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[54] **METHOD OF AN APPARATUS FOR SEMI-HOT FORMING OF METALLIC WORKPIECES IN A ROLLING OPERATION**

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April 17, 1970 Germany.....P 20 19 734.6

[52] **U.S. Cl.** **72/69,** 72/108, 72/342
[51] **Int. Cl.**.....**B21h 1/00,** B21h 3/00
[58] **Field of Search**.....72/69, 108, 342, 364

[56] **References Cited**

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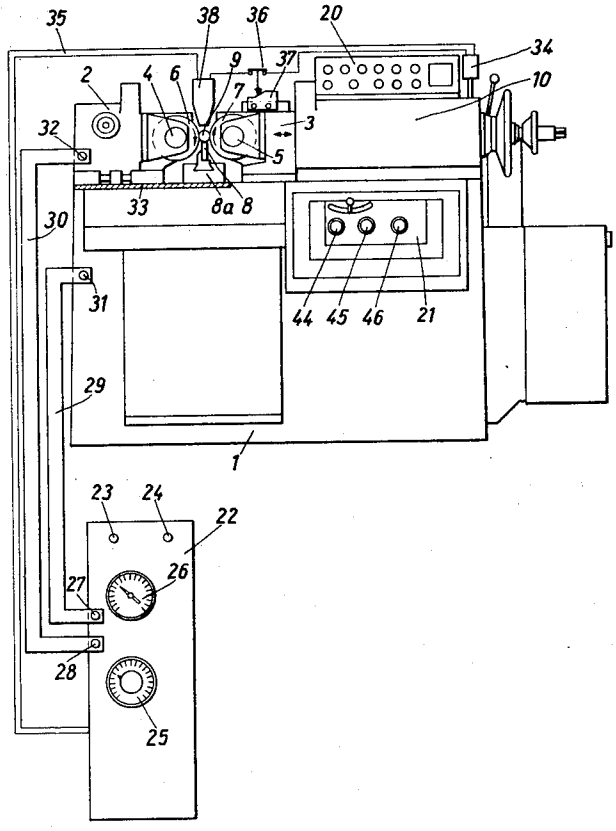
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[57] **ABSTRACT**

In a semi-hot forming operation, a workpiece is supported between two tool rollers which are rotated in the same direction. During the rotational cycle of the rollers the workpiece is first electrically preheated to a desired temperature after which the forming operation takes place. The contact pressure between the rollers and the workpiece is relatively low during the preheating operation and is increased when the roll forming takes place. To heat the workpieces effectively, the rotational speed of the roller can be varied to preheat at a regulatable reduced speed and then to form the workpiece at an increased rate of speed. The circumferential surfaces of the rollers are segmented with a smooth portion and a profile portion, with the preheating taking place when the smooth part of the rollers are in contact with the workpiece and the forming taking place when the profile portion is in contact with the workpiece.

27 Claims, 11 Drawing Figures



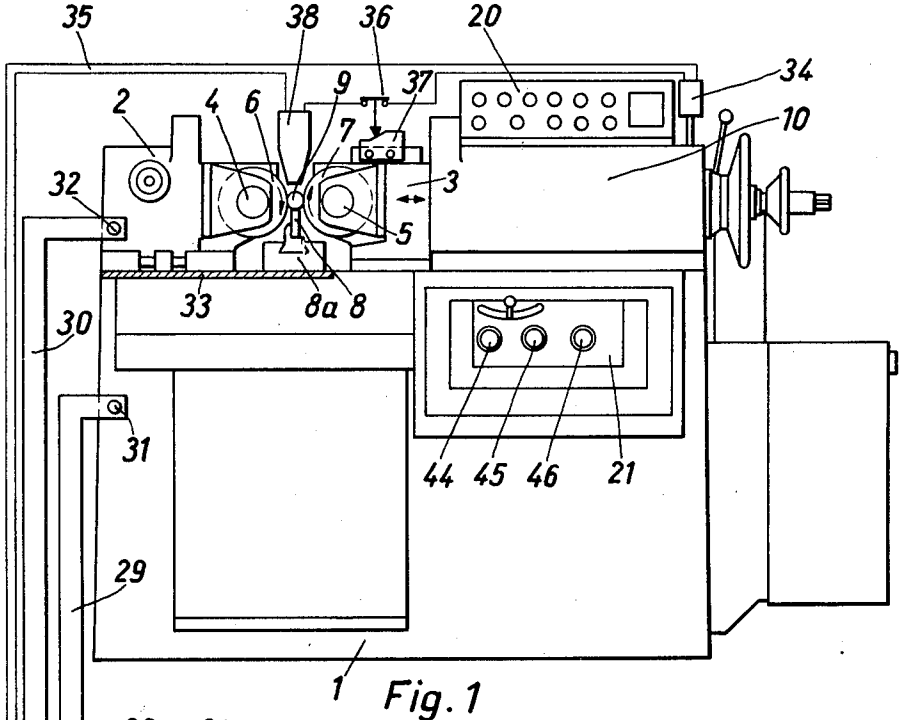


Fig. 1

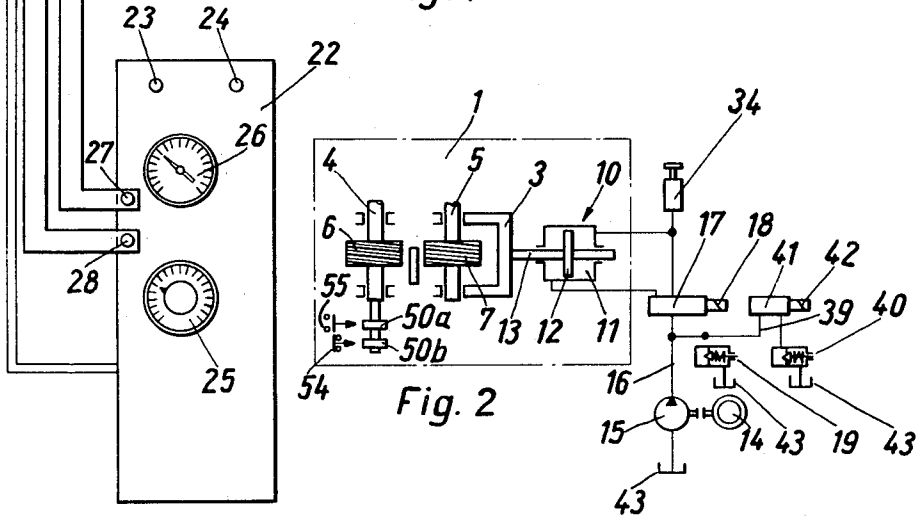


Fig. 2

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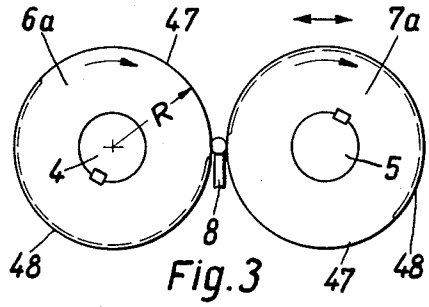


