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Solid projectile, intermediate for producing a solid projectile and method for
producing a solid projectile

The present invention relates to a solid projectile for ammunition in particular with a caliber of less than 13 mm. Furthermore, the present invention relates to an intermediate for producing such a solid projectile. Furthermore, the present invention provides a method for producing such a solid projectile.

For environmental and health reasons, in particular on practice shooting ranges, the use of lead as material for solid projectiles is more and more unsuitable. In the choice of material for solid projectiles, there is therefore a conflict of interests in particular between good precision as well as flight range and environmental compatibility. Alternative materials to lead, such as tin, zinc, copper, have proved to be less suitable due to their low density, which would ensure better environmental compatibility, but would entail with significant losses in terms of precision and flight range. Furthermore, alternative solutions as steel or brass solid projectiles have decisive disadvantages in terms of barrel life and press-through resistance through the firearm barrel. This results in unfavorable interior ballistics. The pressure during powder burn-off is too high, while the resulting muzzle velocity is too low.

From US 4,109,581 a solid projectile made of soft iron is known. The solid projectile comprises an ogive-like projectile front, an adjoining slightly conical driving band, which makes up about 1/3 to 1/4 of the projectile length, and a conical projectile tail. The ballistics, in particular precision and flight range, of the projectile according to US 4,109,581 have proven to be disadvantageous. Furthermore, the elongated driving band has a disadvantageous effect on the interior ballistics of the projectile.

An object of the present invention is to overcome the disadvantages of the prior art, in particular to provide a solid projectile that is compatible with the environment and health and has improved ballistics, in particular precision.

The object is solved by the subject matter of claims 1, 8, 12, 14, 17, 18, 19, 21 and 22.

According to this, a solid projectile for ammunition in particular with a caliber of less than 13 mm is provided. The caliber is generally referred to as measure of the outer diameter of projectiles or bullets and the inner diameter of a firearm barrel. For example, solid projectiles according to the invention can also be used for ammunition with a caliber of less than 7 mm or at most 5,6 mm. In contrast to full jacket projectiles, which normally comprise a projectile jacket made of a deformable material, such as tombac, and a projectile core arranged therein, in particular pressed therein, which is manufactured separately from the projectile jacket, solid projectiles do not comprise a separate projectile jacket. In particular the solid projectile is made in one piece.

According to an aspect of the present invention, the solid projectile is made of iron, in particular soft iron, with a carbon content of more than 0,05 %. It has been found that by increasing the carbon content the hardness and tensile strength of the solid projectile increase, which has a positive effect on the projectile ballistics. By means of the solid projectile according to the invention an environmentally compatible solid projectile is created that has improved ballistics. Furthermore, it has been found, that the carbon content according to the invention has a corrosion protecting effect on the solid projectile. In addition, the increased carbon content also helps to limit diffusion between the firearm barrel and the solid projectile when the solid projectile is fired by a firearm.

According to an example embodiment, the carbon content is in the range of 0,06 % to 1,14 %, in particular in the range of 0,08 % to 0,12 %. Such carbon ranges have proved particularly advantageous in terms of ballistics. In particular it has been found, that with carbon contents that are too high, the brittleness of the solid projectile body is increased too much, which has a disadvantageous effect on the manufacturing and formability of the solid projectile.

In an example embodiment, the solid projectile according to the invention is made of a material that, in addition to iron, comprises at least one further transition metal, for example selected from the group comprising manganese and copper, in particular with a mass portion of 0,01 % to 1,2 % or of 0,3 % to 1 %.

In a further example embodiment of the present invention, the material of the solid projectile can comprise at least one further additive selected from the carbon group, the nitrogen group and/or the oxygen group. For example, the at least one additive can be a metalloid. For example, the at least one additive can have a weight percentage of at least 0,01 % to at most 0,48 %.

In a further example embodiment, the iron of the solid projectile has a manganese content of 0,01 % to 0,8 %, in particular of 0,03 % to 0,6 %.

According to an example further development, the iron has a silicon content of less than 0,5 %, in particular less than 0,4 % or less than 0,3 %.

In a further example embodiment, the iron has a phosphorus content in the range from 0,01 % to 0,04 %, in particular in the range from 0,02 % to 0,03 %.

Furthermore, it may be provided that the iron has a sulfur content in the range from 0,01 % to 0,04 %, in particular in the range from 0,02 % to 0,03 %.

In another example embodiment, the iron has a copper content of less than 0,4 %, in particular less than 0,3 % or less than 0,25 %.

For example, the solid projectile can be made of a Saerstahl C10C.

In an example further development, the solid projectile according to the invention does not contain lead.

According to a further aspect of the present invention, that can be combined with the previous aspects and example embodiments, a solid projectile for ammunition in particular with a caliber of less than 13 mm is provided. The solid projectile is made of iron. In particular the solid projectile is made in one piece and/or is lead free.

Furthermore, the solid projectile comprises a particularly ogive-like projectile nose, an at least sectionally cylindrical driving band adjoining thereto for guiding the solid projectile in a firearm barrel and a projectile tail adjoining to the driving band. When in the present description reference is made to nose, front, nose-sided or front-sided, or tail, tail-sided or rear-sided, this is to be understood with reference to a longitudinal axis

of the projectile pointing in flight direction of the projectile. For example, the driving band can be designed in such a way that it engages in a land-groove profile of a firearm barrel, which serves in particular to give the solid projectile a spin as it slides within the firearm barrel, to stabilize the trajectory of the projectile.

