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54 **A method of bending metal objects.**

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Description

The invention relates to a method of bending a metal object by locally heating the object to plasticise the metal and by cooling the object thereafter as well as by repeating the heating and cooling step.

DE-16 27 490 A describes as general prior art the orientation of metal objects by locally restricted heating of the metal object in order to produce shrinking stresses within the object. Such shrinking stresses result from upsettings because of prevented heat expansion and subsequent cooling.

The special prior art of this publication refers to bending straight cylindrical pipes into an arc by first heating an inner section of the pipe up to a plasticised state of the material and heating thereafter a corresponding outer section of the pipe joined by cooling of the sections. This sequence of steps can be repeated. Preferred is flame heating or heating by induction. Additionally, the parts between the inner section and the outer section to be heated can be cooled during heating, preferably by a protective inert gas. The locally heating sections have a shape of the surfaces similar to a rhombus, a diagonal of which extends in axial direction. This prior art method is not applicable for bending flat parallel objects especially of brittle or hard materials.

It is the object of the invention to make use of the method of the generic kind for controlled bending of plate-shaped metal objects with high accuracy of deformation.

This object is achieved with the method of the generic kind in that a plate-shaped metal object is heated and cooled, in that the local heating is carried out on one side of the plate shaped metal object along a straight line which becomes the bending line, in that the heating along the straight line is performed such that the metal is partially melted and in that the metal is plasticised and melted to a depth smaller than the thickness of the plate-shaped metal object, wherein such heating causes an outflow of metal within the region of the bending line while subsequent cooling at ambient temperature or additionally in a stream of blown gas transforms the metal into solid state and causes shrinking of the metal perpendicularly to the bending line which results in a permanent bending deformation at an angle along the bending line.

With the method according to the invention plate-shaped metal objects can be bent at a predetermined angle without exertion of external forces. Such bending is successfully carried out even if the plate-shaped object consists of a brittle material or of a material of high strength or high hardness. Further, the method can be used for

bending plate-shaped objects when access to them is difficult, i.e. under vacuum or under hazardous conditions as high tension, harmful radiation and the like.

Preferably, the heating is performed with a focussed laser radiation beam or a concentrated high-power electron beam.

It is convenient that the surface of the heated metal is covered with a substance increasing the coefficient of absorption of the flow of energy.

Referring to the attached drawings the invention is further explained by way of example.

Fig. 1 is an end view of a flat parallel plate bent according to the invention,

Fig. 2 is a side view of the flat parallel plate of Fig. 1,

Fig. 3 shows a detail of the plate of Fig. 1 during heating,

Fig. 4 shows the detail of Fig. 3 during cooling,

Fig. 5 is a graph illustrating the temperature distribution along the thickness of the plate during heating and

Fig. 6 is a graph showing the stress distribution over the thickness of the plate during cooling.

During the first phase, the metal of the plate-shaped object being bent is subject to heating with concentrated flow of energy SE of laser radiation. Application of the flow of energy SE of the laser radiation, moving at speed V along the bending line AA entails a local change in the condition of a region P of the metal characterised by different properties at depth G.

Within that region P, two zones can be observed, the material being liquid in the first zone S1 and plasticised in the second zone S2, with the boundary U of the area encompassing the melting and plasticising zones.

The temperature distribution of the heated material, as shown schematically in Fig. 5 as a function of thickness L of the object indicates additionally the material melting temperature T_m . In the heating stage the material of the first zone S1 and the second zone S2 flows out to occupy an increased volume as a result of the stresses caused by the effect of thermal expansion. This temperature distribution related to melting temperature T_m determines the size of the first zone S1 and the second zone S2 relative to material thickness L.

During the second phase the material is cooled at ambient temperature or, additionally, in a stream of a blown gas. The material within the region of the bending line, i.e. the liquid in first zone S1 and the plasticised material in the second zone S2 is transformed into solid state. The boundary of the region encompassing the plasticising and melting zone in the heating phase has been marked with

line U in Fig. 4.

Due to internal stresses σ_t caused by the shrinkage of the cooled material, it becomes shorter along the fibres marked with arrow, which is shown through the stress distribution along the thickness L of the object in Fig. 6.

In this graph, the values of limit compression σ_s and of limit tensile stress σ_r are marked. Should the limit tensile stress σ_r , for example, be exceeded, the brittle materials may crack.

The heating and cooling conditions are selected so that the tensile and compressive stresses created in the material should be much smaller than are their limit stresses. By changing the heating and cooling parameters, such as the energy flow movement speed, the power of the energy flow, the absence or presence and nature of a layer absorbing the flow of energy, etc., one may affect the temperature distribution in the heating phase (Fig. 5) and the stress distribution in the cooling phase (Fig. 6). In the abovementioned manner, control is exercised on the magnitude of the stresses created in the material in order to obtain the desired angle of bending (Figs. 1 and 4) during one cycle of heating and cooling along the bending line.