Fig. 3

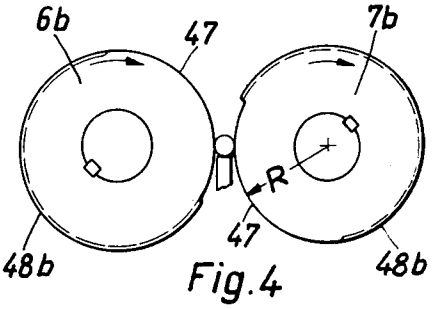


Fig. 4

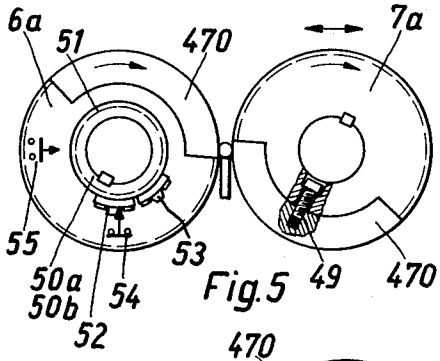


Fig. 5

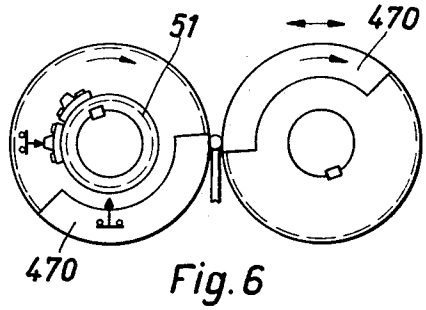


Fig. 6

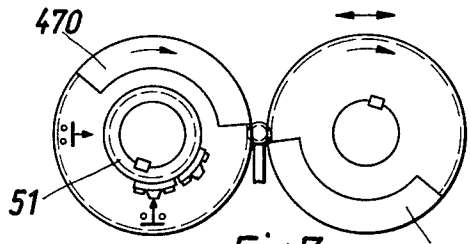


Fig. 7

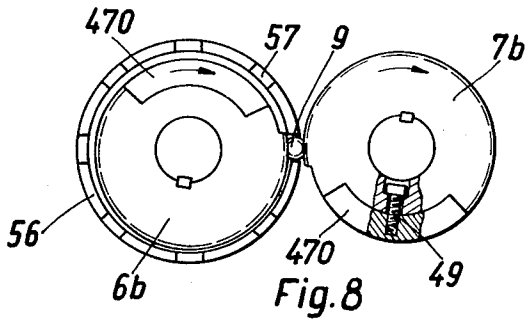


Fig. 8

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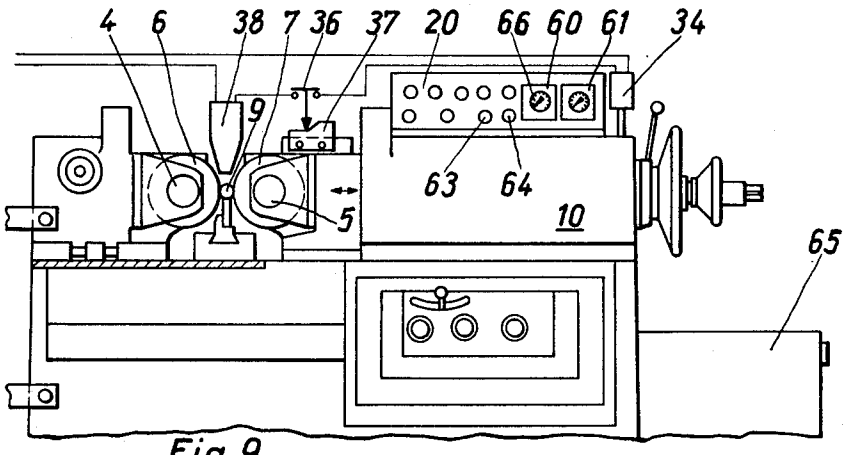