According to this aspect of the present invention, the projectile tail comprises a bottom, which is in particular facing a power transmission part, such as a firing pin, of the firearm, and a projectile base that opens into the bottom. The projectile base tapers at least sectionally concavely in the direction of the bottom. This means that the projectile base does not need to extend completely concavely, in particular does not need to taper concavely completely from the driving band to the projectile bottom. In an alternative embodiment, the projectile base tapers concavely completely from the driving band to the projectile bottom. In another example embodiment, on the rear -side of the driving band and a front-side of the concave section of the projectile base, adjoins a substantially cylindrical projectile base section, which has a smaller outer diameter compared to the guiding band. According to the present invention it has been found that due to the lower density of the iron material compared to standardly used lead materials, there is a mass loss, which can however be compensated in terms of ballistics and/or precision by the constructive design of the projectile tail according to the present invention. By providing a projectile base, additional mass is added to the solid projectile, wherein the concavity has a positive effect on the ballistics of the solid projectile, in particular stabilizes the solid projectile during flight, but without increasing the press-through resistance of the solid projectile within a firearm barrel.

According to an example further development of the solid projectile, a radius of curvature defining an outer contour of the projectile base is in the range of 0,1 times to 0,5 times a maximum projectile outer diameter. For example, the radius of curvature is about 0,2 times the maximum outer diameter of the projectile. The maximum outer diameter of the projectile is in the region of the driving band.

According to an example further development of the solid projectile, the at least sectionally concave projectile base extends in longitudinal direction of the solid projectile by 0,2 times to 0,6 times a maximum projectile outer diameter, in particular 0,4 times a maximum projectile outer diameter, which for example can be in the region of the driving

band. The said length of the projectile base has been identified as advantageous in terms of providing additional mass as well as creating an aerodynamic projectile structure, whose press-through resistance within the firearm barrel is positively influenced.

In another example embodiment of the solid projectile, the bottom comprises an outer diameter in the range of 0,6 times to 0,9 times a maximum projectile outer diameter. In particular, the outer diameter is about 0,8 times the maximum outer diameter of the projectile. For example, the concave section of the projectile base opens directly into the projectile bottom, which is arranged concentrically with respect to the longitudinal axis of the projectile. For example, the bottom has a rear-sided end face, which is oriented substantially perpendicular to the longitudinal axis of the projectile.

According to a further aspect of the present invention, that can be combined with the previous aspects and example embodiments, a solid projectile for ammunition in particular with a caliber of less than 13 mm is provided. The solid projectile is made of iron and/or is lead free.

Furthermore, the solid projectile comprises a particularly ogive-like projectile nose, an at least sectionally cylindrical driving band adjoining thereto for guiding the solid projectile in a firearm barrel and a projectile tail adjoining to the driving band. For example, the driving band can be designed in such a way that it engages in a land-groove profile of a firearm barrel, which serves in particular to give the solid projectile a spin as it slides within the firearm barrel, to stabilize the trajectory of the projectile.

According to this aspect of the present invention, a transition from the projectile tail into the driving band is formed by an outer contour projection, at which an outer diameter of the solid projectile increases continuously or abruptly. According to the invention it has been found that by providing the outer contour projection (viewed from the projectile tail) or an outer contour recess (viewed from the projectile nose), the phenomenon of the so-called breathing of the firearm barrel is guaranteed. Due to the outer contour projection, when pressure builds up during firing, a particularly radial widening of the firearm barrel can be realized when pressure builds up during the firing process, resulting in gentle sliding of the solid projectile within the firearm barrel. It was found that the gas produced as a result of a combustion process inside the firearm barrel is pressed, during a firing process, into an angular annular space region formed on the

outside by the firearm barrel inner surface and on the inside by the tail-side outer contour projection from the projectile tail into the driving band. As a result, the firearm barrel expands slightly elastically at least in radial direction, so that the press-through resistance within the firearm barrel can be reduced. This also reduces the abrasion between the outer surface of the solid projectile and the inner surface of the firearm barrel and thus reduces the wear. Transverse to the longitudinal axis of the projectile, i.e. in radial direction, it is preferred that the outer contour projection is less than 0,2 mm deep. The outer contour projection can, for example, run straight or be concavely curved. Furthermore, the outer contour projection can ensure that the solid projectile is movable in a transition fit in the land profile. One advantage of the transition fit is the reduction of the press-through resistance. By means of the transition fit, additionally the gas slip can be adjusted, which, depending on the type of the solid projectile, is an important influencing factor in terms of its precision. In addition, the transition fit can delay in time the process of the initial press-in operation in such a way that when the firearm is fired, the impact, so-called initial impact, on the solid projectile and the firearm barrel (short-term dynamics) can be reduced. The reduction of the initial impact positively influences the service life of the firearm barrel and the precision of the solid projectile.

According to an example further development of the solid projectile according to the present invention, the outer contour projection has an inclination angle with respect to a projectile longitudinal axis oriented in longitudinal direction of the solid projectile in the range from 10° to 90° , in particular in the range from 20° to 80° , 30° to 70° or in the range from 40° to 80° .

