample was left uncompacted for five minutes, then compacted at 5.0 mm/min until 0.5MPa was achieved in the first transducer and 0.1MPa in the second transducer, then left uncompacted for another five minutes before measurement was started. Bagley and Rabinowitsch corrections were done on the viscosity measurements by Flowmaster software.

According to one exemplary embodiment there is provided a feedstock for injection molding, extrusion or additive manufacturing, the feedstock comprising a metal powder, carbides and a binder system, the binder system having polyethylene glycol (PEG) as main constituent, wherein the binder system further comprises a backbone polymer being a polyacrylate, a surface active agent and a crystallization inhibitor.

According to one exemplary embodiment the binder system of the above described feedstock additionally comprises an antioxidant and/or a paraffin wax.

The feedstock may comprise cemented carbide powder of any cemented carbide composition and all WC grain sizes commonly used in cemented carbide. The binder phase for the cemented carbide may be Co alone, or combinations of Co, Ni, and Fe, or Ni and Fe. The cemented carbide may also contain other metal carbides, such as metal carbides with the general composition (Ti,Nb,Ta,W,Cr)C, as well as metal carbonitrides, for example, Ti(C,N).

According to an exemplary embodiment the feedstock is obtained according to the following:
1) Wet milling of tungsten carbide, cobalt, optional metallic carbides, and polyethylene glycol in water or alcohol or a combination thereof.

2) Drying of the slurry formed during the above-mentioned wet milling process step such that agglomerated powder is achieved

3) Mixing the dried powder by kneading with a binder system, consisting of a backbone polymer being a polyacrylate, a surface active agent, and a crystallization inhibitor, optionally an antioxidant and/or a wax. The mixing is performed in, for example, a batch mixer or twin screw extruder, heated to 130-220 ^{O}C.

4) Injection moulding of the feedstock in a conventional injection moulding machine. The material is heated to 100-240 ^{O}C, preferably 130-180 ^{O}C, and then forced into a cavity with the desired shape. The obtained part is cooled and then removed from the cavity.

5) Debinding the obtained part. Debinding may be done in one or several steps, such as solvent extraction or thermal debinding.

6) Presintering of the part in vacuum at 900-1250 ^{O}C, preferably at about 1200 ^{O}C.

7) Sintering of the parts to full density using conventional sintering technique.

According to an exemplary embodiment the powder composition is a WC-10 wt-% Co cemented carbide powder made by wet milling PEG-granulated Co-powder, Cr3C2-powder, WC and polyteylene glycole (PEG) in milling liquid consisting of ethanol and water. The made powder slurry was dried to obtain a powder. According to the example the powder has a composition being 87.26 wt% wolfram carbide, 10.00 wt% cobalt, 0.46 wt% chromium carbide (Cr_3C_2), 0.04 wt% carbon black and 2.24 wt% polyethylene glycole.

Example 1

The cemented carbide powder described above was mixed by kneading 2870 g of the powder with 10.61 g polymethyl methacrylate (PMMA) and 1.62 g Paraffin wax (PW, Sasol Wax) and 10.16 g hydroxypropyl methylcellulose (HPMC) and 8.77 g polyvinylpyrrolidone (PVP) and 1.89 g tert-butylhydroquinone (TBHQ) and 1.69 g stearic acid (SA) and 1.61g oleic acid (OA) and 91.66 g polyethylene glycol (PEG) in a sigma blade kneader mixer (Werner & Pfleiderer LUK 1,0). The 91.66 g PEG is added in addition to the PEG already contained in the powder. PEG, and PMMA were melted at 160 ºC in the sigma blade mixer to form an opaque liquid t. When all polymers had melted, the cemented carbide powder was added and mixed for 30 minutes at 160 ºC and 60 rpm in a nitrogen atmosphere. Finally, the rest of the organic components were added to the mixer and mixed for one hour at 160 ºC and 60 rpm in a nitrogen atmosphere. This resulted in a feedstock, sample 1, with a density of 8.01 g/ml, corresponding to a solid loading, ϕ, of 0.524, and a measured viscosity of 153.2 Pa*s at 5000 s^{-1} as measured with a Malvern Panalytical, Rosand RH10.