Fig. 9

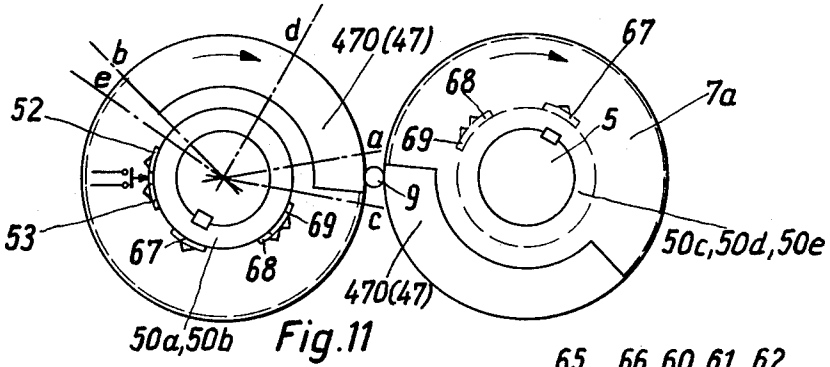


Fig. 11

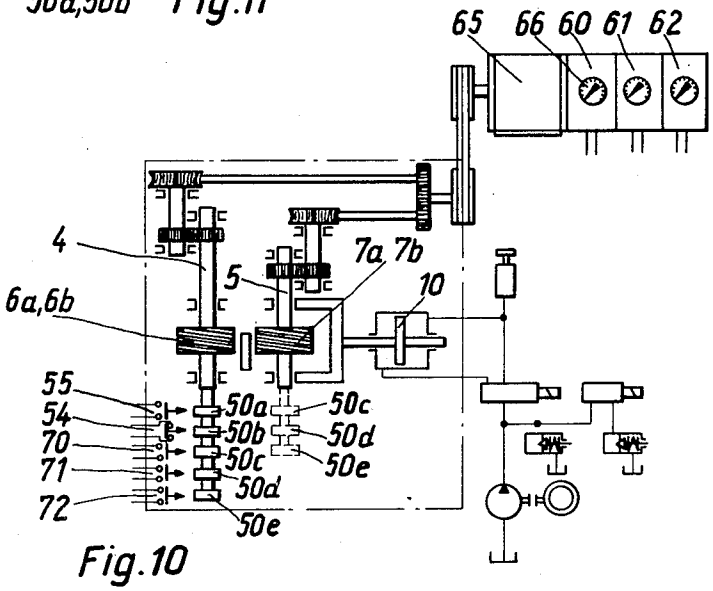


Fig. 10

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METHOD OF AN APPARATUS FOR SEMI-HOT FORMING OF METALLIC WORKPIECES IN A ROLLING OPERATION

SUMMARY OF THE INVENTION

The present invention is directed to the semi-hot forming of metallic workpieces in a rolling operation and, more particularly, it is concerned with electrically preheating the workpieces to a desired temperature while in contact with the forming rollers and also to the provision of variable pressure and variable rotational speeds of the rollers for effecting the preheating and forming operations at different pressures and speeds, respectively.

In semi-hot forming operations, the preheating temperature of the workpieces is maintained at a low level so that there is no risk of a structural change in the material after the rolled workpieces have cooled off. The preheating temperatures are below the limit at which scale will form on the material. It has been known to heat the workpieces in heating boxes and liquid baths which include meltable salt mixtures, these heating devices being located as closely as possible to the forming machine. The heated workpieces are subjected to non-cutting shaping on conventional cold-forming machines, such as thread-and-gear rolling machines. In such arrangements the workpieces are fed, usually by hand, to the machining station between the two rollers.

Another known manner of heating the workpieces involves inductive heating which takes place inside a feed duct around which a heating coil is arranged. In such an arrangement the special feeding devices are complicated and expensive.

A disadvantage in these heating operations is the necessity of feeding the workpiece, after it has been heated, to the point where the roll forming operation takes place, with the result that a certain optimum temperature cannot be maintained in the workpieces. However, to obtain uniformity in semi-hot forming, it is a prerequisite that the preheating temperature be maintained at the desired level.

Another disadvantage experienced in such forming operations is that the tool rollers, when applied to the preheated workpiece, which is at rest, deform the workpiece at the point of application and, as a result, cause a defect in the surface of the workpiece. Usually such defects cannot be eliminated during the subsequent rolling operations.

Therefore, the primary object of the present invention is to avoid the disadvantages experienced in previous semi-hot forming operations by preheating the workpieces between the forming rollers immediately preceding the forming operation so that the workpieces are uniformly heated and are in position for the forming operation.

Accordingly, in the present invention the problem of transporting the workpiece after it is preheated to the forming station is eliminated. In the present invention, since the preheating step takes place between the tool rollers, there is no feed path required for the workpiece in positioning it in the forming station. As a result, constant rolling conditions are achieved for the semi-hot forming operation and uniformly rolled end products are obtained. In this arrangement, the workpieces can be fed in the cold state to the tool rollers with the result that known available feeding devices can be utilized.

Another advantage of the method embodying the present invention is that the tool rollers are subjected to a low contact pressure with the workpiece during the heating period and form the contact points for conducting the heating current through the workpiece, and full rolling pressure is exerted on the workpiece only when the desired preheating temperature has been attained. Since the workpiece is cold at the time the tool rollers are first applied to its surface, it acts at that point the same as in the presently used cold rolling method. Initially, the feeding force is set at a low contact pressure as the workpiece rotates between the tool rollers. If the usual cylindrical rolling tools are used, the penetration of the profile tips is only a few hundredths to tenths of a millimeter. The electrical preheating starts while the rolling is performed at the initial low contact pressure and the full rolling pressure is exerted only after the preheating has been completed.

The action of contacting the tool rollers to the workpiece should be completely or substantially without current with the heating current being supplied after a delay and then reduced or cut out before the termination of the rolling process. By effecting contact without any flow of current, it is possible to avoid any arcing between the rollers and the workpiece so that the workpiece is not damaged.

With only small deformation cross sections and correspondingly small rolling paths, it is possible to reduce or to cut out the heating current shortly before the commencement of the rolling process. Otherwise, it is advantageous if the preheating temperature is kept substantially constant during the rolling process. The switching process during the semi-hot forming treatment is determined by the required preheating temperature of the workpiece which is achieved by the application of heating current to the workpiece.

It is possible to select the preheat temperature for the workpiece and to measure it as the workpiece is rotated. Further, the preheating temperature can be attained after an empirically determined number of revolutions of the tool rollers has taken place or after a predetermined heating time has elapsed. These possibilities exist when cylindrical tool rollers are used as are customary in cold forming. However, the invention is not limited to attaining the preheating temperature during a period which involves a number of revolutions of the tool rollers. Accordingly, the possibilities of preheating are particularly suitable for workpieces with a large cross section.

Where workpieces having a smaller cross section are used, which are deformed in cold rolling with so-called segment rollers in less than one revolution of the rollers, these can also be heated to the desired preheat temperature and deformed in one revolution after the workpiece has rotated through a given contact zone on the circumference of the tool rollers.

Surprisingly, it has been found that the tool rollers are not heated to any marked degree during the electrical contact transfer of the heating current to the workpiece even when there is continuous operation. Apparently, this is due to the fact that the substantially larger surface of the tool roller helps to cool it sufficiently and the transfer of heat from the heated workpiece to the tool rollers is very insignificant due to the relatively small area of contact between the workpiece and the rollers.

Usually the speed of the tool rollers is constant during a rolling operation. The number of revolutions of the workpiece depends on the diameter ratio of the tool rollers to that of the workpiece. If the workpiece experiences too many revolutions during the heating operation, changes may occur on its surfaces or cross section which will result in defects. To avoid such defects, the heating time can be reduced to decrease the number of revolutions of the workpiece. However, this is not readily possible because the heating of a workpiece to a desired temperature requires a certain minimum time which cannot be decreased for an available maximum heating current. Further, the speed of the rolling tools cannot be reduced at random, since this would be likely to impair the rolling process.