Furthermore, the solid projectile comprises a particularly ogive-like projectile nose and an at least sectionally cylindrical driving band adjoining thereto for guiding the solid projectile in a firearm barrel. For example, the driving band can be designed in such a way that it engages in a land-groove profile of a firearm barrel, which serves in particular to give the solid projectile a spin as it slides within the firearm barrel, to stabilize the trajectory of the projectile.

According to this further aspect of the present invention, a transition from the driving band into the projectile nose is formed by an outer contour recess, at which an outer diameter of the solid projectile decreases continuously or abruptly. According to the

invention it was found that providing the outer contour recess results in a gentle sliding of the solid projectile within the firearm barrel. Consequently, the abrasion between the outer surface of the solid projectile and the inner surface of the firearm barrel can be reduced. The outer contour recess can, for example, run straight or be concavely curved. Furthermore, the outer contour recess can ensure that the solid projectile is movable in a transition fit in the land profile. By means of the transition fit, additionally the gas slip can be adjusted, which, depending on the type of the solid projectile, is an important influencing factor in terms of its precision. In addition, the transition fit can delay in time the process of the initial press-in operation in such a way that when the firearm is fired, the impact, so-called initial impact, on the solid projectile and the firearm barrel (short-term dynamics) can be reduced. The reduction of the initial impact positively influences the service life of the firearm barrel and the precision of the solid projectile.

According to an example further development of the solid projectile according to the invention, the outer contour projection from the projectile tail into the driving band and/or the outer contour recess from the driving band into the projectile nose has a radial depth, dimensioned transversely to the projectile longitudinal axis, of less than 0,5 mm, in particular less than 0,4 mm, 0,3 mm or 0,2 mm. By means of the radial projection of the driving band relative to the projectile tail and/or the projectile nose, it can be ensured that essentially only the driving band engages in the groove profile of the firearm barrel or slides along it during a firing process. In this respect, the abrasion between the firearm barrel and the outer surface of the solid projectile can be reduced.

According to a further aspect of the present invention, that can be combined with the previous aspects and example embodiments, a solid projectile for ammunition in particular with a caliber of less than 13 mm is provided. The solid projectile is made of iron and/or is lead free.

The solid projectile comprises an at least sectionally cylindrical driving band for guiding the solid projectile in a firearm barrel, in particular for engaging in grooves of a land-groove profile of a firearm barrel. The land-groove profile serves in particular to give the solid projectile a spin as it slides within the firearm barrel, to stabilize the trajectory of the projectile.

According to the further aspect of the present invention, the at least sectionally cylindrical driving band has an axial length, dimensioned in longitudinal direction of the solid projectile, in the range of 10 times to 100 times a land-groove profile difference of a firearm barrel. The inventors of the present invention have found that a length of the cylindrical driving band that is too great, is less suitable to be used for iron solid projectiles. For example, it can be provided that an axial section of the driving band, which deviates from a cylindrical shape before the driving band forms the cylindrical driving band section, adjoins the particularly ogive-like projectile nose. For example, the cylindrical driving band section can be dimensioned in such a way that a contact circumferential ring line is formed between the driving band and the inner surface of the firearm barrel.

According to a further aspect of the present invention, that can be combined with the previous aspects and example embodiments, a solid projectile for ammunition in particular with a caliber of less than 13 mm is provided. The solid projectile is made of iron and/or is lead free.

The solid projectile comprises a particularly ogive-like projectile nose, having a substantially planar end face oriented in the direction of the projectile longitudinal axis. The planar end face can, for example, be produced by cutting to length. For example, the planar end face has a diameter that is at least 10%, in particular 15%, at least 20% or at least 25%, of a diameter of the projectile bottom. On the one hand, it has been found that the planar nose-sided end face has a positive effect on the external ballistics of the solid projectile, in particular that the solid projectile flies more stably, so that its precision can be increased. Another advantage is that during the manufacturing process, for example during the forming process, in particular the solid forming process, lower forces are required to produce the solid projectile.

According to a further aspect of the present invention, that can be combined with the previous aspects and example embodiments, a solid projectile for ammunition in particular with a caliber of less than 13 mm is provided. The solid projectile is made of iron and/or is lead free.

The solid projectile comprises an at least sectionally cylindrical driving band for guiding the solid projectile in a firearm barrel, in particular for engaging in grooves of a land-

groove profile of a firearm barrel. The land-groove profile serves in particular to give the solid projectile a spin as it slides within the firearm barrel, to stabilize the trajectory of the projectile.

According to the further aspect of the present invention, a Vickers hardness in the region of a driving band outer diameter is at most 150 HV. For example, the production of a solid projectile according to the invention is carried out in such a way that an iron blank of certain dimensioning and certain Vickers hardness is provided. The inventors of the present invention have found that even in the case of a starting material of an iron blank with a Vickers hardness of 140 HV, the manufacturing can be carried out in such a way that the Vickers hardness is only slightly increased in the region of the driving band outer diameter, in particular up to a value of 150 HV at most. It has been found that machining, in particular movement and/or displacement, of iron material causes a change in hardness of the solid projectile. However, the aim during the manufacturing process is to perform only as much forming work as necessary, but as little as possible, at least in the area of the driving band. It has been found that with the homogeneous hardness distribution, at least in the region of the driving band and a projectile center, which is close to the projectile center axis in axial direction, allows to achieve external ballistic advantages.

