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Andrij Dzyubyk[1], Liudmyla Dzyubyk[2], Yaroslav Zinko[3], Oleh Dzhaliuk[4],

[1] Department of Oil and Gas Engineering and Welding, Lviv Polytechnic National University, 12, S. Bandery str., Lviv, Ukraine, e-mail: andrii.r.dziubyk@lpnu.ua, ORCID: 0000-0003-2091-171X
[2] Department of Technical Mechanics and Dynamics of Machines, Lviv Polytechnic National University, 12, S. Bandery str., Lviv, Ukraine, e-mail: liudmyla.v.dziubyk@lpnu.ua, ORCID: 0000-0001-6942-9436
[3] Department of Technical Mechanics and Dynamics of Machines, Lviv Polytechnic National University, 12, S. Bandery str., Lviv, Ukraine, e-mail: yaroslav.a.zinko@lpnu.ua, ORCID: 0009-0002-4682-6863
[4] Department of Oil and Gas Engineering and Welding, Lviv Polytechnic National University, 12, S. Bandery str., Lviv, Ukraine, e-mail: oleh.dzhaliuk.mmptz.2022@lpnu.ua, ORCID: 0009-0009-7093-6166

TECHNOLOGICAL FEATURES OF RESTORATION OF RIMS OF SUPPORT ROLLERS FOR TRACKED VEHICLES

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Abstract. The use of tracked (caterpillar) vehicles enables us to meet the requirements concerning harmless impact upon the environment, the considerable amounts of work to be fulfilled being saved. In particular, as compared to wheeled vehicles, there is less pressure upon the ground; there is also the opportunity to work in specific conditions of marshy, sandy, and low-bearing soils; stable performance in hard climatic conditions, etc. is also possible there. A necessary and important part of the tracked vehicle is its special suspension. Such a suspension contributes to smoother motion of the mechanism, it also cushions shocks, and ensures transmission of motion from the engine to the tracks. Independently of the design of the suspension, there are always several couples of support rollers. These rollers make up the intermediate link between the mover and the carrier frame, they transmit not only great weight but also the created loading, they guide the tractor's caterpillars, etc. In the course of their work, the support rollers of tracked vehicles experience intensive wear and tear of the outer surface of their rims. As a result, changing them is necessary; dismounted ones are to be repaired.

The use of restorative technology through overlaying (building up) by means of the electric arc is considered in this paper. This enables us to ensure cost savings and to repair support rollers of hardly loaded track vehicles. It is also possible to increase their serviceability by optimizing the overlayed metal; in particular, by increasing the hardness of the overlayed layer and increasing its resistance against impact and abrasive wear.

The weldability of the main metal of a support roller has been analyzed. It is shown that the use of high-carbon material complicates the conditions for overlaying the outer rim. It is necessary to use pre-heating to high temperatures. This reduces the tendency of the material to form hardening structures and cracks after the overlaying.

Investigations of peculiarities of overlaying a cylindrical surface of the rim of a tractor's roller have been conducted. In particular, the limit values of the length of a weld pool depending on the diameter (value of wear) of the overlayed rim of a roller have been determined. It is shown that it is necessary to carry out the displacement of the arc from the zenith. This ensures the necessary formation of the weld-pool and the absence of spreading of the metal overlayed on the rim.

The determination of the value of heat input of overlaying a roller has been carried out, the heat input is considered as a function of parameters of the electrode wire. Verification calculation of the obtained values of specific power for the permissible length of the weld-pool has been conducted. Concretization of the obtained results was carried out by taking into account the optimal range and permissible rate of cooling in overlaying the main material of a support roller. According to special nomograms, the dependence between the rate of cooling and the heat input of overlaying has been established.

Especially, there were investigated the temperature conditions during overlaying the weld beads. It is shown that heating the roller takes place at the expense of neighboring weld beads. It is established that in overlaying at the determined values of heat input (per unit length) there can be achieved the temperature of auto heating is sufficient for the pre-heating of a roller.