Therefore, another object of the present invention is to provide tool rollers which can be rotated at different speeds so that different speeds can be utilized for the preheating process and for the rolling process. Such variations in the rotational speed of the rollers afford a better adaptation to the required heating time of the workpiece without impairing the rolling process.

Preferably, a lower speed is used while heating the workpiece than during the rolling operation, with the speed of the tool rollers being increased to the rolling speed after the completion of the heating period. By reducing the speed of the tool rollers during the heating of the workpiece, it is possible to achieve an improved and more uniform heating of the workpiece. In addition, it has been found that the passage of the heating current through the workpiece takes place without any arcing when a lower speed is used with the advantage that no burnt spots are developed on the workpiece.

It may be advantageous if the initial speed during the heating period is at a particular low rate and then is increased at the end of the heating period. By varying the speed during the heating period, it is possible to equalize the temperature in the workpiece.

The variation in speed of the tool rollers is of particular advantage where the heating and rolling steps are completed in less than one full revolution of the rollers. The tool rollers used for effecting the semi-hot forming in less than one full revolution have a spirally shaped profiled circumferential portion on one part of the roller and a smooth concentric contact portion on the remainder of its surface. The lower speed for the heating of the workpiece is used during less than a full revolution of the tool rollers. By reducing the roller speed it is possible to maintain the exact heating time despite the relatively short contact path between the workpiece and the circumferences of the tool rollers.

Additionally, the usual tool rollers, which are profiled over their entire circumferences, can be used for the heating and rolling operations and the reduction in speed during the heating operation would be advantageous when such rollers are employed.

In carrying out the method of the present invention a rolling machine is used, particularly a thread-gear rolling machine, with at least two rollers moving relative to one another, that is, with the rollers rotating in the same direction, and a holder for the workpiece which is being formed such as is known in cold forming. The distinctive feature of the present invention is that the tool rollers are electrically insulated from one another and the workpiece holder is electrically insulated from the tool rollers and the rollers are electrically connected with a low voltage heating current unit arranged for regulating the flow of the heating current. The electrically insulated arrangement of the workpiece holder insures that the heating current traverses the workpiece between the tool rollers and heats the entire cross section of the workpiece.

The differences between such a roll forming machine and the ones used on cold-thread rolling machines is relatively minor and the changes can be provided on such known machines. Such a machine provides a fixed tool roller and a movable tool roller with the workpiece holder arranged to position a workpiece in parallel relationship with the axes of the rollers. The simplest way to arrange the machine is to insulate both the roller spindle socket of the stationary tool roller and the workpiece holder on the machine bed with the spindle socket connected to one terminal of the heating unit and the other terminal of the heating unit connected to the machine bed or support frame.

Such known rolling machines contain a hydraulic feeding device for the carriage of the movably mounted tool roller. The hydraulic feeding device provided with a pressure switch which cuts in the heating current when a low-hydraulic pressure is applied.

To cut off the heating current a temperature-monitoring device can be used, particularly one with an infrared measuring head in the heat radiation range of the workpiece, for example, aligned above the workpiece holder. The temperature monitoring device can switch the movable spindle carriage to feed or to full rolling pressure after the preselected temperature has been attained in the workpiece. Furthermore, the preheat temperature of the workpiece can be kept constant by means of an electronic control. The supply and interruption of the heating current can be effected by means of properly positioned limit switches. Such switches are particularly useful where the rollers have a non-profiled contact portion adjoining a profiled portion on their circumference. The radius of the non-profiled contact portion corresponds to the radius of the addendum circle of the adjoining profiled portion. The non-profiled contact portion can be designed as a separate part and can be formed of a contact material and be inserted into and secured within a recess in the tool rollers. Further, trip cams can be arranged in different switching planes and driven in synchronism with the tool roller for actuating the limit switches as they rotate.

The low voltage-heating unit supplies, for example, a voltage of from 12 to 42 V, and for this low voltage the corresponding high current intensity can amount to 250 A and more. At this low voltage, no safety measures are required for the machine, as far as its operation is concerned. The machine equipped for hot-forming operations has a higher output than when used for cold-forming. The semi-hot rolled workpieces meet the highest standards of precision. Semi-hot forming can be used primarily for austenitic materials as well as for titanium alloys which do not lend themselves readily to economical cold-forming.

Where the tool rollers can be rotated at different speeds during the preheating and forming operations, the drives for the roller spindles are regulated for various speeds and are connected by switching means with

at least two regulators on which different speeds can be selectively established. In this setup, it is possible to use, in succession, different speeds of the tool rollers in the preheating and the forming operations on a metallic workpiece.

If cylindrical tool rollers are used which are profiled over their entire circumference, the first regulator for the heating speed can be actuated either manually or automatically from a starting switch on a control desk, and a known heat measurement instrument can be employed for switching over to the rolling pressure and also for changing to the second regulator which determines the speed of the rollers during the forming operation.

Alternatively, if tool rollers having a contact part or contact segment are used which include two trip cams and two limit switches for supplying and interrupting the heating current, the limit switches can also be utilized for making the changeover in the speeds of the tool rollers. In providing this double function, when the limit switches close the heating circuit the lower speed of rotation of the rollers becomes effective, and when the heating circuit is opened at the end of the heating period the higher speed for the rolling operation is commenced at the same time. The double function of the switches can be eliminated if two additional trip cams and limit switches are provided on the tool roller with one pair of cams and switches supplying and interrupting the heating current while the other pair affords the switching between the selected speeds of the tool rollers independent of the supply or interruption of the heating current. With such a design of the tool roller, it is possible to compensate for any switching delays in the arrangement. For example, the rotational speed for the heating operation can be commenced and then the heating current can be connected or supplied. Similarly, at the end of the heating period the heating current can be interrupted and then the higher speed for the rolling process can be instituted.

In some cases it may be of advantage to increase the number of additional trip cams and limit switches on the tool rollers to three, in addition to the existing two trip cams and limit switches for supplying and interrupting the heating current. Accordingly, it would be possible to switch between two different speeds during the heating period, with the second speed being higher than the first and being used to equalize the temperature in the workpiece during the heating period.