According to an example further development of the projectile according to the invention, a Vickers hardness in the region of a driving band outer diameter is less than 10 %, in particular less than 5 % or less than 3 %, larger than a Vickers hardness in the region of a projectile center at the same height with respect to a projectile longitudinal axis.

According to a further aspect of the present invention, that can be combined with the previous aspects and example embodiments, an intermediate for producing a solid projectile, particularly formed according to one of the previous embodiments or aspects, in particular lead free, is provided.

The intermediate consists of a pre-press body made of iron, in particular soft iron, in particular Saerstahl C10C, with a substantially cylindrical tail section and an adjoining concavely tapering front section. The front section can, for example, be produced by forming, in particular cold forming, such as pressing. For example, the tail section is

designed to be further processed into the projectile tail. Furthermore, the front section can be designed to be further processed into the particularly ogive-like projectile nose. The inventors have found that by means of the concave front section the deformation forces for further processing of the intermediate into a solid projectile can be reduced. Thereby on the one hand the manufacturing costs can be reduced and on the other hand the hardness changes that occur in the projectile as a result of forming, as described above, are reduced. The pre-press body also makes it possible to produce more complex solid projectile shapes in a simple manner.

According to a further aspect of the present invention, that can be combined with the previous aspects and example embodiments, a method for producing an intermediate, formed according to one of the previous aspects, for producing a particularly lead free solid projectile, in particular for producing a solid projectile formed according to one of the previous example embodiments or aspects of the present invention, is provided.

First, a cylindrical, in particular lead free, iron blank is provided. The iron blank has certain outer dimensions and hardness, in particular Vickers hardness.

The iron blank is then given a concavely tapering shape in a front section. For example, this can be done by forming, in particular cold forming, in particular pressing. During further processing into the solid projectile, the concave front section can be further processed into an ogive shape, in particular by forming, in particular by cold forming, in particular by pressing.

Adjacent to the front section, an at least sectionally cylindrical driving band is formed for guiding the solid projectile in a firearm barrel. The driving band can be produced by forming, in particular cold forming, in particular pressing.

If necessary, subsequently a projectile tail with a constant or at least sectionally continuously tapering outer diameter is formed at the rear side of the driving band, wherein, if necessary, an at least sectionally concavely tapering projectile base is formed in the region of the projectile tail. The projectile tail can be produced by forming, in particular cold forming, in particular pressing.

According to an example further development of the method according to the invention, the solid projectile is produced, in particular by forming, in such a way that the iron blank is shortened by less than 20 %, in particular less than 15 %, Alternatively or additionally it can be provided that a diameter of the iron blank increases at most 25 %, in particular at most 20 %. Furthermore, alternatively or additionally it can be provided that a Vickers hardness in the region of a driving band outer diameter increases less than 15 %, in particular less than 10 %. The production method according to the invention for producing an intermediate and/or for producing a solid projectile ensures that the necessary material deformations on the iron blank can be reduced, resulting in a significantly more homogeneous hardness distribution in the region of the intermediate and/or the solid projectile than was previously possible in the prior art.

Preferred embodiments are given in the subclaims.

In the following, further properties, features, and advantages of the invention will become clear by means of description of preferred embodiments of the invention with reference to the accompanying exemplary drawings, in which show:

Fig. 1 a side view of an example embodiment of a solid projectile according to the invention;

Fig. 2 a side view of an example embodiment of an intermediate according to the invention;

Fig. 3 a side view of the solid projectile in Fig. 1, wherein a hardness distribution is indicated;

Fig. 4 a side view of a further example embodiment of a solid projectile according to the invention;

Fig. 5 a sectional view along line V-V in Fig. 4, wherein a firearm barrel is added;

Fig. 6 a sectional view along line VI-VI in Fig. 4, wherein a firearm barrel is added;

Fig. 7 a side view of a blank for producing an intermediate according to the invention and/or for producing a solid projectile according to the invention;

Fig. 8 a side view of an example embodiment of an intermediate according to the invention; and

Fig. 9 a side view of a further example embodiment of a solid projectile according to the invention.

In the following description of example embodiments of the invention, solid projectiles according to the invention are generally given the reference numeral 1 and intermediates according to the invention are generally given the reference numeral 100. For the following description of example embodiments based on the figures, intermediate 100 and solid projectile 1 are made of iron material, in particular a C10C Saerstahl with a carbon content of more than 0.05%. The decisive advantage of the material used is its improved environmental compatibility compared to the projectile materials used so far, such as lead in particular.

Fig. 1 shows an example embodiment of the solid projectile 1 according to the invention in a side view. A flight direction F is schematically indicated by an arrow and points to the right in Fig. 1. With reference to the projectile flight direction F, the terms nose, nose-sided, front or front-sided and tail, tail-sided or rear-sided are to be understood. Basically, solid projectiles 1 according to the invention can be divided into three main sections: A projectile nose 3; a driving band 5 adjoining it; and a projectile tail 7 adjoining the driving band 5. The projectile nose has a substantially ogive-like shape and tapers in the flight direction F, forming an ogive 9, towards a planar end face 11 pointing in the flight direction F. Unlike standard known solid projectiles, in which the ogive 9 opens into a projectile tip, which is realized, for example, by forming, the planar end face 11 is formed by cutting the ogive 9 to length. It has been found that the ogive area flattened in this way and the resulting planar end face 11 have a positive effect on the external ballistics of the solid projectile 1 and that significantly lower forces are required in the production of the nose-sided projectile ogive, which can be realized, for example, by forming.

