

- - IMPROVED SAWING WIRE SPOOL - -**Technical Field**

[0001] The invention relates to a spool for winding a fine metal wire on. More specifically the present invention relates to a spool made of metal sheet for winding a sawing wire on.

Background Art

[0002] A conventional spool has a core and two flanges. The two flanges are e.g. welded to either end of said core. The core and the two flanges are made of thick metal sheets 1 to 6 mm made out of carbon steel.

[0003] An example of a fine metal wire to be wound on said spool is a sawing wire. Sawing wire has a diameter of between 0.08 to 0.16 mm – 0.12 mm is the most typical diameter - although sawing wire of 0.25 mm is known to exist. The trend is to even finer sawing wires in ever increasing lengths. Sawing wire is used on loose abrasive sawing machines wherein the sawing wire drags slurry comprising a liquid carrier and abrasive particles into the progressing cut of the material to be sawn. This type of sawing machines is extensively used to cut silicon ingots for use in the semiconductor industry or for solar cell manufacturing. Alternatively, the spool can be used also to wind fixed abrasive sawing wire on: then the abrasive particles are firmly attached to the wire and no carrier slurry is needed.

[0004] The spool can also be used to wind hose reinforcement wire on. This kind of wire is braided or spiralled around an inner hose body for reinforcing the hose. Such hoses are amongst other used in hydraulically activated machinery. Hose wire generally has a diameter of 0.16 mm up to 0.25 mm and more.

[0005] When winding layers of wire on a spool, each layer added to the spool exerts a pressure on the underlying layers. This pressure is proportional to the force used to wind the wire on the spool and on the number of layers wound. The pressure is transferred to the core of the spool as well as to the flanges. This pressure causes both flanges to be pushed outwardly. In

extreme cases, the forces can be so immense that the flanges separate from the core or, even more extreme, the core simply collapses.

[0006] In the sawing application mentioned, a single wire of diameter 0.12 mm in a length of 800 km is wound on the spool. As the diameter of the metal wire is small the cumulative number of layers of wire is large (the number of layers can be as high as 500 to 800 layers). The winding tension is typically 2 to 40 Newton. Hence, the side pressure generated on the flanges is large. The flanges will deform and spread open while winding wire on the spool. This is very disadvantageous for the later use in the cutting process as during cutting the spool flanges will tend to revert to their initial position as the pressure diminishes while the number of layers is reduced. Hence, there is a genuine risk that the remaining wire loops nearby the inner sides of the flange get trapped between the remaining wire pack and the flange and subsequently break when drawn from the spool.

[0007] To provide sufficient strength and rigidity to withstand such side pressure, some prior-art spools have flanges of metal discs with a thickness of about 20 to 50mm (see e.g. USD 399857). However, such a spool is so heavy that its operability becomes very poor. Furthermore this spool suffers from high costs of material, treatment and transportation. Due to the excessively high side pressure, even this mechanically strong spool can not avoid plastic deformation of the flanges and the core. After repeated use, the spool becomes unusable due to further deformation or breakage. As such this spool fails to ensure an appropriate durability compared to its high costs.

[0008] Another solution has been sought in making spools with flanges that comprise different layers of metal sheet that are welded together to increase the stiffness of the flange. An example of such a solution is described in EP 1295836 B1. However, the winding capacity of such a type of spool remains low.

[0009] Still another solution was sought in JP 2006 240 865 wherein the outer side of the flange is shot peened in order to reduce the deformation of the flanges due to the side pressure of the wire windings.

[0010] The most widely used spool for sawing wire is depicted in USD 441772 and is made of thick metal sheet. Although it is sturdy, it can only be used once as the flanges are plastically deformed after only one use cycle. Moreover, the spool has not been designed to wind wires on of diameter 0.120 mm or less.

Disclosure of Invention

[0011] It is an object of the invention to avoid the disadvantages of the prior art. It is a specific object of the invention to provide a spool for winding fine wire on, such as a sawing wire, said spool having sufficient mechanical strength to minimise deformation of the flanges, as such gaining reusability. It is also an object of the present invention to achieve a reduction in weight and cost. It is a further object of the invention to be able to wind even finer wires - for example of diameter 0.08 mm - on in lengths of 1000 km or more.