The electromotor for driving the tool rollers is preferably thyristor-controlled so that the switching between different speeds can be effected without inertia and in short time intervals. Thyristor controls on electromotors are known. Instead of such controls other electronic controls can be used as well as mechanical or hydraulic regulating means.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its uses, reference should be had to the accompanying drawing and descriptive matter in which there are illustrated preferred embodiments of the invention.

DESCRIPTION OF THE DRAWING

In the Drawing:

FIG. 1 is a schematic representation of a thread-and-gear rolling machine embodying the present invention and arranged for a semi-hot forming operation;

FIG. 2 is a diagrammatic illustration of the arrangement of the hydraulic system in the machine shown in FIG. 1 with the tool rollers of the machine represented as threading rollers;

FIGS. 3 to 8 are end views of the different tool roller arrangements for use in the semi-hot forming operation as shown in FIG. 1;

FIG. 9 is a schematic representation similar to the one shown in FIG. 1, with the tool rollers arranged to be rotated at different speeds;

FIG. 10 is a diagrammatic illustration of the hydraulic system for the machine shown in FIG. 9; and

FIG. 11 is an end view of the tool rollers for use in the machine shown in FIG. 9 indicating the various positions of the trip cams as shown in FIG. 10.

DETAILED DESCRIPTION OF THE INVENTION

The rolling machine represented in FIG. 1 can operate with threading and gear cutting rollers or with other section rollers. It corresponds in its basic design to known rolling machines which have a stationary roller spindle socket 2 and a movable roller spindle carriage 3, positioned ,in a machine bed on which roller spindles 4 and 5 are mounted, operatively connected with a rotary drive (not shown) and supporting the tool rollers 6 and 7, which are driven or rotate in the same direction, as indicated by the arrows in FIG. 1 and in FIGS. 3 to 8. The axes of the rollers are disposed in parallel relationship and their circumferential peripheries are spaced apart so that a workpiece 9 can be supported between them by a workpiece holder 8 which can be of any desired form. As shown in FIG. 1 the workpiece holder 8 is a so-called rule on which the workpiece to be rolled rests. The feed of the moving tool rollers 7, represented on the right-hand side of the workpiece 9, is effected by a hydraulic feeding device 10 mounted on the machine bed 1. The hydraulic feeding device is of a known type and consists of a cylinder 11 and a piston 12 with a piston rod extending outwarding from the piston and connected to the roller spindle carriage 3, as seen in FIG. 2.

A pump 15, driven by a motor 14, supplies the pressure medium for the hydraulic feeding device 10 through a pressure line 16 to a reversing valve 17 which can be controlled in the usual manner by a solenoid 18 and controls the reciprocating movement of the roller spindle carriage 3. The rolling or forming pressure is set on a relief pressure valve 19. The rolling machine has an electric control desk 20 and a hydraulic control desk 21.

Since the above-mentioned details of the rolling machine are well known, they are not discussed in detail herein.

In accordance with the present invention, the rolling machine is equipped with a known heating device 22 which is a low voltage-heating unit and supplies a low voltage of about 12 to 42 volts with a corresponding high current intensity. The heating device has a circuit closer 23 and a circuit breaker 24, a temperature indicator 25 and an ammeter 26 as well as a pair of output terminals 27 and 28. The other parts of the heating unit are not represented since they are well known.

Conductors **29** and **30** are connected to the terminals **27** and **28**, respectively, and are selected for conducting high current intensities, for example, **250** amps or more. Conductor **29** is connected to a terminal **31** on the machine bed **1** and the other conductor **30** is connected to a terminal **32** on the stationary roller spindle socket **2**. Both the stationary roller spindle socket **2** and the workpiece holder **8** are electrically insulated from the machine bed **1** by a thick insulating plate **33**. The insulating plate **33** is arranged so that the workpiece holder **8** is secured to it and its foot **8***a* is insulated from the machine bed. In place of the rule **8** represented in FIG. **1** other devices can be used for supporting the workpiece, such as a tip receiver for receiving hollow bodies, a tilt-rolling device with a freely rotating workpiece receiver and other similar devices. Additionally, it is possible to use a so-called circular rule which surrounds the insulated roller like a cage and has a plurality of recesses about its circumference for receiving the workpieces. Such a circular rule **56** is shown in FIG. **8** of the drawing with the workpiece **9** positioned within one of the recesses **57**.

The heating current, which may be either a direct current or an alternating current, is conducted over the roller spindle socket bearings to the rotating tool rollers **6** and **7** and traverses the workpiece **9** in its transverse direction while the workpiece is rotated between the rollers.

In the hydraulic feeding device for the rolling machine, as shown in FIG. **2**, a pressure switch **34** which is also called a pressure monitor is connected through lines **35**, see FIG. **1**, with the heating device **22**. Disposed in series with the pressure monitor **34** is a circuit breaker **36** which responds to the depth of the roller and is actuated by a trip cam **37** connected to the roller spindle carriage **3**. Further, a temperature measuring instrument **38** of a known design, preferably an infrared measuring instrument, is positioned in the line **35** and is located adjacent the workpiece disposed between the rollers **6** and **7**. The instrument **38** is located in the radiation range of the preheated workpiece for measuring the temperature of the workpiece **9**.

It can be noted in FIG. **2** that a second relief pressure valve **40** is connected through the line **39** with the pressure relief valve **19** for determining the pressure applied to the roller **7** through the carriage **3**. A shut-off valve **41** is positioned in the line **39** and is actuated by a solenoid **42**. The solenoid-controlled shut-off valve **41** either admits the flow to the second pressure relief valve **40** or interrupts the flow. Where flow is admitted to the second pressure relief valve **40**, the valve is set to a pressure lower than the pressure used in the forming operation, and when it is operative it determines the low contact pressure acting through the hydraulic feeding device **10**. When the shut-off valve **41** is closed, the second pressure relief valve is inoperative and the higher forming pressure is supplied through the first pressure relief valve **19**. The discharge lines from the two pressure relief valves lead into the common sump **43**.