The ogive 9 opens at the tail into the driving band 5. In the direction of the driving band 5, a curvature of the ogive 9 decreases continuously, so that immediately before a transition 13 into the driving band 5, the projectile nose 3 at least approaches a cylindrical shape. The driving band 5 generally serves to guide the solid projectile 1

within a firearm barrel 15 (Figs. 5, 6) and/or to engage a land-groove profile A, B (Figs. 5, 6) of the firearm barrel 15. The driving band 5 determines a maximum outer diameter $D_{a,max}$ of the solid projectile 1 in the solid projectiles 1 according to the invention. This is realized, among other things, in that the transition 13 from the driving band 5 into the projectile nose 3 is formed by an outer contour recess at which an outer diameter D_a of the solid projectile 1 is reduced abruptly. The circumferential outer contour recess is indicated schematically in Fig. 1 by the visible edge marked by means of the reference sign 15. By means of the outer contour recess 15 it can be ensured that essentially only the driving band 5 engages in the groove profile of the firearm barrel 15. This is illustrated further below with reference to Figs. 4 to 6. By minimizing the engagement and/or sliding contact between the solid projectile 1 and the firearm barrel 15 to essentially a preferably narrow driving band 5, the press-through resistance of the solid projectile 1 within the firearm barrel 15 could be reduced.

Furthermore, as shown in Fig. 1, the driving band 5 is also radially offset at the rear from the projectile tail 7 adjoining it at the rear. A transition 17 from the projectile tail 7 into the driving band 5 is formed by an outer contour projection, at which an outer diameter D_a of the solid projectile 1 increases continuously. This is illustrated by the two visible edges 19, 21, which are axially spaced apart in the longitudinal direction of the projectile and between which the outer contour of the solid projectile 1 widens continuously in radial direction in the direction of the driving band 5.

The outer contour steps in the region of the transitions 13, 17 can have an angle of inclination with respect to a longitudinal axis of the projectile oriented in the longitudinal extension of the solid projectile 1 in the range from 10° to 90° , wherein according to Fig. 1 the transition 17 is in the range from 15° to 45° , while at the transition 13 a 90° outer contour projection is formed from the projectile nose 3 into the driving band 5. Furthermore, a radial depth of the outer contour projection or outer contour recess to be dimensioned transversely to the longitudinal axis of the projectile is less than 0.5 mm, in particular about 0.2 mm. In addition to the technical effect of reducing the press-through resistance through the firearm barrel 15, the rear-side outer contour projection from the projectile tail 7 into the driving band 5 has the technical effect of so-called breathing of the firearm barrel 15. This is achieved in that when a firearm is fired, the gas pressure that forms or builds up generates an elastic widening of the firearm barrel 15, resulting

in a gentler sliding of the solid projectile 1 within the firearm barrel 15. This means that the press-through resistance is increasingly reduced. It has been found that the resulting gases press into the annular space bounded between the outer contour projection in the region of the transition 17 and the firearm barrel 15 and thus expand the barrel radially elastically, as a result of which there is less abrasion between the firearm barrel 15 and the solid projectile 1.

According to Fig. 1, the projectile tail has a cylindrical tail section 23 directly adjoining the driving band 5 or the transition 17. At the rear, the cylindrical tail section 23 is adjoined by a projectile base 27 which opens into a bottom 25 and tapers at least sectionally concavely in the direction of the bottom 25. Here, the radius of curvature of the concave section 27 of the projectile base is in the range of 0.1 times to 0.5 times the maximum projectile outer diameter $D_{a,max}$. The at least sectionally concave projectile base 27 further extends in the longitudinal direction of the solid projectile 1 by 0.2 times to 0.6 times the maximum projectile outer diameter $D_{a,max}$. In addition, the bottom 25 of the projectile has an outer diameter D_a which is in the range of 0.6 times to 0.9 times the maximum projectile outer diameter $D_{a,max}$.

Furthermore, according to the solid projectile 1 in Fig. 1, it is provided that an axial length of the driving band 5 dimensioned in the longitudinal direction of the solid projectile 1 is in the range of 10 to 100 times a land-groove dimension difference of the firearm barrel 15. The land-groove dimension difference is to be understood as the difference between the inner diameter D_i in the region of the groove dimension A (Fig. 6) and the inner diameter D_i in the region of the land dimension B (Fig. 6).

Fig. 2 shows a side view of an intermediate 100 according to the invention for producing a solid projectile 1. The intermediate 100 comprises a pre-press body 101 with a substantially cylindrical tail section 103 and an adjoining, concavely tapering front section 105. The front section 105 serves to be further formed into the particularly ogive-like projectile nose 3. In general, the production of the intermediate 100 or the solid projectile 1 can be done by forming, in particular cold forming, such as pressing, from one piece. It was found that by providing an intermediate 100 with a concavely tapering front section 105, the forces required for forming can be reduced. As a result, the ballistics of the solid projectile 1 could be improved. Deformations on the material, in

particular on the iron blank and/or on the intermediate 100, result in local hardness changes which have a negative effect on the ballistics. This determined correlation is explained with reference to Figs. 7 to 9.