Example 2

The cemented carbide powder described above was mixed by kneading 2870 g of the powder with 10.61 g polymethyl methacrylate (PMMA) and 1.62 g Paraffin wax (PW, Sasol Wax) and 12.95 g hydroxypropyl methylcellulose (HPMC) and 11.18 g polyvinylpyrrolidone (PVP) and 9.45 g tert-butylhydroquinone (TBHQ) and 1.69 g stearic acid (SA) and 8.05 g oleic acid

(OA) and 71.56 g polyethylene glycol (PEG) in a sigma blade kneader mixer (Werner & Pfleiderer LUK 1,0). The 71.56 g PEG is added in addition to the PEG already contained in the powder. PEG, and PMMA were melted at 160 °C in the sigma blade mixer to form an opaque liquid t. When all polymers had melted, the cemented carbide powder was added and mixed for 30 minutes at 160 °C and 60 rpm in a nitrogen atmosphere. Finally, the rest of the organic components were added to the mixer and mixed for one hour at 160 °C and 60 rpm in a nitrogen atmosphere. This resulted in a feedstock, sample 2, with a density of 8.01 g/ml, corresponding to a solid loading, ϕ, of 0.524, and a measured viscosity of 24.7 Pa*s at 5000 s^{-1} as measured with a Malvern Panalytical, Rosand RH10.

Example 3

The cemented carbide powder described above was mixed by kneading 2915 g of the powder with 8.45 g polymethyl methacrylate (PMMA) and 6.44 g Paraffin wax (PW, Sasol Wax) and 8.08 g hydroxypropyl methylcellulose (HPMC) and 8.90 g polyvinylpyrrolidone (PVP) and 1.50 g tert-butylhydroquinone (TBHQ) and 1.35 g stearic acid (SA) and 6.41 g oleic acid (OA) and 43.11 g polyethylene glycol (PEG) in a sigma blade kneader mixer (Werner & Pfleiderer LUK 1,0). The 43.11 g PEG is added in addition to the PEG already contained in the powder. PEG, and PMMA were melted at 160 °C in the sigma blade mixer to form an opaque liquid t. When all polymers had melted, the cemented carbide powder was added and mixed for 30 minutes at 160 °C and 60 rpm in a nitrogen atmosphere. Finally, the rest of the organic components were added to the mixer and mixed for one hour at 160 °C and 60 rpm in a nitrogen atmosphere. This resulted in a feedstock, sample 3 with a density of 8.80 g/ml, corresponding to a solid loading, ϕ, of 0.582, and a measured viscosity of 134.6 Pa*s at 5000 s^{-1} as measured with a Malvern Panalytical, Rosand RH10.

Example 4

The cemented carbide powder described above was mixed by kneading 2870 g of the powder with 42.43 g polymethyl methacrylate (PMMA) and 1.62 g Paraffin wax (PW, Sasol Wax) and 10.15 g hydroxypropyl methylcellulose (HPMC) and 11.17 g polyvinylpyrrolidone (PVP) and 1.89 g tert-butylhydroquinone (TBHQ) and 8.46 g stearic acid (SA) and 8.05 g oleic acid (OA) and 44.24 g polyethylene glycol (PEG) in a sigma blade kneader mixer (Werner & Pfleiderer LUK 1,0). The 44.24 g PEG is added in addition to the PEG already contained in the powder. PEG, and PMMA were melted at 160 °C in the sigma blade mixer to form an opaque liquid t. When all polymers had melted, the cemented carbide powder was added and mixed for 30 minutes at 160 °C and 60 rpm in a nitrogen atmosphere. Finally, the rest of the organic components were added to the mixer and mixed for one hour at 160 °C and 60 rpm in a nitrogen atmosphere. This resulted in a feedstock, sample 4, with a density of 8.01 g/ml,

corresponding to a solid loading, ϕ, of 0.524, and a measured viscosity of 78.5 Pa*s at 5000 s^{-1} as measured with a Malvern Panalytical, Rosand RH10.