Knobs **44**, **45** and **46** are arranged on the hydraulic control desk **21** of the rolling machine for setting the rolling or forming pressure and the contact pressure and for initiating the feed of the movable roller **7**. Initially, the reversing valve **17** is set for forward feed and ordinary switches (not represented) or limit switches are used for the control of this valve. At the outset, the shut-off valve **41** is open and the second pressure relief valve **40** for supplying the contact pressure for the preheating operation is operative. The roller spindle carriage **3** carries the tool roller **7** toward the advancing workpiece and positions the workpiece between it and the stationary roller **6** at the predetermined contact pressure. With the workpiece in position, in contact with the rollers **6** and **7**, the pressure monitor **34** cuts in the heating current with a delay. The workpiece is heated to the preheat temperature, which is measured and monitored by the infrared measuring instrument **38**. When the desired temperature is reached, the shut-off valve **41** is actuated electromagnetically over the control line **35** and the pressure relief valve **19** for establishing the forming or rolling pressure is cut in. Simultaneously, either the current is cut out or shortly before the end of the rolling process the heating current is interrupted by the circuit breaker **36**. The preheat temperature can be kept constant automatically during the rolling process by a known electronic control. The electronic control would be arranged in the heating unit **22** and is known as such.

Instead of the normal cylindrical rolling tools, where the preheating of the workpiece is effected generally in several revolutions of the tool rollers, the preheating temperature can also be attained in less than one revolution where the workpiece is rotated in contact with a given zone on the circumference of the tool rollers. These special rollers are illustrated in FIGS. **3** to **8**.

FIG. **3** shows two cylindrical tool rollers **6**a and **7***a* and FIG. **4** shows two segment rollers **6***b* and **7***b*. The tool rollers of each pair are identical, accordingly, only one of them will be described. The cylindrical tool rollers shown in FIG. **3** have, on their circumference, a non-profiled concentric contact portion **47** which is followed by a circumferentially extending profiled portion **48**. The radius R of the non-profiled contact portion **47** corresponds to the radius of the addendum circle of the adjoining profiled portion **48**. As can be easily noted, the non-profiled contact portion **47** extends over a smaller angular portion of the circumference than does the profiled section **48**. The angular dimension of the contact zone about the circumference of the tool roller can vary in accordance with the existing conditions. The non-profiled contact portion is designed as a part of a smooth cylindrical barrel. Therefore, the workpiece supported on the holder **8** between the tool rollers **6***a* and **7***a* is in complete contact bearing with the rollers and as a result is heated more uniformly and faster than between the profiled tips of the known tool rollers. In this arrangement, it is possible to heat the workpiece to the preheat temperature in only a part of one revolution of the tool rollers and then to complete the roll forming of the workpiece during the remainder of the revolution.

In FIG. **4**, the segment rollers **6***b* and **7***b* are provided on their circumference with a non-profiled concentric contact portion **47** and an adjoining profiled portion **48***b* and the radius of the addendum circle of the profiled portion corresponds to the radius R of the non-profiled contact portion **47**. The profiled portion **48***b* rises from the non-profiled portion, as is customary in

segment rollers. The rollers are arranged, as usual, a fixed distance apart corresponding to the diameter of the workpiece. The reciprocating movement of the roller spindle carriage required in cylindrical rolling tools is not necessary in this arrangement.

The contact portion **47** of the rollers can be designed in cylindrical rollers and in segment rollers as a separate part. The separate part consists of a contact material and is inserted and secured within a corresponding recess in the tool rollers. For example, the contact section can be formed of a hard bronze. In FIGS. **5** to **8**, the contact segment is designated as **470** and, as shown in FIG. **5**, it is secured in place by screws **49** introduced through bores in the roller.

For these special rollers two supporting rings **50***a* and **50***b* are arranged in side by side relationship on the extension of the roller spindle of the stationary tool roller, that is, the left-hand roller in FIG. **5**. The supporting rings **50**a and **50**b carry trip cams **52** and **53** which can be adjusted in circular grooves **51** and in turn are associated with limits switches **54** and **55**. These limit switches serve to supply and interrupt the flow of heating current as well as controlling the feeding force which initially supplies the contact pressure between the rollers and the workpiece and after the preheat temperature has been reached provides the rolling or forming pressure. The limit switches can replace the temperature measuring instrument **38**.

In FIGS. **5**, **6** and **7**, the various positions of the rollers **6***a* and **7***a* are shown for the preheating and forming operations. FIG. **5** illustrates the starting point when the tool rollers produce the contact pressure against the workpiece and the preheating is commenced. In FIG. **6**, the position of the rollers is shown at the end of the preheating stage and that the commencement of the semi-hot forming stage while FIG. **7** represents the end of the semi-hot forming stage.

FIG. **8** shows two segment rollers **6***b* and **7***b* with the inserted contact segments **470**. The left-hand or stationary segment roller **6***b*, which could also be a cylindrical roller **6***a*, is surrounded by a circular rule **56** with recesses **57** for the workpieces **9** to be rolled. In this arrangement, the tool roller and the circular rule **56** are insulated from the machine frame **1**.

The tool rollers represented are shown by way of example and are not intended to limit the configuration of the rollers which could be used in the present invention.

In FIG. **9**, a rolling machine is represented similar to that shown in FIG. **1** and corresponding parts in FIG. **9** have the same reference numerals as in FIG. **1**. On the electric control desk **20** two regulators **60** and **61** are located for selecting and setting the speeds at which the tool rollers **6** and **7** rotate. In addition, a start switch **63** and a stop switch **64** are arranged on the control desk. A driving motor **65** drives the roller spindles **4** and **5** which in turn drive the rollers **6** and **7** whose speeds are set on the regulators **60**, **61**. The driving motor **65** is, for example, a variable speed motor with a known thyristor control. However, instead of the variable speed motor a known variable speed transmission can be provided. The switching means shown in FIG. **9**, that is, the heat measuring instrument **38** and the limit switch **36** are characteristic of the means employed in conventional cylindrical tool rollers which are profiled about their entire circumference. The first regulator **60** which determines the speed of rotation of the rollers during the heating of the workpiece is initiated either by hand or automatically by actuating the start switch **63**. The heating current, as explained previously, flows through the contact-making tool rollers **6** and **7**, transversely across the workpiece **9**, heating the workpiece as it is rotated between the driven tool rollers. When the preheat temperature of the workpiece is reached, the heat measuring instrument **38** responds and changes the feed pressure on the movable roller **7** for changing over from the contact pressure maintained during the heating operation to the rolling pressure exerted during the forming operation. In addition, the instrument **38** also switches over to the second regulator **61** for establishing the speed of the rollers during the forming operation. The regulators are set to different predetermined speeds of the roller spindles and the speeds can be read from the scales **66** on the regulators. During the heating period of the workpiece **9** the speed of the rollers **6** and **7** is considerably reduced relative to the normal rolling speed, that is, the circumferential speed of the rollers in the forming operation. This means that the heating of the workpiece by the passage of heating current is effected at a lower speed than the speed of the rollers during the forming operation which is determined by the speed set on the regulator **61**.