Fig. 3 again shows the solid projectile 1 according to Fig. 1, wherein hardness distribution according to Vickers is schematically indicated by dashed lines marking areas of essentially equal Vickers hardness. The areas will be discussed in more detail below: The representation according to Fig. 3 is to be understood in that the percentage change of the material hardness according to Vickers was measured on the finished solid projectile 1 compared to an initial hardness according to Vickers of the provided iron blank 200 (Fig. 7), from which first an intermediate 100 according to the invention and then a solid projectile 1 according to the invention was produced.

In the present example, an initial hardness of 140 HV 10/30 of the iron blank was selected, wherein a test load of 10 N was applied for a loading time of 30 s. The test load was determined based on the test load. The mass of the finished solid projectile 1 is approximately 7,3 g. Based on the dashed areas in the side view of the solid projectile 1, increases in hardness with respect to the Vickers hardness are indicated, which can be divided into local areas of approximately the same hardness. In Fig. 3, areas of essentially the same hardness are marked with the same reference number, which will be discussed in detail below.

The greatest percental hardness change, in particular hardness increase, was identified at the front and rear, indicated by the reference number 29. Hardness increases of over 40% were measured in the areas immediately adjacent to the projectile bottom 25 or the nose-sided end face 11, which are symmetrical with respect to the center axis M of the projectile and taper convexly from the respective end face, projectile bottom 25 or end face 11. In areas 29, a Vickers hardness of at least 200 HV 10/30 is present. Most of the solid projectile, indicated by the reference sign 35, experienced a hardness increase of about 10% to 20%, so that Vickers hardnesses in the range of 150 HV 10/30 to 170 HV 10/30 could be measured. In an elongated, approximately elliptical area 33, which extends over about 2/3 to 3/4 of the axial dimension of the solid projectile 1 in the region of the projectile center axis M, the smallest hardness changes were introduced in the material. In the area 33, the hardness increase is less than 50%, so that Vickers

hardnesses of less than 150 HV 10/30 can be measured. It is interesting for the solid projectiles 1 according to the present invention that it could be achieved that in the region of the driving band 5 and in axial direction clearly beyond, in particular in the cylindrical tail section 23 as well as in a part of the ogive 9, very small hardness increases of about 7 % or resulting Vickers hardnesses in the range of about 150 HV 10/30 were generated, so that in the region of the groove-land dimension of the solid projectile 1 as well as in the region near the projectile center axis M (area 33) substantially the same Vickers hardness is present. According to the invention, it was found that the homogeneous hardness distribution formed in this way has a positive effect on the ballistics and precision of the solid projectile 1.

Fig. 4 shows a further example embodiment of a solid projectile 1 according to the invention. In order to avoid repetition, in the following description essentially the differences compared to the preceding embodiments will be explained. For example, the solid projectile 1 according to Figs. 1 and 3 represents a so-called 9mm projectile, whereas Fig. 4 shows a 13mm projectile. Another essential difference of the solid projectile 1 according to Fig. 4 is that the transitions 13, 17 are realized differently: In contrast to Figs. 1, 3, in the solid projectile 1 according to Fig. 4 the nose-sided transition 13 is formed by an outer contour projection widening radially outward from the projectile nose 3 into the driving band 5, at which the outer diameter D_a of the solid projectile 1 increases continuously before the outer contour is defined by the narrow-banded, cylindrical driving band 5 that engages in the groove dimension A of the firearm barrel 15. Again, at the rear of the driving band 5, the transition 17 from the driving band 5 into the projectile tail 7 is formed by an abrupt outer contour recess in which the outer diameter D_a abruptly reduces. In contrast to the embodiment according to Figs. 1, 3, the projectile tail 7 adjoining the driving band 5 on the rear side does not comprise a concave projectile base 27, but a chamfered projectile bottom 25, which opens into the elongated cylindrical section 23 of the projectile tail 7 by means of a phase 37 oriented at an angle with respect to the longitudinal axis of the projectile.

With reference to Figs. 5, 6, which are cross-sectional views corresponding to lines V-V and VI-VI, respectively, and in which the firearm barrel 15 is added schematically, the different outer diameters D_a of the solid projectile 1 are apparent. The cross-sectional view V-V in Fig. 5 is cut along the driving band 5, while the cross-sectional view VI-VI in

Fig. 6 is cut at the rear in the region of the cylindrical tail section 23. Schematically and notably enlarged, the groove-land dimension profiles are indicated in Figs. 5, 6, wherein the land dimension profile is indicated by means of the reference sign B and the groove dimension profile is indicated by means of the reference sign A. Grooves 39 arranged on the inner circumference 41 of the firearm barrel 15, which are expressed in the form of notches, are indicated by means of the reference sign 39. From a combination of Figs. 5 and 6 it can be seen that the outer diameter D_a in the region of the driving band 5 (Fig. 5) is dimensioned larger than the outer diameter D_a in the region of the cylindrical tail section 23 (Fig. 6). For the sake of clarity, the dimensions of the grooves 39 in radial direction are larger than is actually the case. Furthermore, the radial distances between the solid projectile 1 and the firearm barrel inner circumferential surface 41 are also shown enlarged. It can be seen from Fig. 5 that the narrow-banded cylindrical driving band 5 is configured to substantially map the groove dimension A of the firearm inner barrel and thus to engage the grooves 39 of the firearm barrel 15. In contrast, the cylindrical tail section 23 substantially maps the land dimension profile B of the firearm barrel 15 and therefore engages essentially exclusively in the fields 43 each arranged between two adjacent grooves 39.

