Sept. 9, 1958 R. KAPLAN ET AL 2,851,000

METHOD OF MAKING AN EMBOSSED STEEL SHEET

Filed July 5, 1955

Fig. 1

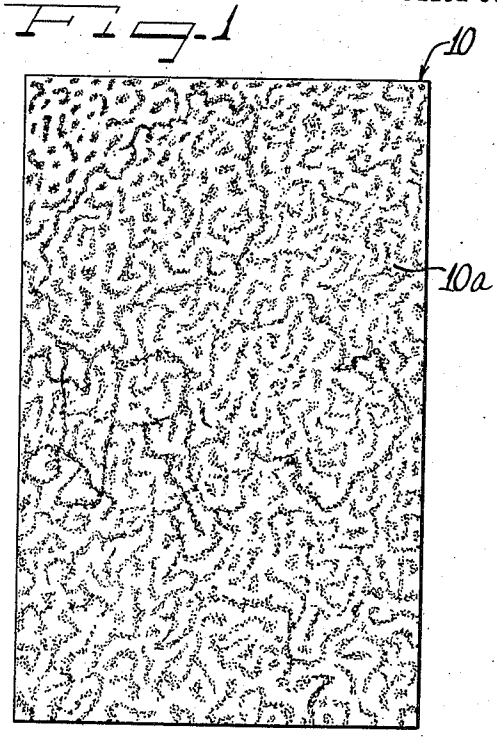


Fig. 2

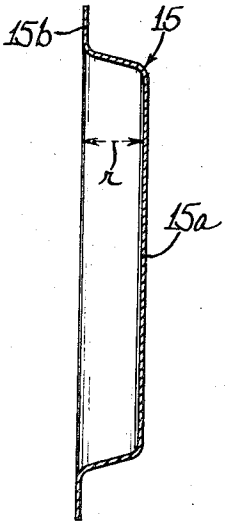


Fig. 3

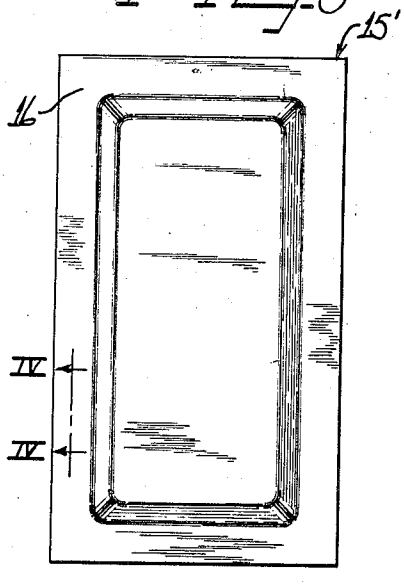
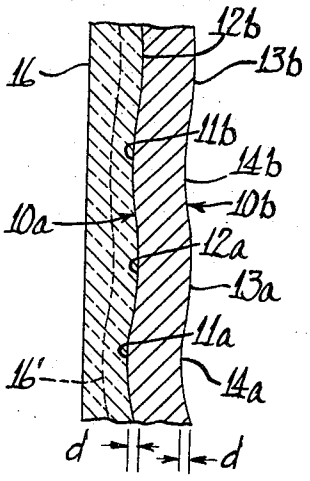


Fig. 4



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METHOD OF MAKING AN EMBOSSED STEEL SHEET

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2 Claims. (Cl. 113—120)

This invention relates to the mechanical treatment of steel and products relating therefrom, and more particularly, to the mechanical treatment of carbon steel sheet and to the products relating therefrom.

As is well known, there are a number of problems involved in the handling of steel sheet, usually in the form of hot rolled sheets of carbon steel, i. e. steel wherein the principal alloying element is carbon or steel of the SAE 1000 series. One of the properties of particular importance in SAE 1000 series steel is cold formability. Cold forming or cold working of steel is contrasted to hot working in the mechanical treatment of steel in that such working is carried out below the critical range. The cold working of steel involves a number of operations including cold forming, which may involve merely bending or stamping, or it may involve the relatively more difficult operation of drawing. In drawing a generally flat sheet of metal is subjected to bending combined with a shearing force, but metal having good drawing quality yields to the shearing force to the extent that it is deformed in drawing rather than be sheared or cut. In general, drawing involves the formation of a dish-shaped article from a generally flat metal sheet and this operation is contrasted to mere stamping or bending in that steel having deep drawing quality is capable of being drawn perhaps four inches using a piece one square foot in area. Extra deep drawing may involve the formation of as much as an eight inch depression in a one square foot sheet of metal.