Keywords: support roller of a tracked vehicle, the rim of the roller, overlaying on a roller, wear and tear of support rollers, electric-arc overlaying, heat input in welding, electrode core-wires, wear-resisting coatings, heat affected zone, heating for overlaying, hardening structures, weld pool.

Introduction

Modern special and general-purpose vehicles widely use caterpillar undercarriages. This makes it possible to reduce the pressure onto the ground, improves their cross-country ability, and expands their scope (hard meteorological conditions, marshy grounds, highlands, the same-type cumbersome works, etc.). Universal and special tractors are considered to be the most widely used caterpillar vehicles [1, 2]. In the process of their work, they create less pressure on the ground, ensure better cross-country ability, higher efficiency, etc. Such tractors are used in regions of low load-bearing capacity where it is necessary to carry out considerable amounts of work without the danger of being jammed in hard meteorological conditions. With this, the transportation to places of their work is mainly carried out by wheel transport. This improves the mobility of tracked vehicles and does not damage the roadway covering.

Results of operation and analysis of conditions of work of tracked vehicles indicate that the undercarriage experiences considerable influences. The cause of this is their focus on continuous operation in the field, where soil intrusion from the outside and the ingress of various dirt and precipitation is a common occurrence. As a consequence, there takes place intensive abrasive wear, often under considerable shock, dynamic and static loads. With this, the support parts such as rollers are one of the most highly loaded parts of the undercarriage. They constantly work under the aforesaid conditions; and therefore, the problem of repair arises not only in the stages of scheduled inspections but also in the process of operating the vehicles [2, 3]. The wear of rims of support rollers, pitting (flaking destruction), and fracture lead to redistribution of working loads on the suspension, on the bearing frame, and finally on the mover. All these harmfully influence the work of the machine and reduces its resource.

It is known [4–6] that in the cost structure of the repair technology, a significant part of the costs (60–70 %) is spent on the purchase of spare parts. With this, under market conditions, the wide nomenclature of products is not always ensured with the necessary quality of machine parts.

The cause of this is the fact in manufacturing the spare parts the manufacturers try to combine the following two principles: reduction in the cost with a maximal approach to technical requirements and quality of the structure. Therefore, the main trend of reduction of the cost of repairs of vehicles is focused on the introduction of repair technologies and on the restoration of worn parts. This provides essential savings, and the cost of the restoration depends on the complexity of the technological process, on its mass character, and on the level of mechanization. According to literature data [3–5], the cost of restoration of a machine part ranges between 20 % and 60 % of that of the new part. This also essentially reduces the load for global manufacturing and saves resources of labor and row materials. As compared to expenditures on the restoration of an already existing element, the expenditures on obtaining new amounts of metal and other materials are several times greater. It is also known that in remelting of weared machine parts, the possible wastes amount up to 30 % [5].

In special literature [6, 7], there is shown that the service life of a tractor's roller can be several times different: 400 through 2000 hours. With this, the crucial factor is the conditions under which it works and the character of loading. It is the rim of a roller that is most often destroyed due to the soil which enters the space between the roller and the track. With this, in places of transition to the track belt, a local overload is possible due to single stones, etc.

It is known [2–7] that the application of various repair operations makes it possible to restore the functional properties and geometric characteristics of machine parts. In this, it is possible to get results that exceed basic values. With regard to the considerable mass of a support roller, its design, and the technology of its manufacturing (cast cylindrical element with spokes), the production of a new one is rather expensive.

The cost of repaired machine parts is less than that of new ones. In such a way, prolongation of service life and, at the same time, improvement of economic conditions are achieved.