With reference to Figs. 7 to 9, on the one hand the manufacturing method according to the invention is explained and the homogeneous hardness distribution according to the invention on the manufactured solid projectile 1 is discussed once again. In Fig. 7, a cylindrical iron blank 200 is provided which has a predetermined dimensioning, for example an axial length of just under 30 millimeters, in particular of 28,55 millimeters, and a diameter of less than 5 millimeters, in particular of about 4,7 millimeters. First, an intermediate 100 according to the invention (Fig. 8) is first formed from the iron blank 200, in particular by forming, preferably cold forming. For this purpose, a concavely tapering front section 105 is formed on the front side, preferably by forming, in particular cold forming.

The pre-press body 101 produced in this way is then further processed into a solid projectile 1 according to the invention, which is shown in Fig. 9. The iron blank 200 was further machined in such a way that the intermediate 100 according to Fig. 8 underwent a diameter increase of about 15% and a length reduction of about 5%, so that the intermediate 100 has, for example, a length of 27,09 millimeters and a diameter of 5,4

millimeters. Starting from the intermediate 100, the finished solid projectile 1 according to Fig. 9 has been shortened again by about 9%, wherein the diameter has again increased by about 5%, so that the solid projectile has, for example, a length of 24,7 millimeters and a maximum outer diameter $D_{a,max}$ of 5,66 millimeters. For example, the 5,56mm solid projectile 1 has a mass of 3,88 g. In relation to the originally provided iron blank made of C10C material, this means an overall diameter increase of about 20% and an overall length reduction of about 13,5%.

The features disclosed in the foregoing description, figures, and claims may be significant, both individually and in any combination, for the realization of the invention in the various embodiments.

Reference sign list

1	solid projectile
3	projectile nose
5	driving band
7	projectile tail
9	ogive
11	end face
13, 17	transition
15	firearm barrel
19, 21	visible edge
23	tail section
25	bottom
27	projectile base
29, 31, 33, 35	area of substantially equal hardness
37	phase
39	groove
41	inner circumference
43	field
100	intermediate
101	pre-press body
103	tail section
105	front section
200	iron blank
M	center axis
F	flight direction
A	groove profile
B	land profile

Claims

1. Solid projectile (1) for ammunition in particular with a caliber of less than 13 mm, wherein the solid projectile (1) is made of iron, in particular soft iron, with a carbon content of more than 0,05 %.
2. Solid projectile (1) according to claim 1, wherein the carbon content is in the range of 0,06 % to 1,14 %, in particular in the range of 0,08 % to 0,12 %.
3. Solid projectile (1) according to claim 1 or 2, wherein the solid projectile (1) is made of a material that, in addition to iron, comprises at least one further transition metal, for example selected from the group comprising manganese and copper, in particular with a mass portion of 0,01 % to 1,2 % or of 0,3 % to 1 %.
4. Solid projectile (1) according to one of the preceding claims, wherein the iron of the solid projectile (1) comprises at least one additive selected from the carbon group, the nitrogen group and/or the oxygen group, wherein in particular the at least one additive is a metalloid, in particular silicon, and/or has a weight percentage of at least 0,01 % to at most 0,48 %.
5. Solid projectile (1) according to one of the preceding claims, wherein the iron has a manganese content of 0,01 % to 0,8 %, in particular of 0,03 % to 0,6 %.
6. Solid projectile (1) according to one of the preceding claims, wherein the iron has a silicon content of less than 0,5 %, in particular less than 0,4 % or less than 0,3 %.
7. Solid projectile (1) according to one of the preceding claims, wherein the iron has a phosphorus content in the range from 0,01 % to 0,04 %, in particular in the range from 0,02 % to 0,03 %.
8. Solid projectile (1) according to one of the preceding claims, wherein the iron has a sulfur content in the range from 0,01 % to 0,04 %, in particular in the range from 0,02 % to 0,03 %.
9. Solid projectile (1) according to one of the preceding claims, wherein the iron has a copper content of less than 0,4 %, in particular less than 0,3 % or less than 0,25 %.
10. Solid projectile (1), in particular according to one of the preceding claims, for ammunition in particular with a caliber of less than 13 mm, made of iron, comprising an particularly ogive-like projectile nose (3), an at least sectionally cylindrical driving band (5) adjoining thereto for guiding the solid projectile (1) in a firearm barrel (15), in particular for engaging in grooves of a land-groove profile of a firearm barrel (15),

and a projectile tail (7) adjoining to the driving band (5), the projectile tail (7) comprising a bottom and a projectile base that opens into the bottom and tapers at least sectionally concavely in the direction of the bottom.

