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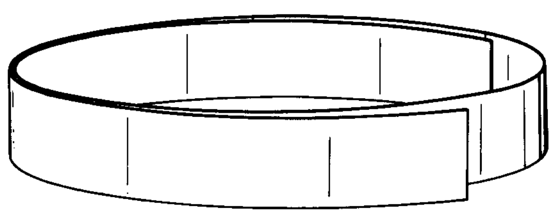
(54) **Use of a steel alloy.**

(57) A composition of a steel alloy consisting of, in percentage by weight:
0.46-0.70 C
0.2-1.5 Si
0.1-2.0 Mn
1.0-6.0 Cr
0.5-5 Mo
0.5-1.5 V
maximum 0.01 B
and the remainder essentially only iron, contaminants and accessory elements in normal proportions, as material for the manufacturing of coater and doctor blades, in the shape of cold-rolled 0.05-1.00 mm thick, hardened and tempered strips.

Fig.1.



EP 0 672 761 A2

FIELD OF ENGINEERING

The invention is in the area of coater and doctor blades, in the shape of cold-rolled, 0.1-1 mm thin, hardened and tempered bands. More specifically, the invention concerns the use of a steel alloy, with a very special composition, to be used as material for making coater and doctor blades.

STATE OF THE ART OF THE FIELD

In the paper industry, coater blades in the shape of thin, long blades are used for coating the paper web with a coating slip. These blades are pressed against the moving paper web, usually with back pressure provided by a counter roll, or by a blade, on the opposite side of the paper web, when two-sided coating is performed. To provide even and top quality coating the coater blade must be straight. The normal specification is that the machined edge of the coater blade must not deviate more than 0.3 mm/3,000 mm coater blade length, from complete straightness. To satisfy this requirement it is be necessary to select a steel alloy which prevents the strips from deforming during hardening and tempering, if the steel strips must undergo these processes. It is a well known fact that alloy steels provide more problems in this respect than non-alloy steels, and this is particularly true for steel alloys which contain several different interacting alloying elements. The most common material in coater blades is consequently still carbon steel, for example the steel with the trade mark UHB20C, which has the principal analysis 1.00 C, 0.30 Si, 0.40 Mn, 0.15 Cr, and the remainder iron and contaminants in normal proportions. Martensite stainless steel is also used for making coater blades, for example, the steel with the trade mark UHB®716, which has the principal analysis 0.38 C, 0.5 Si, 0.55 Mn, 13.5 Cr, 1.0 Mo, and the remainder iron and contaminants in normal proportions.

In the printing industry band-shaped spreading tools, known as scrapers, are also used. They are similar to the coater blades used in the paper industry. These scrapers must also satisfy high requirements in terms of straightness. The same material is used in both scrapers and coater blades.

When coater and doctor blades are used they are worn down heavily by the pigment in the surface application material, which is abrasive and by the base paper in the case of coater blades, and by the color pigment in the application ink, which is spread by the doctor blades. It is thus also desirable that both coater blades and doctor blades have a high abrasion resistance and consequently long life span. Neither carbon steel nor martensite stainless steel doctor blades do, however, satisfy this condition. Consequently, it is standard practice to replace blades already after a few hours of operation in a paper machine. This is of course a disadvantage, especially because of the loss of production when replacing the blades.

A well known method for increasing the life span of the doctor blades is to coat the edges with a ceramic layer. This increases the effective life span considerably, but these doctor blades are very expensive and are consequently not in widespread use. It is a well known fact that the abrasion resistance of alloyed steel can be higher than that of non-alloy steel. This is an advantage in certain tool steel and structural steel. Some examples of this are the alloy steels described in JP-A-61/41749, as well as in US 4,743,426 and US 2,565,264, intended, respectively, for guide pins in plastic molds, hot-working steel, for example dies for aluminum extrusion at high temperatures, and for turbine blades, forging tools, cutting tools and similar products, which are made of block or rod material. However, steel alloys of this kind have not been used for manufacturing of thin, cold-rolled, hardened and tempered strips for coater and/or doctor blades, probably because the professional assessment was that major problems would occur during cold-rolling and heat treatment, which could result in crack formation, deviations from straightness and similar defects, making the material unsuitable for coater and doctor blades.