It is also well known that the concentration of forces is so great in the cold drawing operation that metallurgical changes are effected in certain steels, usually to the extent that brittleness may be imparted to higher carbon steels. On the other hand, higher carbon steels such as SAE 1020 have increased rigidity or strength so as to resist cold drawing and make the operation much more difficult from the point of view of forces applied as well as wear and tear on the dies. In general, it has been the practice in industry for some time to use carbon steels in the series SAE 1006 to SAE 1015 (i. e. having about 0.05–0.15% C and about 0.30–0.60% Mn) for drawing automobile body and fender stock, fluids, lamps, oil pans, and a number of other deep drawing operations. Steel of this type, usually referred to as mild steel, possesses very good ductility or the ability to withstand cold deformation, but it possesses such ductility at a sacrifice in strength or rigidity. Also, steels of this carbon content are susceptible to serious grain growth (resulting in extreme brittleness and/or warping) when subjected to a cold drawing operation followed by heating to elevated temperatures above 1100° F. For example, steels of this type may be coated with ceramic enamelling which involves firing at temperatures of at least 1100° F. and usually as much as 1500° F., but there is a great tendency for sheets of such steel to undergo warping during the firing process, and it is only with a great deal of difficulty that such warpage may be controlled within reasonable tolerances. In fact, enamelling steel of the desired high grade has only about 0.02% C content and sells at a much higher price than one of the most commonly used mild steels, SAE 1010. Such enamelling steel is used predominantly in the ceramic enamelling industries, however, because it does not afford the very difficult warpage problem which higher carbon mild steels such as SAE 1010 possess. Again, it will be appreciated that the very low carbon content of enamelling steels is employed at a sacrifice in strength or rigidity, as well as cost.

The instant invention affords a solution to many of the problems confronting workers in this art. A key to the instant invention resides in the concept of embossing carbon steel sheet as an initial treatment before drawing and/or ceramic enamelling or other secondary operations. Although a substantial number of advantages are obtained by carrying out an initial embossing step, some of the more striking include much greater ease of drawing, greater strength in the embossed sheet (notwithstanding the greater ease of drawing), and a unique ability to avoid warping when subjected to elevated temperatures such as the ceramic enamelling firing temperatures.

It is an important object of the instant invention to provide an improved method of handling carbon steels, including ceramic enamelling thereof, and further to provide improved carbon steel articles, including articles coated with a ceramic enamelling.

It is a further object of the instant invention to provide an improved process which comprises embossing carbon steel sheet followed by drawing the embossed sheet to a desired form; and to provide further the product resulting therefrom.

It is another object of the instant invention to provide an improved process which comprises embossing carbon steel sheet and ceramic enamelling the sheet by the usual firing process; and to provide an improved product resulting therefrom.

Other objects, features and advantages of the instant invention will become apparent to those skilled in the art from the following detailed disclosure thereof and the drawings attached hereto and made a part hereof.

On the drawings:

Figure 1 is a top plan view of one modification of an embossed carbon steel sheet embodying the instant invention;

Figure 2 is a sectional elevational view of an embossed sheet of the instant invention (such as that shown in Figure 1) which has been drawn to form a generally dish-shaped panel, for example, for a refrigerator drawer or the like;

Figure 3 is a side elevational view of the drawn embossed sheet of Figure 2 with a porcelain enamel coating applied to the exposed surface thereof; and

Figure 4 is an enlarged sectional detail taken substantially along the line IV—IV of Figure 3.

As shown in the drawings:

In Figure 1, the reference numeral **10** indicates generally an embossed carbon steel sheet having a multitude of alternating bosses or raised portions **11***a*, **11***b*, etc. (Figure 4) surrounded by valleys or depressions **12***a*, **12***b*, etc. (Figure 4) on the exposed face thereof, which is the face **10***a* in Figures 1 and 4. The opposite face **10***b* of Figure 4 is also provided with bosses **13***a*, **13***b*, etc. surrounded by valleys or depressions **14***a*, **14***b*, etc.; with the depressions **14***a*, **14***b*, on the rear face **10***b* opposed to bosses **11***a*, **11***b*, on the front face **10***a*. This is the general outline of the cross-sectional shape of the embossed sheet **10**, although the positioning of the bosses and recesses on the opposed faces **10***a* and **10***b* need not be positioned with such precise regularity or uniformity, so long as the recesses on one side are opposed generally to the bosses on the opposite side. In fact, it is generally preferable to present a surface such as the surface **10***a*

of Figure 1 wherein the positioning of the bosses appears to be a random positioning such as in simulated stucco, rather than a perfectly uniform positioning. Such an arrangement is generally much more ornamental and attractive to the observer. Actual designs presenting greater uniformity or symmetry in the positioning of the bosses may be used, however, to substantially the same advantage in the practice of the instant invention.