Nowadays, there are developed highly productive technologies for the restoration of geometric characteristics of rims of support rollers by means of the following ways: automatic overlaying on weared layers, fit and welding on of special bandages, electro slag facing, spreading with liquid metal, etc. [3, 7, 8]. This is caused by a considerable program of restoration of support rollers, several couples of which are undercarriage in each balance carriage; wherein tracked vehicles are of considerable application in industry. However, highly productive technologies require the organization of specialized jobs, specially trained personnel, and rhythmic loading for the payback of the process. Taking into account the expansion of the range of the used tracked vehicles and the need to organize quick repairs, repair works are often carried out by means of universal equipment. In the aforesaid case, it is simple to organize electricarc processes in repair workshops; such a process does not call for the use of highly-specialized equipment; there is no need for special technological processes either. At the same time, the base metal of a support roller used for track rollers is characterized by an increased tendency to form structures of hardening after overlaying. There may be the formation of a technological crack, which worsens the performance of the product. The provision of special conditions of overlaying to achieve the required quality is studied in this work.

Object and subject of research

The object of our investigation is a worn support roller of a track vehicle. The subject matter of the investigation is the restoration of the rim of the support roller and of its working characteristics by electricarc overlaying.

Purpose and Objectives of the Study

The aim of the investigations carried out is to ensure the working characteristics of the rim of a roller restored by an electric arc, the geometric characteristics as well as properties of the base material are taken into account.

To achieve this aim, the following tasks were solved in this work:

– to investigate weldability of the material of a roller of the tracked vehicle with taking into account the chemical composition of the material;

– to study the peculiarities of the formation of a zone of thermal influence in overlaying on the weared rim of a roller and to determine the permissible range of base material cooling rates;

– to investigate the permissible value of heat input (per unit length) of the rim of a roller of a tracked vehicle;

– to determine the necessary deposited materials and technological features of the restoration of the weared rim of a support roller.

The practical significance of the obtained results

Investigations of the material of a roller by the chemical composition of the latter have indicated that the steel is characterized by poor weldability. Usually, the process of overlaying calls for the application of pre-heating followed by post-welding thermal treatment. A study of the cooling rate during overlaying on the roller was carried out based on the optimal range and the permissible cooling rate. There were taken into account the formation of the necessary structure of the welded joint in the zone of thermal influence and the resistance to cold cracks. According to special nomograms, the dependence between the cooling rate and the heat input (per unit length) of the overlaying is established. Calculation of the heat input (per unit length) of overlaying (surfacing) the first welding bead in the restoration of the rim of a roller according to the given value of the cross-sectional area of the welding wire has been carried out.

Calculation of temperature conditions for overlaying (surfacing) on the rim of a roller in the way of several parallel beads was conducted. It is shown that there takes place the heating of the roller due to overlayed layers. The auto heating temperature in overlaying at determined values of heat input (per unit length) has been established. It is shown that the increase in thickness of the overlayed rim leads to some decrease in pre-heating temperature.

Analysis of Literary Sources

Modern track vehicles ensure, as compared to wheeled transport, less pressure onto the ground. Conditions are created for a more complete transfer of forces from the engine to the working bodies. This is achieved due to better traction with the ground and less slippage. Here, the support rollers, resting on the treadmill of the caterpillars, transmit forces and perceive reactions from the side of the road or the ground. With this, diverse influences (presence of soil, abrasive substances, ground), as well as heavy-duty working conditions, lead to intensive wear of the rim of the roller [1–6].

The thickness of the track roller rim walls of a tractor enables us to use highly productive ways of overlaying with a powerful source of heating without any danger of burn-through of the base. However, in the case of over-wear of the rim of a roller, it is necessary to take into account its ultimate thickness [9–11]. The application of highly productive methods of restoration of weared surface of a rim [2, 3] call for the organization of highly specialized jobs under the conditions of industrial plant, where mass production, which has no flexibility concerning wide nomenclature of support rollers of tracked vehicles is common. Under market conditions, the electric-arc overlaying (surfacing) by automatic welding machines is more practical [11, 12]. However, the support rollers are made of high-carbon steel, which is characterized by poor weldability and a tendency to formation of cracks. In such a case, the use of solid welding electrodes leads to an increase in the percentage of base material in the overlayed layer [11–13]. With this, the penetration depth of the base metal and the thermal influence on neighboring regions of the roller under restoration increase [13, 14]. All these factors harmfully affect the structure-phase composition of near-bead regions, Regulation of the chemical composition of the metal overlayed is complicated because of the limited nomenclature of solid welding wires.