BRIEF SUMMARY OF THE INVENTION

The basis for the invention is the surprising discovery that hot-rolled strips of a certain steel alloy, of the composition presented in the patent claims, without too much difficulty can be cold-rolled into a thickness smaller than 1 mm and hardened and tempered into an adequate hardness for coater and doctor blades, and that these blades are straight and have an abrasion resistance, and thus effective life span, which is many times higher than that of carbon steel and stainless martensite chromium steel and even is comparable to or the same as what can be achieved using ceramic coated doctor blades.

Other characteristic attributes and aspects of the invention are evident from the following detailed description and from the obtained results.

BRIEF DESCRIPTION OF FIGURES

The figures in the drawing show:

Fig. 1
a coater blade, cut to size, in rolled-up condition for delivery, and

Fig. 2 and Fig. 3
show a couple of typical edge configurations for coater and doctor blades.

DETAILED DESCRIPTION OF THE INVENTION

As previously mentioned, the invention concerns the use of a steel alloy of a specific composition for making coater and doctor blades, the latter also called scrapers, in the shape of cold-rolled, hardened and tempered strips. The figures in the drawing show typical designs. The width B is between 10 and 100 mm (4"), while the thickness of coater blades is between 0.05 and 1 mm, and in a typical case 0.25-0.64 mm, and for doctor blades, in a typical case, 0.07-0.203 mm (0.003-0.008 in.).

The machined edge can either be straight (90°) - see Fig. 3 - an edge design typical of coater blades, or be beveled, an edge design used both for coater and doctor blades, see Fig. 2.

The content of various alloying elements and their importance in the steel, for this particular application area, will be explained in detailed below.

Carbon should exist in sufficient amounts in the steel to give it a basic hardness, sufficient to endure being pressed against the paper web or ink application roll, respectively, without suffering permanent deformation, and to form MC carbides during tempering. The MC carbides provide precipitation hardening and thus improved abrasion resistance. The carbon content should consequently be at least 0.46 %, and preferably at least 0.50 %. On the other hand, the carbon content must not be high enough to risk inducing primary carbides to any great extent, since this could destroy the toughness of the material and also result in scratches in the coated paper surface. Maximum carbon content is thus 0.70 %, and preferably at most 0,65 %. It is advantageous if the steel contains between 0.52 and 0.58 C. The optimal carbon content in the steel is thought to be 0.55 %.

Vanadium should exist in the steel to form very small MC carbides during tempering, through precipitation. These MC carbides are thought to be the major reason for the surprisingly good abrasion resistance of the doctor blades. The carbides are of a submicroscopic scale, which means a maximum size of the order of magnitude 100 angstrom. To provide a sufficiently high volume fraction of MC carbides, the vanadium content should be at least 0.5 %, preferably at least 0.6 % and it is advantageous to make it at least 0.7 %. On the other hand, vanadium content must not be too high, since this can cause the formation of primary carbides, which are not dissolved during the austenitizing. These primary carbides would then bond to carbon, which would reduce the amount of precipitated MC carbides during tempering, making the steel too soft. The steel must then at most contain a maximum of 1.5 % vanadium, preferably at most 1.4% and it is advantageous if it contains at most 1.3%.

Chromium content should be at least 1 %, preferably at least 1.5 % and it is advantageous to make it at least 2 %, to give the steel sufficient hardenability, i.e., transform it into martensite during air quenching or after austenitizing. However, chromium is also carbide forming, which makes it compete with vanadium for the carbon in the steel matrix. The higher the chromium content, the less stable are the vanadium carbides. The chromium carbides, however, do not provide the precipitation hardening that is desirable and that vanadium in the above mentioned amounts can provide. Thus, the chromium content in the steel is limited to 6 %, preferably at most 4 % and it is advantageous to make it at most 3 %.