In carrying out the embossing step, it has already been mentioned that carbon steel sheet is used. Such sheet may have about 0.05–0.30% C, and preferably has only about 0.30–0.90% Mn. This involves the steels within the range SAE 1006 to SAE 1030, except for SAE 1019, 1022, 1024, and 1027 which have a higher Mn content (of as much as 1.65% Mn). Preferably, the Mn content is 0.25–0.60%, using C contents as high as 0.30%; and in many instances the greatest advantages of the instant invention are obtained using steels within the range SAE 1006 to SAE 1015 (0.05–0.15% C and 0.25–0.60% Mn).

The advantages obtained using the SAE 1006 to SAE 1015 steel series are very striking. For example, SAE 1010 steel (specification: 0.08–0.13% C, 0.30–0.60% Mn, 0.04% P maximum, 0.05% S maximum, 0.10% Si maximum, remainder Fe) in the form of 20 gauge (0.035 inch thickness) rolled sheet stock that is embossed according to the practice of the instant invention has the same rigidity or strength in large sheet sections as unembossed 18 gauge (0.050 inch thickness) SAE 1010 sheeting; and the embossed sheeting may be cold deep-drawn much more easily than the unembossed sheeting (or for that matter much more easily than unembossed 20 gauge sheeting of the same original thickness). In addition, the embossed sheeting is even flatter than the so-called "stretcher leveled" unembossed sheeting; and the embossed sheeting, with or without preliminary drawing, exhibits unusual resistance to warpage when exposed to elevated temperatures above 1100° F. Comparable results are obtained with the other carbon steel sheets hereinbefore mentioned.

In general, the embossing operation is a cold working or cold forming operation. Although the original sheet thickness may vary rather widely to include the commercially employed stock thicknesses, the advantages of the instant invention are most apparent using sheet thicknesses within the range of about 0.020 inch to about 0.1 inch, most preferably using about 0.030 to about 0.050 inch thickness. The plain sheet is passed between matched hard steel embossing rolls, at cold warking temperatures preferably, and the embossing rolls are provided with a multitude of small bosses matingly aligned on the two rolls so as to avoid having the bosses on one roll directly opposite the bosses on the other roll at the embossing nip therebetween through which the sheet passes. The bosses, in order to obtain the full benefit of the instant invention have an average height or extend an average distance from the roll periphery of about 0.010 to about 0.014 inch for embossing stock of 0.035 inch thickness (or stock of the preferred range of 0.030–0.050 inch). Expressed in other terms, the bosses are approximately 1/10 to 1/2 of the sheet thickness in height and preferably about 20 to 45% of the sheet thickness. The distances *d*, *d* (Figure 4) between the tops of the bosses and the depressions in the sheet **10** are substantially the same as the proportions just given for the bosses on the embossing rolls, although the distances just mentioned on the sheet **10** may be slightly less if completely effective embossing is not accomplished because of spacing between the rolls or reduced pressure at the nip.

Although the instant embossing process may be carried out using carbon steel sheeting of carbon content up to as high as perhaps SAE 1052 (about .52% C and as high as 1.55% Mn) there are practical limitations such as wear and tear on the embossing rolls or dies which would subtract to some extent from the overall advantages of the instant invention. Also, the relatively poorer cold-formability of such high C and high Mn steels would necessitate greater embossing operating pressures and greater care in carrying out the operation, the operation in such cases necessarily results in metallurgical changes in these high C-Mn steels which require subsequent heat treatment. In any event, however, the embossed steel sheets of the invention afford unusual advantages in cold forming. The embossing step effects a definite increase in rigidity or strength of approximately 25 to 35% over the unembossed stock; but contrary to expectations, this increase in rigidity greatly facilitates rather than making more difficult cold forming operations. Wear and tear on the die is reduced (presumably because there is less metal-to-metal contact and a better chance for lubrication) rather than increased as would be expected because of the supposedly roughened metal surface of the embossed workpiece. This affords an advantage even in the case of the higher carbon steels which may have to be heat treated once or several times during any sort of cold forming operation.