Example 5

The cemented carbide powder described above was mixed by kneading 2895 g of the powder with 23.70 g polymethyl methacrylate (PMMA) and 4.34 g Paraffin wax (PW, Sasol Wax) and 10.32 g hydroxypropyl methylcellulose (HPMC) and 8.91 g polyvinylpyrrolidone (PVP) and 5.06 g tert-butylhydroquinone (TBHQ) and 4.53 g stearic acid (SA) and 4.31 g oleic acid (OA) and 44.53 g polyethylene glycol (PEG) in a sigma blade kneader mixer (Werner & Pfleiderer LUK 1,0). The 44.53 g PEG is added in addition to the PEG already contained in the powder. PEG, and PMMA were melted at 160 °C in the sigma blade mixer to form an opaque liquid t. When all polymers had melted, the cemented carbide powder was added and mixed for 30 minutes at 160 °C and 60 rpm in a nitrogen atmosphere. Finally, the rest of the organic components were added to the mixer and mixed for one hour at 160 °C and 60 rpm in a nitrogen atmosphere. This resulted in a feedstock, sample 5, with a density of 8.40 g/ml, corresponding to a solid loading, ϕ, of 0.552, and a measured viscosity of 126.61 Pa*s at 5000 s^{-1} as measured with a Malvern Panalytical, Rosand RH10.

Additionally, three exemplary feedstocks, samples 6-8, were manufactured according to the method described in examples 1-5 above. The samples have the composition and resulting viscosity according to the table 1.

Comparative examples were conducted having another backbone polymer than PMMA but with all the other components in approximately the same amount as the respective sample 1-8 in Table 1. The comparative backbone polymer tested was polypropylene. It was found that the viscosity of the resulting feedstock was higher at the same shear rates when compared to the examples with PMMA and therewith the feedstocks with polypropylene are not as suitable for powder injection molding, extrusion or additive manufacturing.

Sample	Powder filling [vol%]	OA [vol% of binder]	SA [vol% of binder]	PW [vol% of binder]	PMMA [vol% of binder]	TBHQ [vol% of binder]	PEG [vol% of binder]	PVP [vol% of binder]	HPMC [vol% of binder]	Viscosity in RH10 at 5000s^{-1} [Pa*s]
1	52.4%	1.00%	1.00%	1.00%	5.00%	1.00%	82.88%	4.06%	4.06%	153.20
2	52.4%	5.00%	1.00%	1.00%	5.00%	5.00%	72.64%	5.18%	5.18%	24.71
3	58.2%	5.00%	1.00%	5.00%	5.00%	1.00%	73.76%	5.18%	4.06%	134.60
4	52.4%	5.00%	5.00%	1.00%	20.00%	1.00%	58.76%	5.18%	4.06%	78.48
5	55.2%	3.00%	3.00%	3.00%	12.50%	3.00%	66.26%	4.62%	4.62%	126.61
6	55.2%	3.00%	3.00%	3.00%	12.50%	3.00%	66.26%	4.62%	4.62%	71.68
7	55.2%	3.00%	3.00%	3.00%	12.50%	3.00%	66.26%	9.24%	0.00%	96.96
8	55.2%	3.00%	3.00%	3.00%	12.50%	3.00%	66.26%	0.00%	9.24%	63.86

Table 1

Table 1 shows the compositions for samples 1 to 8, and the measured viscosity for the respective sample. The viscosity for samples 1 to 8 seen in Table 1 have been measured using the above described methodology. All the viscosities in Table 1 are good and the feedstocks may be used for injection molding. Example 2 has the most suitable measured viscosity for injection molding. It is therewith showed that metal powder granulated with PEG may be used for powder injection molding by mixing it with a binder system according to the present disclosure. A feedstock according to the disclosure is expected to provide excellent mold filling, decreased mold wear and decreases mold release problems.