In one embodiment, the flat parallel slab shown in Figs. 1 and 2 has been subjected to a process of bending according to this present invention. The slab, 0.7 mm thick and 20 mm wide, is made of 50HSA steel and heated with a radiation beam of a continuously operating 300 W CO₂ laser, the source of energy moving along line AA (Fig. 2) at the speed of 2.5 cm/sec. The beam is directed perpendicularly to the surface of the slab.

The heating takes place under a protective argon atmosphere. The slab was cooled in the ambient atmosphere within about 1 second. With such conditions after a single heating and cooling cycle, the slab was bent at the angle σ of 2,8°.

Claims

1. A method of bending a metal object by locally heating the objects to plasticise the metal and by cooling the object thereafter as well as by repeating the heating and cooling steps, **characterized**
 - in that a plate-shaped metal object is heated (SE) and cooled,
 - in that the local heating (SE) is carried out on one side of the plate-shaped metal object along a straight line (AA) which becomes the bending line,
 - in that the heating (SE) along the straight line (AA) is performed such that the metal is partially melted (S1), and
 - in that the metal is plasticised (S2) and

melted (S1) to a depth (G) smaller than the thickness (L) of the plate-shaped metal object,

- wherein such heating (SE) causes an outflow of metal within the region of the bending line while subsequent cooling at ambient temperature or additionally in a stream of blown gas transforms the metal into solid state and causes shrinking of the metal perpendicular to the bending line, which results in a permanent bending deformation at an angle (δ) along the bending line (AA).

2. A method according to claim 1, **characterized** in that the heating (SE) is performed with a focussed laser radiation beam or a concentrated highpower electron beam.
3. A method according to claim 1 or 2, **characterized** in that the surface of the heated metal is covered with a substance increasing the coefficient of absorption of the flow of energy (SE).

Patentansprüche

1. Verfahren zum Biegen eines Gegenstands aus Metall durch lokales Erhitzen der Gegenstände, um das Metall weichzumachen, und durch anschließendes Abkühlen des Gegenstands sowie durch Wiederholung der Erhitzungs- und Abkühlschritte, dadurch **gekennzeichnet**,
 - daß ein plattenförmiger Gegenstand aus Metall erhitzt (SE) und abgekühlt wird,
 - daß das lokale Erhitzen (SE) auf einer Seite des plattenförmigen Gegenstands aus Metall längs einer geraden Linie (AA) ausgeführt wird, welche die Biegelinie wird,
 - daß das Erhitzen (SE) längs der geraden Linie (AA) so durchgeführt wird, daß das Metall teilweise geschmolzen (S1) wird und
 - daß das Metall auf eine Tiefe (G) weichgemacht (S2) und geschmolzen (S1) wird, die kleiner ist als die Dicke (L) des plattenförmigen Gegenstands aus Metall,
 - wobei ein solches Erhitzen (SE) einen Ausfluß von Metall in den Bereich der Biegelinie verursacht, während ein darauffolgendes Abkühlen bei Umgebungstemperatur oder zusätzlich in einem Blasgasstrom das Metall in den Festzustand überführt und ein Schrumpfen des Metalls senkrecht zur Biegelinie verursacht, was eine permanente Biegeverfor-

mung in einem Winkel (δ) längs der Biegelinie (AA) zur Folge hat.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das Erhitzen (SE) mit einem fokussierten Laserstrahl oder mit einem konzentrierten hochenergetischen Elektronenstrahl durchgeführt wird. 5
3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Oberfläche des erhitzten Metalls mit einer Substanz bedeckt wird, die den Absorptionskoeffizienten des Energieflusses (SE) steigert. 10
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Revendications

1. Procédé de cintrage d'un objet métallique par chauffage local de l'objet pour plastifier le métal et par refroidissement subséquent de l'objet ainsi que par répétition des étapes de chauffage et de refroidissement, caractérisé 20
- en ce qu'un objet métallique en forme de plaque est chauffé (SE) et refroidi, 25
 - en ce que le chauffage local (SE) est réalisé sur un côté de l'objet métallique en forme de plaque suivant une ligne droite (AA) qui devient la ligne de cintrage, 30
 - en ce que le chauffage (SE) le long de la ligne droite (AA) est réalisé de telle manière que le métal est partiellement fondu (S1), et 35
 - en ce que le métal est plastifié (S2) et fondu (S1) jusqu'à une profondeur (G) inférieure à l'épaisseur (L) de l'objet métallique en forme de plaque, 40
 - ce chauffage (SE) provoquant un écoulement de métal dans la région de la ligne de cintrage tandis que le refroidissement subséquent à la température ambiante ou en plus dans un courant de gaz soufflé fait passer le métal à l'état solide et provoque un retrait du métal perpendiculairement à la ligne de cintrage, ce qui entraîne une déformation de cintrage permanente sous un angle (δ) le long de la ligne de cintrage (AA). 45
2. Procédé selon la revendication 1, caractérisé en ce que le chauffage (SE) est réalisé avec un faisceau laser focalisé ou un faisceau électronique concentré de haute énergie. 50
3. Procédé selon la revendication 1 ou 2, caractérisé en ce que la surface du métal chauffé est recouverte d'une substance qui augmente le coefficient d'absorption du flux d'énergie (SE). 55