Molybdenum content should be at least 0.3 %, preferably at least 1 % and it is advantageous to make it at least 2 %, so that it jointly with vanadium can be a part of the MC carbides and in a positive way contribute to the formation of these carbides. In this function, molybdenum can be said to be a complement to the vanadium. Since there is molybdenum in the MC carbides, these dissolve more easily during austenitizing when hardening occurs and are then a part of the MC carbides formed during the tempering. Molybdenum content may, however, not be so high as to form detrimental amounts of molybdenum carbides, which are instable, just like chromium carbides, and grow at high temperatures. The molybdenum content should therefore be limited to 5 %, preferably 4 % and it is advantageous to make it at most 3 %. Molybdenum can, in the usual fashion, be replaced, completely or partially, by the double amount of tungsten. It is best, however, to avoid this, to make the steel composition less complex. In the preferred form of implementation the alloy composition should therefore not contain tungsten, more than contaminant levels.

Manganese content in the steel is between 0.1 and 2 % and contributes, just like chromium, to give the steel the desired hardenability.

Silicon content should be at least 0.2 %, preferably at least 0.6 % and it is advantageous to make it at least 0.8 %, to increase the carbon activity in steel and speed up the precipitation of the small vanadium carbides during tempering. The increased carbon activity can, however, also lead to a faster coarsening of the carbides, resulting in a quicker softening of the steel. In other words, the tempering curve is moved to the left and the hardness hump is moved upwards, when silicon content is high. The steel should, however, not contain more than at most 1.5 % silicon and preferably at most 1.2 % silicon.

Boron may possible be added to the steel, with a maximum content of 0.01 %, to further increase the hardenability of the steel.

Nickel does not provide any positive contributions to the steel in the intended application area. On the other hand, the nickel content of up to at most approximately 1 % does not provide any significant negative effects on material properties, but may somewhat complicate the heat treatment thereof. A nickel content of at most 1 % is therefore acceptable, a maximum of 0.5 % is preferable, but it is best if the steel does not contain more nickel than contaminant levels.

Niobium content in the steel for the current application area was not specifically tested. It is well known from other tests, however, that niobium can partially replace vanadium, but niobium can give embrittlement effects and should therefore be avoided. A maximum of 0.2 % niobium should, however, not provide any significant detrimental effects.

Otherwise, the steel contains essentially nothing but iron. Other elements, including for example aluminum, nitrogen, copper, cobalt, titanium, sulphur and phosphorus, only exist in contaminant levels or as unavoidable accessory elements in the steel.

The nominal composition of the material which according to the invention will be used for the manufacturing of coater or doctor blades is the following: 0.55 C, 1.0 Si, 0.80 Mn, 2.6 Cr, 2.3 Mo, 0.90 V and the remainder iron and unavoidable contaminants.

The manufacturing of coater or doctor blades, according to the present invention, will be done as follows. An alloy containing the desired composition, described above and in the patent claims, is produced using conventional pyrometallurgical processing. The alloy is made into ingots, which are hot-rolled into strips of an approximate thickness of 3 mm. These strips are cold-rolled to desired thickness of less than 1 mm, alternating with reheating operations. The cold-rolled strips produced in this fashion will be hardened using austenitizing at a temperature in excess of 1000 °C, followed by quenching in liquid lead at a temperature of between 240 and 270 °C and tempering at 400 °C. This is followed by brushing of the sides of the strips, which are subsequently yellow tempered through heating to a temperature between 320 and 370 °C, in an oxidizing atmosphere. The strips are cut to correct length and width, and the edge machined through planing and/or grinding to obtain the desired edge profile, see Fig. 2 and 3. The performing edge may be hardened using local heating of the edge section, for example by induction heating.