11. Solid projectile (1) according to claim 10, wherein a radius of curvature defining an outer contour of the projectile base is in the range of 0,1 times to 0,5 times a maximum projectile outer diameter.
12. Solid projectile (1) according to one of claims 10 to 11, wherein the at least sectionally concave projectile base extends in longitudinal direction of the solid projectile (1) by 0,2 times to 0,6 times a maximum projectile outer diameter.
13. Solid projectile (1) according to one of claims 10 to 12, wherein the bottom comprises an outer diameter in the range of 0,6 times to 0,9 times a maximum projectile outer diameter.
14. Solid projectile (1), in particular according to one of the preceding claims, for ammunition in particular with a caliber of less than 13 mm, made of iron, comprising an particularly ogive-like projectile nose (3), an at least sectionally cylindrical driving band (5) adjoining thereto for guiding the solid projectile (1) in a firearm barrel (15), in particular for engaging in grooves of a land-groove profile of a firearm barrel (15), and a projectile tail (7) adjoining to the driving band (5), wherein a transition from the projectile tail (7) into the driving band (5) is formed by an outer contour projection, at which an outer diameter of the solid projectile (1) increases continuously or abruptly.
15. Solid projectile (1) according to claim 14, wherein the outer contour projection has an inclination angle with respect to a projectile longitudinal axis oriented in longitudinal direction of the solid projectile (1) in the range from 10° to 90°.
16. Solid projectile (1), in particular according to one of the preceding claims, for ammunition in particular with a caliber of less than 13 mm, made of iron, comprising an particularly ogive-like projectile nose (3), an at least sectionally cylindrical driving band (5) adjoining thereto for guiding the solid projectile (1) in a firearm barrel (15), in particular for engaging in grooves of a land-groove profile of a firearm barrel (15), and a projectile tail (7) adjoining to the driving band (5), wherein a transition from the driving band (5) into the projectile nose (3) is formed by an outer contour recess, at which an outer diameter of the solid projectile (1) decreases continuously or abruptly.

17. Solid projectile (1) according to claim 16, wherein the outer contour recess has an inclination angle with respect to a projectile longitudinal axis oriented in longitudinal direction of the solid projectile (1) in the range from 10° to 90°.
18. Solid projectile (1) according to one of claims 14 to 17, wherein the outer contour projection and/or the outer contour recess has a radial depth, dimensioned transversely to the projectile longitudinal axis, of less than 0,5 mm, in particular less than 0,4 mm, 0,3 mm or 0,2 mm.
19. Solid projectile (1), in particular according to one of the preceding claims, for ammunition in particular with a caliber of less than 13 mm, made of iron, comprising a particularly ogive-like projectile nose (3), an at least sectionally cylindrical driving band (5) adjoining thereto for guiding the solid projectile (1) in a firearm barrel (15), in particular for engaging in grooves of a land-groove profile of a firearm barrel (15), having an axial length, dimensioned in longitudinal direction of the solid projectile (1), in the range of 10 times to 100 times a land-groove profile difference of a firearm barrel (15).
20. Solid projectile (1), in particular according to one of the preceding claims, for ammunition in particular with a caliber of less than 13 mm, made of iron, comprising a particularly ogive-like projectile nose (3), having a substantially planar end face, in particular produced by cutting to length, oriented in the direction of the projectile longitudinal axis.
21. Solid projectile (1), in particular according to one of the preceding claims, for ammunition in particular with a caliber of less than 13 mm, made of iron, comprising an at least sectionally cylindrical driving band (5) for guiding the solid projectile (1) in a firearm barrel (15), in particular for engaging in grooves of a land-groove profile of a firearm barrel (15), wherein a Vickers hardness in the region of a driving band outer diameter is at most 150 HV.
22. Solid projectile (1) according to claim 21, wherein a Vickers hardness in the region of a driving band outer diameter is less than 10 %, in particular less than 5 % or less than 3 %, larger than a Vickers hardness in the region of a projectile center at the same height with respect to a projectile longitudinal axis.
23. Intermediate (100) for producing a solid projectile (1) in particular formed according to one of the preceding claims, consisting of a pre-press body made of iron with a substantially cylindrical tail section (103) and an adjoining concavely tapering front section (105), in particular produced by forming, in particular cold forming, such as pressing.

24. Method for producing an intermediate (100) in particular according to claim 23 for producing a solid projectile (1), in particular for producing a solid projectile (1) according to one of claims 1 to 22, in which a cylindrical iron blank (200) is provided and the iron blank (200) is in a front section (105) shaped, in particular by forming, in particular cold forming, in particular pressing, into a concavely tapering shape, wherein in particular the concave front section (105) is shaped by forming, in particular cold forming, in particular pressing, into an ogive shape, and adjoining to the front section (105) an at least sectionally cylindrical driving band (5) for guiding the solid projectile (1) in a firearm barrel (15) is shaped, in particular by forming, in particular cold forming, in particular pressing, and possibly an projectile tail (7) adjoining to the driving band (5) with a constant or at least sectionally continuously tapering outer diameter is shaped, in particular by forming, in particular cold forming, in particular pressing.
25. Method according to claim 24, wherein the solid projectile (1) is produced, in particular by forming, in such a way that the iron blank (200) is shortened by less than 20 %, in particular less than 15 %, and/or a diameter of the iron blank increases at most 25 %, in particular at most 20 %, and/or a Vickers hardness in the region of a driving band outer diameter increases less than 15 %, in particular less than 10 %.