[0012] According to an aspect of the invention there is provided a spool made of metal sheet for winding metal wire on, said spool comprising a core and two flanges coupled to either end of said core, wherein the outer side of each of said flanges comprises multiple debossed areas that extend radial from said core. In a preferable embodiment said debossed areas are angularly evenly distributed around said core.

[0013] The flanges of the spool can for example be welded to the spool. Alternatively they can be brazed onto the core, or they can be attached with mechanical fastening means to the core. Still another possibility is that the flanges are foreseen with a collar at the centre hole. The rim of the collar is subsequently welded to the core. Or the collar can be made to slide into the core at the end and point welded there. The person skilled in the art may well find other methods to connect the core to the flange.

[0014] With 'debossed areas that extend radial' it is meant that the debossed areas have their longer dimension in a direction radial from the core to the outer rim of the flange.

[0015] For the purpose of this application with 'debossed area' is meant an area in the metal sheet that has been plastically compressed. Hence, the area that is debossed is lower than the area surrounding it. This as opposed to

‘embossing’ – as for example to strike the ‘head’ of a coin - wherein the area that is embossed is higher than the area surrounding it.

- [0016] The lowering of the debossed area is solely due to the compression of the material. The lowering of the area is not the consequence of taking away surface material in order to obtain the depressed area.
- [0017] Likewise, debossing is not the local deformation of the metal sheet as a consequence of stamping the metal sheet. During stamping the thickness of the metal sheet largely remains the same and the negative of the imprint becomes visible at the side opposite to the stamping. The area where debossing has taken place should barely be visible at the inner sides – i.e. the sides facing one another - of the flanges. The inner sides of the flanges should be as smooth as possible in order not to lead to wiggling of the wire as it nears the side during winding.
- [0018] It is known from material science that locally compressing a material may affect the yield stress of the material. For example, compressing a metal strip may lead to an increase in tensile yield strength of the metal strip. Hence, a higher stress is needed before the metal will yield. This is known in material science as the ‘Bauschinger effect’ (named after the German engineer Johann Baushinger). Without being bound by this theory, it is believed that locally debossing the flanges made of metal sheet advantageously increases the yield strength of the flanges, hence makes them more resistant to the pressure of the wire layers.
- [0019] The surface area of one single debossed area is upper limited by the tooling used: too high a surface area will result in less depth as the press used can only generate a maximum compressive force. In the lower limit, the area of one single debossed area should not be too small as otherwise the material will flow outside the compressed area with a less effective compression inside the area as a consequence.
- [0020] In a first embodiment the number of debossed areas is 4, preferably one debossed area every 90 degrees. In another embodiment the number of debossed areas is 6 preferably one debossed area at regular 60 degrees intervals. In a further embodiment the number of debossed areas is between 4 and 18.

- [0021] The spool of the present invention provides a core having an outer diameter D_1 and two flanges having an outer diameter D_2 , whereby the free radius of said flanges is half of D_2 minus D_1 . The spool is further characterized in that said debossed areas radially extend over at least 25% preferably at least 35%, most preferably at least 50% of said free radius. That is the largest dimension of the area measured in radial direction is at least 25%, preferably at least 35%, most preferably at least 50% of the free radius. In one embodiment the free radius of said flanges is between 5cm and 20cm and the radial length of said debossed areas is between 2.5cm and 10cm.
- [0022] The surface area of said debossed areas is in total more than 2% and less than 40 % of the annular surface area between said core and the rim of one of said flanges.
- [0023] The depth of said debossed areas is between 3% and 50% of the thickness of said flanges. In one embodiment said flanges are between 2.5 mm and 6.0 mm thick and the depth of said debossed areas is between 0.2 mm and 1.25 mm. In a specific embodiment said flanges are between 4.0 mm and 5.0 mm thick and said embossings are between 0.15 and 2.0 mm deep. In a more specific embodiment said flanges are 4.5 mm thick and said debossed areas are between 0.15 and 1.5 mm deep.
- [0024] In a preferable embodiment said debossed areas are substantially rectangular in shape, the longer side of said rectangular shape being in radial direction. In one embodiment the width of said rectangular debossed areas is between 5 and 20 mm.
- [0025] In an alternative embodiment said debossed areas are truncated sectors in shape. The sectors have their tips at the center of the spool flange. Each of said sectors subtends an angle when seen from the centre of the spool. The sum of the angles subtended by said truncated sectors is preferably between 10 and 180 degrees of arc.
- [0026] In an embodiment of the present invention one or both of said flanges are provided with one or two or more protruding drive studs for entrainment of said spool during use. The drive studs engage with circular or semicircular cut-outs in the drive plate of the sawing machine. As the drive plate turns, the spool is driven by the plate through action of the studs. The studs can