COMPLETED EXPERIMENTS - RESULTS

The choice of the particular alloy composition and the use of the described manufacturing procedure will create doctor blades with very high flatness and straightness, as well as a hardness in the main blade of approximately 600 HV. This hardness is higher than what is normally achieved using conventional carbon steel doctor blades, i.e., a hardness of approximately 500 HV. This change in hardness alone is, however, not enough to explain the very substantial improvement in effective life span that was obtained through the use of the new, for this application, steel alloy.

In comparative field studies, coater blades with completely straight edges and the thickness 0.381 mm and 0.508 mm were used, see Fig. 2. The experiments were performed in a Jagenberg coating unit, in a fine paper machine. Using the coating unit, the fine paper was coated with a conventional coating slip, containing abrasive material. (The exact composition of the coating slip is confidential manufacturer information.) The blades were considered to be worn out when desired coating quality was no longer achieved by adjusting, for example, the following parameters: the contact pressure between the blade and the paper web, the contact angle and similar parameters. Using conventional coater blades made of carbon steel the effective life span was 2-4 hours, but using coater blades made according to the invention the effective life span was 12-16 hours.

Claims

1. A composition of a steel alloy consisting of, in percentage by weight:
0.46-0.70 C
0.2-1.5 Si
0.1-2.0 Mn
1.0-6.0 Cr
0.5-5 Mo
0.5-1.5 V
maximum 0.01 B
and the remainder essentially only iron, contaminants and accessory elements in normal proportions, as material for the manufacturing of coater and doctor blades, in the shape of cold-rolled 0.05-1.00 mm thick, hardened and tempered strips.

2. A composition, according to claim 1, of a steel alloy containing 0.50-0.65 C, preferably 0.52-0.58 C.

3. A composition, according to claim 1, of a steel alloy containing 1.4-4 Cr.

4. A composition, according to claim 3, of a steel alloy containing 2-3, preferably 2.5-3 Cr.

5. A composition, according to claim 1, of a steel alloy containing 1-4, preferably 2-3 Mo.

6. A composition, according to claim 1, of a steel alloy containing 0.6-1.4 V, preferably 0.7-1.3 V.

7. A composition, according to claim 1, of a steel alloy containing 0.6-1.2 Si.

8. A composition, according to claim 1, of a steel alloy containing no more than contaminant levels of cobalt.

9. A composition, according to claim 1, of a steel alloy containing no more than contaminant levels of tungsten.

10. A composition of a steel alloy, according to any of the claims 1-9, in the shape of hot-rolled strips, as material for the manufacturing of coater and doctor blades, in the shape of cold-rolled 0.05-1.00 mm thick, hardened and tempered strips.

Fig.1.

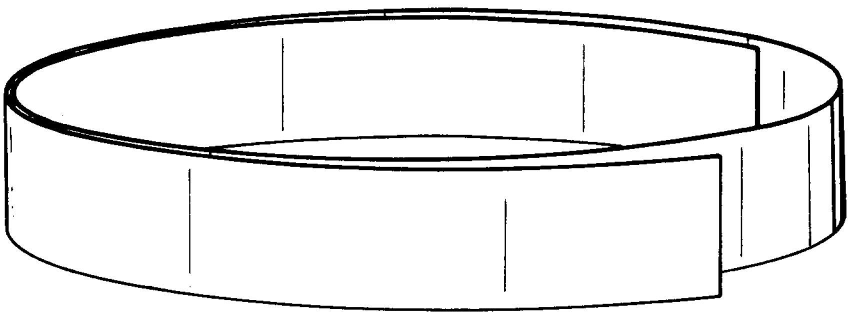


Fig.2.

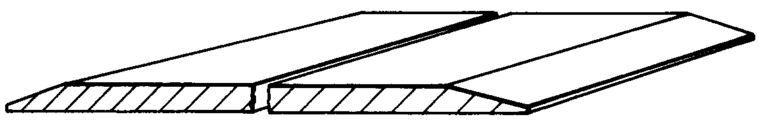


Fig.3.