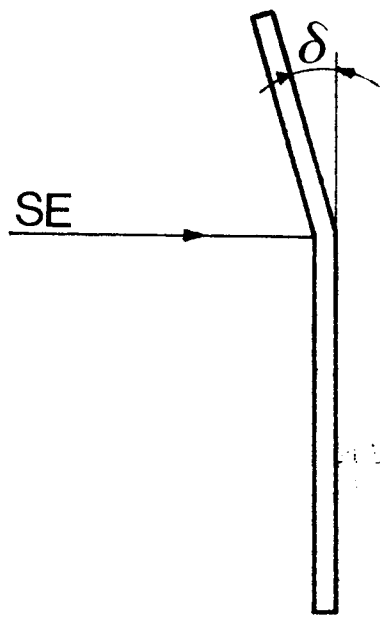


Fig.1

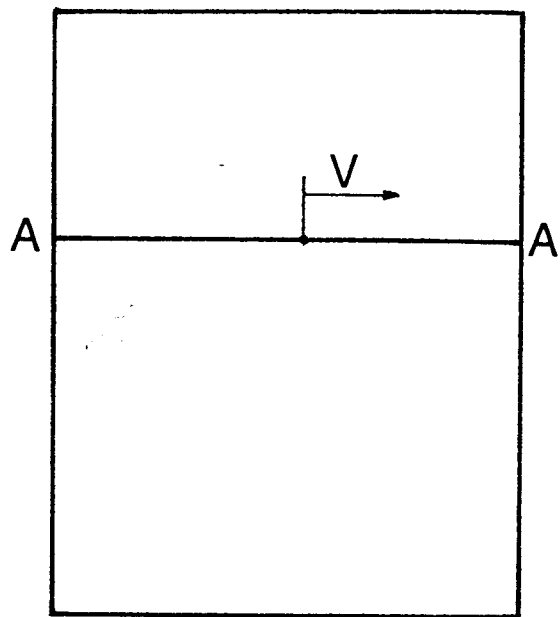


Fig.2

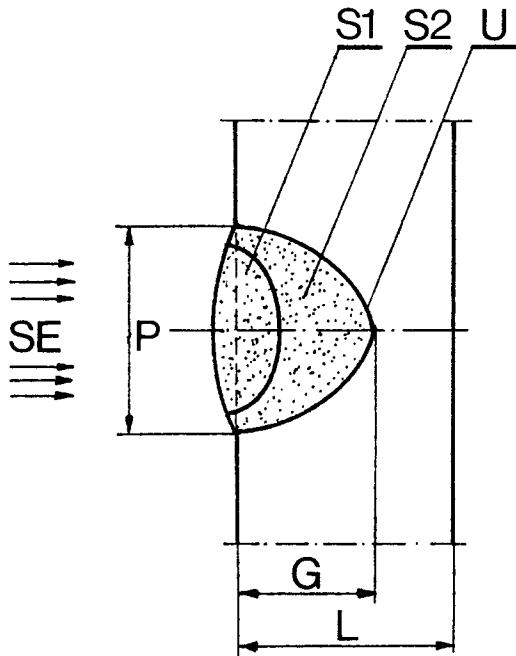


Fig. 3

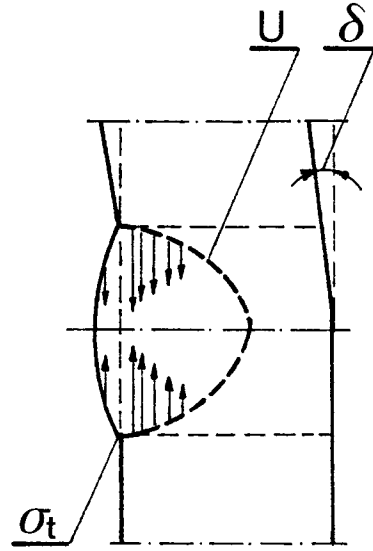


Fig. 4

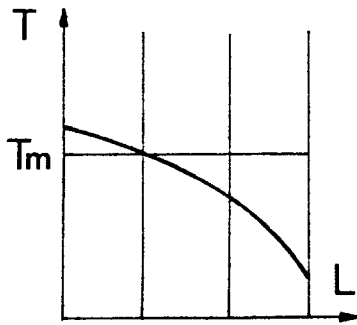


Fig. 5

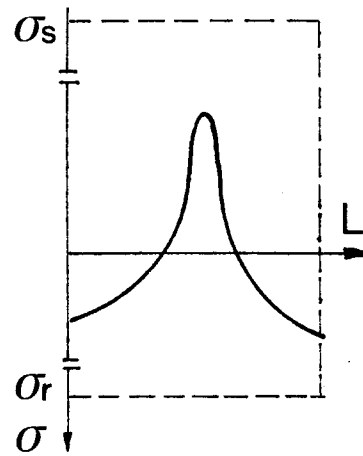


Fig. 6