In FIG. **10**, the arrangement of the hydraulic feed device is shown which is similar to the arrangement illustrated in FIG. **2** and similar parts have the same reference numerals. The hydraulic feeding device **10** is associated with the variable speed motor **65** which is provided with three variable speed regulators **60**, **61** and **62**. The regulators, as represented in FIG. **10** can be positioned on the motor **65**, or, as shown in FIG. **9**, they can be located on the control desk **20**. The tool rollers shown in FIG. **11** are similar to those illustrated in FIG. **3** and have a partly profiled circumferential portion and a contact part extending about the circumferential periphery of the roller. In this arrangement, either of the rollers **6***a*, **7***a* and **6***b*, **7***b* of FIGS. **3** to **8** could be used. As shown in FIG. **11**, the workpiece is heated as it passes through the contact zone **470** (**47**) and the forming takes place as the workpiece is in contact with the profiled portion of the circumference. The non-profiled or smooth portion of the circumference of the roller occupies less than half of the circumference and the remainder is taken up by the profiled portion.

The supporting rings **50***a* and **50***b* carry trip cams **52** and **53** which are associated with the limit switches **54**, **55** for supplying and interrupting the flow of heating current and for switching between the contact pressure used during heating and the higher pressure used during the forming operation.

Further, for controlling the speed, three additional supporting rings **50***c*, **50***d*, and **50***e* are provided either on the extension of the roller spindle **4** or on a similar extension of the roller spindle **5** which is driven in synchronization with the roller spindle **4**. These additional supporting rings carry adjustable trip cams **67**, **68** and **69**, as seen in FIG. **11**, which are associated with the limit switches **70**, **71** and **72**.

In FIG. **11**, the switching positions of the five limit switches are shown schematically. The positions *a*, *b*, *c*, *d* and *e* are represented by radial dot dash lines on the

left-hand roller, that is, the stationary roller as shown in FIG. 9. In position a the heating current is cut in by the limit switch 54. In position b the heating current is cut out or intercepted and the rolling pressure is supplied through the movable roller 7*a* at the pressure required for the forming operation. In position c the contact pressure is initiated and the lower speed for heating the workpiece is set by the limit switch 70. In position d the roller speed is increased for heating and equalizing the temperature in the workpiece by means of the limit switch 71. In position e the higher speed utilized in the forming operation is initiated by the limit switch 72. The increased speed used at the latter part of the heating operation according to position d is set on the regulator 62 in FIG. 10. This intermediate speed can be eliminated if only one speed is used during the heating period. The commencement of the contact pressure and of the speed of the rollers for the heating operation in position *c* is effected in advance of position a where the heating current is impressed across the rollers. In this manner it is possible to compensate any switching delay in the drive of the tool rollers. On the other hand, the speed of the rollers for the rolling or forming speed in position e is started only shortly after the heating current is disconnected and the rolling pressure is initiated. In this way an arc-free passage is achieved from the contact segment 470 to the leading end of the profiled part of the rollers.

In a simplified arrangement of the invention, the two limit switches for supplying and interrupting the heating current can also switch the speeds of the rollers.

The arrangement is not limited to the embodiments represented and various alternative arrangements can be employed, for example, the supporting rings for the trip cams can be arranged on the end faces of the rollers and can be rigidly connected with them.

We claim:

1. Method for the semi-hot forming of metallic workpieces by a rolling process, involving electrically heating the workpieces by a heating current to a preheat temperature and then subjecting the workpieces to a non-cutting shaping by a rolling pressure exerted between a pair of tool rollers, the improvement comprising the steps of preheating the workpieces to the desired temperature by transmitting the heating current to the workpieces through the tool rollers, while rotating the workpieces between the tool rollers, and, immediately following the preheating step, continuing the rotating of the workpieces between the tool rollers and roll-forming the workpieces.

2. Method, as set forth in claim 1, comprising the step of varying the contact pressure applied by the tool rollers to the workpiece between a first contact pressure and a higher contact pressure, utilizing the first contact pressure while preheating the workpieces and applying the higher contact pressure while roll forming the workpieces.

3. Method, as set forth in claim 1, comprising the step of contacting the tool rollers to the workpieces before applying heating current and cutting off the heating current before removing the tool rollers from contact after the completion of the roll forming operation to avoid any arcing when contact between the tool rollers and workpieces is made and broken.

4. Method, as set forth in claim 1, comprising the step of cutting off the supply of heating current before commencing the roll forming step.

5. Method, as set forth in claim 1, comprising decreasing the supply of heating current before commencing the roll forming operation.

6. Method, as set forth in claim 1, comprising the step of maintaining the level of the preheat temperature substantially constant during the roll forming operation.

7. Method, as set forth in claim 1, comprising the steps of establishing a preselected preheat temperature, and measuring the temperature of the workpieces during preheating for maintaining the temperature at the desired preselected level.

8. Method, as set forth in claim 1, comprising the step of rotating the tool rollers through several revolutions while preheating the workpieces.

9. Method, as set forth in claim 1, comprising the step of completing the preheating of the workpieces within a preset time period as the workpieces are rotated by the tool rollers.

10. Method, as set forth in claim 1, comprising the step of completing the preheating and roll forming steps during one complete revolution of the tool rollers.

11. Method for the semi-hot forming of metallic workpieces by a rolling process involving electrically heating the workpieces by a heating current to a preheat temperature and then subjecting the workpieces to a non-cutting shaping by a rolling pressure exerted between a pair of tool rollers, wherein the improvement comprises the steps of preheating the workpieces to the desired temperature while rotating the workpieces between the tool rollers, immediately following the preheating step, continuing the rotating of the workpieces between the tool rollers and roll forming the workpieces, completing the preheating and roll-forming steps to be in one complete revolution of the tool rollers, forming a smooth surfaced circumferentially extending segmental portion on the circumferential periphery of the tool rollers and forming a profiled surface circumferentially extending segmental portion on the remaining circumferential periphery of the tool rollers, supporting the workpiece in contact with the surfaces of the tool rollers, preheating the workpiece while it is rotated in contact with the smooth surfaced portion of the tool rollers, and completing the forming operation during the remainder of one revolution while the workpiece is in contact with the profiled surface of the tool rollers.