In this case, a more productive and technological is the use of flux-cored wires for the restoration of a support roller of a tracked vehicle. A characteristic peculiarity of such welding materials is their less penetrability with a greater value of overlaying factor [11, 10, 13]. This is caused by the technological properties of flux-core wires. With this, it is possible to regulate the physico-chemical properties of the filler in a wide range, to ensure the rated features of the overlayed layer. The graphical dependencies [15] which are recommended in this work give the possibility to determine the dimensions of the weld pool in order to avoid the spreading of metal on the cylindric surface of the rim of a roller.

The issue of predicting the properties of the material of the near-bead region in overlaying and welding of disposed to hardening metals is widely described in special literature [12, 16]. There, it is recommended to previously establish the permissible cooling rates for the material considered. This gives us the possibility to regulate to some extent the formation of the established structures of the material and to ensure its crack resistance. However, taking into account the temperature of auto-heating from previously put layers is considered insufficient. In the work [11], the overlaying onto a long cylindrical body in a helix line is considered. However, for machine parts of small width, the overlaying (surfacing) in parallel beads (like in the case of support rollers) is not expedient.

The choice of automatic welding ensures a stable regime of welding. There, effective means for regulation of the thermal cycle of welding are available. Thus, the regulation of the properties of the weld and the of geometry of the weld bead is ensured [17]. In the work [17], it is shown that the deviation of the rated values of heat input (per unit length) in automatic welding from their actual values does not exceed 3.1 %. This completely meets the requirements of the international associations IAKS and IMO [18, 19] in the branch of the welding industry.

It is important to ensure the range of heat input from 1.5 to 5.0 kJ/mm in automatic welding [17–19]. This range covers the recommended ranges of minimal and maximal values of heat input for streels of the given class of strength.

The preliminary setting of the heating temperature is important not only for the workability of the rim surface to be restored; an economic aspect that determines the energy saving of the process elaborated is also significant there [11–13].

Results and Discussion

The support roller of a tracked vehicle is cast of high-carbon ferrous material, then it is to be strengthened by high-frequency electric currents. This ensures the increase in wear resistance of the material; however, this does not always favorably influences the performance in general [6]. Nowadays, the 45-quality structural carbon steel became the most widely used one. In our investigations, a roller of the tractor with an outer diameter of its rim of 350 mm and a thickness of the rim of 20 mm was considered. As to its design, the restored surface of the rim is of the axially symmetric shape of a body of revolution, it is also rather workable from the point of view of restoration. The diameter of the rim of the support roller to be restored gives us possibilities to apply mechanized ways of work, this increases labor productivity. Here it should be noted that the structure is rather heavy and calls for the application of special lifting equipment to carry out technological movements.

1. Estimation of crack resistance of steel by its chemical composition. The preliminary estimation of crack resistance of 45-quality steel was performed in accordance with the obtained value of equivalent content of carbon ($C_{equivalent}$) and subsequent comparison with the permissible values [10, 11].

If the value obtained exceeds 0.45 %, then the steel is considered to be not resistant to either near-weld cracks or hardening structures in the heat-affected zone. Before overlaying, there should be used pre-heating for the machine part. Analysis of the chemical composition of 45-quality steel has shown that there exist standardized ranges of the content of carbon, manganese, and silicon; these elements strongly affect the value of the permissible equivalent content of carbon ($C_{equivalent}$). For thick elements such as rims, it is also expedient to take into account the increase in heat removal into the base metal during the overlaying (surfacing). In the course of calculations carried out, it has been found that for each range of possible values of content of a chemical element the obtained equivalent value of carbon content exceeded the permissible value.