As previously mentioned, the invention affords unusual advantages in connection with those steels which heretofore had been used in deep drawing operations, namely, 0.05–0.15% C and 0.25–0.60% Mn. The invention, however, provides still another very important advantage in connection with steels having somewhat greater inherent strength because of their higher carbon content, namely, SAE 1017, 1020, 1023, and 1025 (0.15–0.28% C and 0.30–0.60% Mn). Embossed steel sheets from this last mentioned group will have their inherently greater strength increased still more and also these embossed sheets have improved cold drawing qualities. These sheets also have inherently greater resistance to warpage even in their unembossed form because of their higher C content; but embossing affords still a greater improvement in resistance to warpage in these sheets. In some extreme forms of cold working, it may be necessary to undertake heat treatment with these sheets, after embossing and/or during or after cold forming or drawing, but many of the advantages are still obtained.

The same is true of steels having even relatively high Mn contents, such as SAE 1016, 1018, 1021, 1026, or 1030 (having 0.60–0.90% Mn and about 0.16–0.30% C), although the combination of higher C and higher Mn makes the embossing and cold forming procedures which may be used somewhat more difficult and tends to increase the desirability of employing heat treatments. Nevertheless, the advantages of substantially improved rigidity are apparent in 0.025 inch SAE 1020 and SAE 1021, for example, sheets, and improved cold-formability is also apparent in such sheets, when embossed in accordance with the instant invention.

The drawing operation which is employed to particular advantage in the instant invention is, of course, a standard drawing operation of the type well known to those skilled in the art. The differences here involved include greater ease of drawing, apparently better lubrication between the die and the workpiece, less wear and tear on the die, and a retention of the embossed contour of the workpiece during the drawing or forming operation. In other respects, the drawing operation is the same as an ordinary commercial operation. Drawing itself is a well known art and need not be described herein detail. For the sake of distinguishing from an ordinary bending, stamping or cutting operation, drawing could probably best be defined as involving the application of forces to the workpiece that are comparable to forces at least sufficient to make a 2 inch depression in a square foot of the workpiece sheet. Expressed in other terms, drawing involves the shaping of a sheet into a dish-shaped article or an article having a bowed contour; and the workers in the art generally consider a

material has good deep drawing quality if it can be drawn 4 inches per square foot. The drawing operation itself involves applying suitably formed male and female dies to the sheet material under pressure (at less than the critical temperature) in order to effect deformation of the sheet to form the dish-shaped article. As mentioned, drawing of the sheet to the ultimate shape need not be accomplished in a single drawing step but may be accomplished through a series of successively deeper draws, with heat treatment in between such steps, if necessary.

An important point of novelty in the instant invention resides in the actual discovery of the desirability of embossing the carbon steel sheets herein described. Embossing for purely ornamental purposes has been suggested heretofore in connection with various metals, and has been used heretofore in connection with the well known "corrosion-resistant" ornamental metals such as aluminum or other non-ferrous metals and stainless steel. The prior art embossing was, however, devoted entirely to the embossing of extremely narrow strips of such materials and the use of such embossed materials primarily for ornamental purposes. For these reasons, the so-called "non-corrosive" metals were ordinarily employed.

In contrast, in the practice of the instant invention sheets of substantial width (up to 48 inches in commercial production) of mild steel are embossed for advantages primarily in connection with structural concepts, although ornamental advantages are also obtained. In other words, the concept of embossing mild steel sheets so as to improve their physical properties, and particularly, to improve simultaneously properties such as rigidity and cold-formability (which heretofore permitted the improvement of one only at a sacrifice to the other) is of significance. Other advantages are also important here. The embossed finish of the instant sheets eliminates any problem created by scratching during subsequent processing, because scratches will not appear as mars on the surface of the instant sheets. Also, the improved drawing qualities may eliminate the use of special dies or drawing compounds. The embossing of the steel sheet will also permit the shipment of the same in coil as well as sheet form, since the instant sheets can be straightened out readily and to afford a flatter sheet than is ordinarily possible with unembossed material. All of these factors reduce greatly the finishing costs and also handling and shipping problems.

In addition, the embossed surface provided on the instant material offers greatly superior bonding between the base metal and paints or other finishes, and particularly ceramic enamels. The instant articles also have greater wear and/or abrasion resistance, because of the particular structure here involved and also because the results of wear and/or abrasion do not become as readily apparent on the ornamental surface here provided.