be rings that are welded to the flange at the inside of the ring. Welding at the outside would lead to a weld burr at the foot of the stud that would prevent proper engagement of the stud in the drive holes. Alternatively, and much preferred, is the use of a circular disk with two opposite, half-moon shaped cut-outs. The welding is done in the cut-outs from the outside which is much more convenient than having to weld in the confined ring space.

Brief Description of Figures in the Drawings

- [0027] The invention will be described into more detail with reference to the accompanying drawings wherein
- [0028] Figure 1 shows a spool according to the invention;
- [0029] Figure 2 is a side view of a spool according to the invention;
- [0030] Figure 3 is a B-B' cross-sectional view of the flange of Figure 2;
- [0031] Figure 4 is a side view of a spool according to an embodiment of the invention;
- [0032] Figure 5 and 6 are side views of a spool according to specific embodiments of the invention;

Mode(s) for Carrying Out the Invention

- [0033] Figure 1 shows a first embodiment of a spool 10 according to the invention. The spool 10 comprises a core 12 and two flanges 14 welded to either end of the core 12. The two flanges 14 are provided with six debossed areas 16, evenly distributed angularly and extending radial from the core 12. The debossed areas 16 are substantially rectangular in shape. Two protruding drive studs 18 are provided for entrainment of the spool 10 during use. The two flanges may have a rim 20, but this is not essential to the invention.
- [0034] Figure 2 is a side view of the first embodiment of the spool according to the invention, wherein the core 12 has an outer diameter D1 and the two flanges 14 have an outer diameter D2. In the first embodiment D1 is 156 mm, D2 is 310 mm. The free radius of the flanges is $(D2-D1)/2$ i.e. 77 mm. The six debossed areas 16 have a substantially rectangular shape with a radial dimension of 40 mm i.e about 50% of the free radius is debossed.

The width of the areas is about 8 mm. About 3% of the free area is debossed.

- [0035] Figure 3 is a B-B' cross-sectional view of the flange of Figure 2, illustrating that the flange 14 has a thickness 'd' and the debossed area 16 has a thickness 'δ', wherein 'δ' is between 50% and 97% of the thickness 'd' of the flange 14 implying that the steel sheet has been compressed 3 to 50%. In the first embodiment the thickness of the metal sheet 'd' was 4.5 mm and the thickness at the depressed area 'δ' was 4.0 mm making the debossed areas 0.5 mm deep. It may be easier in practice to measure both thicknesses 'd' and 'δ' and then derive the depth of the debossed areas rather than measuring the depth of the depressed areas directly.
- [0036] Debossing is done by means of a hardened steel stamp having the desired area shape that is impressed into the flange by e.g. an impact press against an otherwise flat surface. This is done at normal temperatures and no other treatment is necessary. Important is that the stamping does not show significantly at the inner side of the flange: although a minor shade may be visible, there should not be a protrusion at the inner side of the flange. Such protrusion would be detrimental for the winding quality of the fine metal wire.
- [0037] Figure 3 also shows how the flange 14 is attached to the core 12 through two welding seams 15 and 17 at respectively the inner and outer side of the flange. The studs 18 are made of a ring 27 mm in diameter and 12 mm high that is welded from the inside to the flange 14.
- [0038] Figure 4 is a side view of a spool according to an alternative embodiment of the invention differing only from the first embodiment in that the protruding drive studs 18 have a different shape. The studs are made of solid discs 27 mm in diameter and 12 mm high out of which two half-moon shaped parts are cut. The welding of the studs to the flange can be done much easier now as it can be done from the outside into the cut-outs. Figure 5 and 6 show other preferred embodiments of the invention wherein the total surface area of the debossed areas 16 is larger than the surface area of the six debossed areas 16 shown in the previous figures.
- [0039] Figure 5 shows a flange having six debossed areas 16 in the form of truncated sectors. The angle 'α' of one debossed area 16 is about 30

degrees of arc. The sum of the angles subtended by said truncated sectors is about 180 degrees of arc. About 23% of the annular surface area between core and rim is debossed.