12. Method, as set forth in claim 1, comprising the step of varying the rotational speed of the tool rollers during the preheating step as compared to the rotational speed of the tool rollers during the roll forming step.

13. Method, as set forth in claim 12, comprising the steps of rotating the tool rollers and thereby rotating the workpiece at a first rate of speed during the preheating step, and increasing the rate of speed of rotation of the tool rollers to a higher second speed during the roll forming step.

14. Method, as set forth in claim 13, comprising the step of varying the rotational speed of the tool rollers during one complete revolution thereof from the first speed where the preheating of the workpiece takes

place during a portion of one complete revolution and the second speed where the roll forming of the workpiece is completed during the remainder of one complete revolution in which the preheating has been accomplished.

15. Rolling machine for carrying out semi-hot forming of metallic workpieces comprising a pair of tool rollers having their axes disposed in parallel relationship so that the circumferential surfaces of said rollers are spaced apart for receiving a workpiece therebetween in parallel relationship with the axes of said rollers and in contact with the circumferential surfaces of said rollers, said rollers arranged to rotate in the same direction and at least one of said rollers being laterally displaceable relative to the other said roller, a support member for said rollers, means for supporting the workpiece in position between said rollers mounted on said support member, a low-voltage electrical heating unit connected to said rollers, means for electrically insulating said rollers from one another, and means in communication with said heating unit for regulating the supply of heating current to said rollers.

16. Rolling machine, as set forth in claim 15, wherein said means for electrically insulating said rollers from one another comprises an insulating plate mounted on said support member, said pair of tool rollers comprising a stationary tool roller mounted on said insulating plate and insulated from said support member by said plate and a movable tool roller directly mounted on said support member, said means for supporting the workpiece comprising a workpiece holder mounted on said insulating plate and insulated from said support member, said heating unit comprising a first cable connection connected to said stationary tool roller and a second cable connection connected to said support member whereby heating current is supplied to said rollers while said rollers are insulated from one another.

17. Rolling machine, as set forth in claim 15, wherein means are arranged for effecting a variable supply of pressure to said movable roller for varying the contact pressure exerted by said pair of rollers on the workpiece, a pressure switch operatively connected to said means for supplying variable pressure to said movable roller, said pressure switch being electrically connected to said heating unit, whereby a lower hydraulic pressure is supplied to said movable roller for heating the workpiece compared to the pressure supplied to said movable roller for forming the workpiece and said pressure switch is arranged to cut in the heating current with a delay after said movable roller contacts the workpiece and effects the lower contact pressure on the workpiece in combination with said stationary roller.

18. Rolling machine, as set forth in claim 15, wherein a temperature measuring device is positioned adjacent the location of the workpiece between said rollers in the heat radiation range of the workpiece and a circuit breaker connected in series electrically with said temperature measuring device whereby the supply of heating current to said rollers can be terminated.

19. Rolling machine, as set forth in claim 15, wherein each said roller of said pair of rollers comprises a first circumferentially extending portion covering an equal angular part of each said roller, and a second circumferentially extending portion covering the remainder of the circumferential periphery of each said roller, said first circumferentially extending portion having a smooth concentrically arranged surface, and said second circumferentially extending portion having a profiled surface and the radius of said first circumferentially extending portion corresponding to the radius of the roller from which the profiled second circumferentially extending portion is formed.

20. Rolling machine, as set forth in claim 19, wherein each of said rollers has a circumferentially extending recess formed therein which is equal to the angular extent of said first circumferentially extending portion, said first circumferentially extending portion comprising a separate contact member positioned within said recess, and means for securing said separate first circumferentially extending portion within said recess.

21. Rolling machine, as set forth in claim 19, wherein a plurality of support rings is mounted on said rollers and spaced axially from the location of contact between said rollers and the workpiece, a trip cam mounted on each of said support rings and spaced angularly apart on the periphery of said rings, and a limit switch for each said trip cam positioned in the path of said trip cam as it rotates with said roller for supplying and interrupting the flow of heating current to said rollers.

22. Rolling machine, as set forth in claim 15, wherein means are arranged for varying the rotational speed of said tool rollers so that said tool rollers can rotate at the same speeds and the rotational speed can be varied between at least two different speeds while said rollers are positioned in contact with the workpiece.

23. Rolling machine, as set forth in claim 22, wherein each of said pair of rollers is profiled over its entire circumferential periphery, means for regulating the speeds of said rollers, and means for rotating said rollers at a first speed while said heating unit heats the workpiece and for switching to a second increased speed while said rollers form the heated workpiece.

24. Rolling machine, as set forth in claim 22, wherein said means for regulating the supply of heat current to said rollers comprises a plurality of trip cams associated with one of said rollers, and a limit switch positioned in the path of each said trip cam for supplying and interrupting the flow of heating current to said rollers, and said limit switches are arranged operatively connected to said means for varying the rotational speed of said tool rollers so that said trip cams can also effect the change in the rotational speed of said rollers as said rollers rotate.

25. Rolling machine, as set forth in claim 22, wherein the circumferential peripheral surface of each of said rollers is composed of two portions, one of said portions is smooth and the other said portion is profiled, trip cams associated with one of said rollers and a limit switch arranged in the path of each of said trip cams so that as said roller with said trip cams is rotated said limit switches effect the change in rotational speed of said tool rollers.

26. Rolling machine, as set forth in claim 25, wherein at least one additional trip cam is provided on said roller and a limit switch is arranged in the path of said additional trip cam, said additional trip cam being arranged to contact its associated said limit switch as the

smooth surface portion of said rollers is in contact with the workpiece for effecting an increase in speed in said rollers during the period of contact between the workpiece and the smooth surface portion of said rollers.

27. Rolling machine, as set forth in claim 22, wherein a thyristor-controlled electromotor is arranged for driving said tool rollers.

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