CLAIMS

1. Feedstock for injection molding, extrusion or additive manufacturing of cemented carbide parts, the feedstock comprising a metal powder, carbides and a binder system, the binder system having polyethylene glycol (PEG) as main constituent, **characterized** in that the binder system further comprises
   - a backbone polymer being a polyacrylate (PA),
   - 1-20 vol% of a surface active agent, and
   - 5-15 vol% of a crystallization inhibitor.

2. A feedstock according to claim 1, wherein the binder system comprises an antioxidant.

3. A feedstock according to claim 2, wherein the content of the antioxidant is 1-10 vol%, preferably 1-5 vol%, of the total content of the binder system.

4. A feedstock according to claim 2 or 3, wherein the antioxidant is tert-butylhydroquinone (TBHQ).

5. A feedstock according to any of the preceding claims, wherein the content of polyacrylate is 2-30 vol%, preferably 2-20 vol%, most preferably 2-15 vol% of the total content of the binder system.

6. A feedstock according to any of the preceding claims, wherein the polyacrylate is polymethyl methacrylate (PMMA).

7. A feedstock according to any of the preceding claims, wherein the content of the crystallization inhibitor is 8-12 vol% of the total content of the binder system.

8. A feedstock according to any of the preceding claims, wherein the crystallization inhibitor is at least one of the following: polyvinylpyrrolidone (PVP) and hydroxypropyl methylcellulose (HPMC).

9. A feedstock according to any of the preceding claims, wherein the content of said surface active agent is 1-15 vol%, preferably 2-10 vol% of the total content of the binder system.

10. A feedstock according to any of the preceding claims, wherein the surface active agent is at least one of the following: stearic acid (SA) and oleic acid (OA).

11. A feedstock according to any of the preceding claims, wherein the content of the polyethylene glycol is 53-85 vol%, preferably 55-80 vol%, most preferably 60-75 vol% of the total content of the binder system.

12. A feedstock according to any of the preceding claims, wherein the solid loading, ϕ, of the metal powder and carbides is 48-60 vol%, preferably 50-58 vol% of the total content of the feedstock.

13. A feedstock according to any of the preceding claims, wherein the binder system comprises a paraffin wax.

14. Method for manufacturing a feedstock for injection molding, extrusion or additive manufacturing of cemented carbide parts, comprising the following steps:
- wet milling of metal powder and carbides in a slurry comprising polyethylene glycol and at least one of the following: water and alcohol,
- drying of the slurry formed during the wet milling process step,
- mixing the dried powder with a binder system comprising a backbone polymer in the form of polyacrylate, 1-20 vol% of a surface active agent, and 5-15 vol% of a crystallization inhibitor to form the feedstock.

15. Method according to claim 14, wherein additional polyethylene glycol is added during the mixing step.

16. Method according to any of claims 14-15, wherein at least one of the following components is added during the mixing step: an antioxidant and a paraffin wax.

17. Use of a feedstock according to any of claims 1-13, or a feedstock manufactured according to any of claims 14-16, for powder injection molding, extrusion or additive manufacturing.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/057517

A. CLASSIFICATION OF SUBJECT MATTER
INV. B22F3/00 B22F3/20 B22F3/22 C22C29/08 B33Y70/00
ADD. B22F1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B22F C22C B33Y

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	N. CHUANKRERKKUL ET AL: "Flow and void formation in powder injection moulding feedstocks made with PEG/PMMA binders Part 1 - Experimental observations", POWDER METALLURGY., vol. 51, no. 1, 19 March 2008 (2008-03-19), pages 66-71, XP055606492, GB ISSN: 0032-5899, DOI: 10.1179/174329008X271600 abstract Experimental methods table 2 ----- -/--	1-17

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
13 May 2020	25/05/2020

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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