- [0040] Figure 6 shows a specific embodiment of the invention wherein each of the two flanges comprise eighteen debossed areas 16.
- [0041] Tests were performed comparing the spool of the invention to a conventional spool only differing in that no debossed areas on the flanges are present. The spools were according the dimensions and debossing as described for the first embodiment.
- [0042] A conventional and an inventive spool were tested as follows: on each spool a fine wire of diameter 0.14 mm was wound at a controlled winding tension of about 3.5 Newton and a winding step of 0.15 mm. These are more stringent conditions than normally applied. Winding was stopped at a fine wire length of respectively 200, 400 and 800 km. At the stop, the inner flange width was accurately measured in axial direction with an insert gauge at the rim of the spool (at diameter D2). At the rim of the spool, the deformation is maximal. The results shown in Table 1 display a lower deformation at the ends of the flanges for the spools of the invention when compared to the conventional spool. Spools wound with 200 km of fine wire show no deformation compared to a 0.2 mm deformation of a conventional spool. Spools wound with a 400 km fine wire show one third less deformation than conventional spools. Spools wound with a 800 km fine wire show still an improvement all be it somewhat less. It is therefore conjectured that the results can even be more improved by extending the debossing over a longer radial length.
- [0043] Finally when comparing the deformation of the flanges as obtained on the spool of the prior-art as e.g. depicted in USD 441772, there is quite some improvement. Indeed prior-art spools show a spreading of the flanges of more than 10 mm under the same testing conditions as in the tests on the conventional and inventive spools.

[0044] Table 1

Length (km)	Deformation (mm) of conventional spool	Deformation (mm) of debossed spool
200	0.2	0
400	2.7	1.8
800	5.8	5.6

Claims

1. A spool (10) made of metal sheet for winding metal wire on, said spool (10) comprising a core (12) and two flanges (14) coupled to either end of said core (12), characterised in that the outer side of each of said flanges (14) comprises multiple debossed areas of plastically compressed metal sheet (16) that extend radial from said core (12), while the inner side of said flange is substantially flat.
2. The spool (10) according to claim 1 wherein said debossed areas (16) are angularly evenly distributed around said core (12).
3. The spool (10) according any of claims 1 or 2 wherein the number of debossed areas (16) is between 4 and 18.
4. The spool (10) according to any of claims 1 to 3 wherein said core (12) has an outer diameter D1 and said two flanges (14) have an outer diameter D2, whereby the free radius of said flanges (14) is half of D2 minus D1, further characterized in that said debossed areas (16) radially extend over at least 25% preferably at least 35%, most preferably at least 50% of said free radius.
5. The spool (10) according to claim 4 wherein said free radius of said flanges (14) is between 5cm and 20cm and the radial length of said debossed areas (16) is between 2.5cm and 10cm.
6. The spool (10) according to any of claims 1 to 5 wherein the surface area of said debossed areas (16) is in total more than 2% and less than 40 % of the annular surface area between said core (12) and the rim (20) of one of said flanges (14).
7. The spool (10) according to any of claims 1 to 6, wherein the depth of said debossed areas (16) is between 3% and 50% of the thickness ('d') of said flanges (14).

8. The spool (10) according to claim 7, wherein said flanges (14) are between 2.5mm and 6.0mm thick and the depth of said debossed areas (16) is between 0.2 and 1.25mm.
9. The spool (10) according to claim 7, wherein said flanges (14) are between 4.0mm and 5.0mm thick and said debossed areas (16) are between 0.15 and 2.0mm deep.
10. The spool (10) according to claim 7, wherein said flanges (14) are 4.5mm thick and said debossed areas (16) are between 0.15 and 1.5mm deep.
11. The spool (10) according to any of claims 1 to 10 wherein said debossed areas (16) are substantially rectangular in shape.
12. The spool (10) according to claim 11 wherein the width of said rectangular debossed areas (16) is between 5 and 20mm.
13. The spool (10) according to any of claims 1 to 10 wherein said debossed areas (16) are truncated sectors in shape.
14. The spool (10) according to claim 13 wherein the sum of the angles subtended by said truncated sectors is between 10 and 180 degrees of arc.
15. The spool (10) according any of the above claims wherein one or both of said flanges (14) are provided with one or two or more protruding drive studs (18) for entrainment of said spool (10) during use.