Referring to Figure 2, it will be seen that an embossed sheet such as the sheet **10** may be drawn to form a generally dish-shaped panel member **15** wherein the central portion **15***a* is recessed about 4 inches, as the dimension "*r*" indicates and a flange-like portion **15***b* is retained around the periphery. The drawing operation is accomplished in an ordinary drawing press so as to provide a dish-shaped front panel member **15** for a door, such as an ice box door. In Figure 3, the panel member **15'** displays the contour of the side elevation of the panel **15** of Figure 2, but the surface **16** thus exposed is coated with a suitable finish, in this case porcelain enamel.

As mentioned, paints and other finishes may be applied to great advantage in the practice of the instant invention, because the roughened surface **10***a* afforded by the embossing affords better anchoring. In addition, this "stucco" surface provides an extremely striking ornamental appearance when finishes are applied thereto in thin layers so as to follow generally the contour of the stucco finish. For example, as the dotted line **16'** indicates in Figure 4, a relatively thin film of finish will provide a surface **16'** that follows the contour of the embossed surface **10***a*. If the thin surface **16'** is provided by ceramic enamelling, the stucco background will give the appearance of solid ceramic to the material thereby providing unusual attractiveness. On the other hand, it is always possible to apply the ceramic material in sufficient thickness so that firing results in the formation of a smooth surfaced layer **16**, as also indicated in Figure 4.

Ceramic enamelling processes are well known to the art, and they involve generally the application of glass or a similar ceramic material to a metal surface and the fusion of such ceramic material so as to form a continuous film or layer on the metal surface. The glass or ceramic compositions which may be used, in general contain substantial quantities of silica, plus alumina, plus certain lower fusing oxides or compounds capable of fusing to form such oxides. Pickling processes often considered absolutely necessary in the connection with the enamelling of sheet steel are not always necessary in connection with the instant embossed sheet steel, because of the anchoring surface provided thereby.

It has been found that the application of glass or similar ceramic materials to the instant embossed steel sheets and the subsequent firing at temperatures within the range of about 1100° F. to as much as 1650° F. will not result in warpage of the embossed sheet, as is the case with plain unembossed sheets. Glass (or the ceramic material here employed) is essentially an amorphous fusion or solid solution of oxides of silicon, boron, phosphorous, with certain basic oxides such as those of calcium, magnesium, sodium, potassium, iron, cobalt, etc. Using a commercial porcelain or vitreous enamel slurry which has been applied to the embossed surface, it will be observed that the slurry may be used to form the enamel coating either in an oven, or by the use of flame heating of the slurry, in either case without warpage of the embossed sheet. For example, using the slurry specifically described in U. S. Patent No. 2,321,656 and applying the slurry to sheets of embossed SAE 1010, 1020 and 1021, and firing the dried slurry at 1350–1400° F., it will be noted that the resulting enamel coating has extremely good adherence to the embossed surface and warpage of the embossed sheet has been avoided. Using vitreous enamel compositions (which have a lower basic oxide content) and firing at 1500° F. gives the same result with respect to adherence and the lack of warpage in the sheet. In general, this phase of the process comprises exposing the embossed sheet, with or without a preliminary drawing step to temperatures above 1100° F. and below the critical temperature of about 1700° F., but the most useful aspect of this process step is the enamelling step involved with the exposure to the elevated temperature. If the aforementioned steel sheets are first deep drawn to form a panel for a refrigerator door, such as the panel shown in Figure 2 and the above mentioned slurries are applied thereto and fired at the temperatures indicated, substantially the same results are obtained in good adherence of the enamel and lack of warpage in the panel.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

We claim as our invention:

1. A method which comprises pressure embossing 0.02 to 0.1 inch thick carbon steel sheet by passing the sheet through a press nip defined by embossing rolls having bosses thereon having a height of 0.1 to 0.5 times the sheet thickness, and ceramic enamelling the sheet by applying a ceramic coating thereto and firing at 1100° F. to 1700° F. to fuse the ceramic, whereby the embossing eliminates warpage of the sheet during the firing of the ceramic.

2. A method which comprises pressure embossing 0.02

to 0.1 inch thick carbon steel sheet by passing the sheet through a press nip defined by embossing rolls having bosses thereon having a height of 0.1 to 0.5 times the sheet thickness, cold drawing the embossed sheet without eradicating the embossing, and ceramic enamelling the sheet by applying a ceramic coating thereto and firing at 1100° F. to 1700° F. to fuse the ceramic, whereby the embossing eliminates warpage of the sheet during the firing of the ceramic.

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