Therefore, it is necessary to apply special technological methods or concomitant heat and post-weld treatments of the roller of a tractor.

The calculation of pre-heating temperature was conducted according to the analytic relationship which relates the temperature with the equivalent content of carbon in the material [10, 11]. It is shown that, depending on the chemical composition of the material of a specific roller, the pre-heating temperature can range from 216 ^{o}C to 254 ^{o}C. However, the obtained data are advisory in their nature. They do not take into account the following features of implementation of the process of overlaying: the power of electric-arc discharge, heat input (per unit length) of overlaying (surfacing), the technique of muli-layer way of making the weld beads, etc. Below is a refinement of the results obtained based on the simulation of heat propagation during the overlaying.

2. Investigation of overlaying onto the cylindrical surface of the rim of a roller of a tractor. It is known [15, 21] that there exist a number of restrictions for cylindrical elements; the restrictions are caused by peculiarities of the bihaviour of the weld-pool on curvilinear surface. Here, the spreading of melt metal under the action of gravitational force and rotation of the roller of a caterpillar tractor is possible. As a result, the emergence of the following situations are possible:

a) liquid metal flows to place under the column of the electric arc and there proceeds a change in the conditions of heat removal to the base metal. As a consequence; the depth of penetration decreases, but there exists a certain probability of emergence of non-fusion with the base metal, non-uniform width of weld bead and overlap with neighboring beads, overstrengthening of the bead, etc.

b) flow of melt metal from the weld pool. As a result, there is the formation of rolls, the non-uniform height of the overlayed layer, deterioration of the protection of metal during its crystallization, incomplete fusions, shrinkage cavities, etc.

Therefore, we should apply technological methods aimed at the prevention of such defects and to ensure the high-quality formation of the bead overlay. Here is also included the regulation of thermal power of the electric-arc discharge, which depends, first of all on the welding current and voltage of the arc. Here, the increase in power of the arc leads to an increase in the dimensions of the weld-pool, and vice versa. The effect of the speed (V_{ov}) of overlaying is conventionally divided into two groups [15]:

– small speeds (2–3 mm/s); relative increase in power of the arc increases the weld-pool in its length rather fast;

– great speeds (5–8 mm/s); the influence of the increase in power of the arc is less.

Whence the conclusion can be drawn that the combination of high speed of overlaying by means of a flux-cored wire with the corresponding power of the welding arc ensures the necessary quality of formation of the restored layer of the rim of a roller of a tracked vehicle.

It is especially characteristic of the considerable diameter of the surface overlayed, for example, that in the structure of a support roller. The dependence of the length (L) of the weld-pool on the diameter of the overlayed element is presented in the work [15].

This dependence is obtained in an experimental way and gives us the possibility to determine the permitted maximal value of the length of the weld-pool. For the case of overlaying the rim of a roller, results of the graphical investigation have indicated that the dimensions of permissible length may amount to up to 53 mm. Therefore, we use a shift of the burner of the welding apparatus relative to the upper generatrix of the rim of a roller. This ensures partial crystallization of the weld-pool in approaching to the upper generatrix and prevents the spreading of the metal.

3. Determining the value of heat input (per unit length) of overlaying the surface on a roller by parameters of the electrode wire. To determine the heat input (per unit length) of overlaying on the surface of a roller of a caterpillar tractor, it is expedient to use the recommended in special literature [15–17] approaches, which are based on taking into account the following conditions:

– ensuring the stable burning of the arc and no spreading of molten slag and metal of the weld-pool for determined cross-section;

– creation of favorable conditions for increasing the crack resistance of the heat-affected zone during the overlaying [16].

For the calculation of the heat input (per unit length) for a given cross-section, we use the technique suggested in work [15]. In this case, for comparative analysis, we use the study of flux-cored electrode wire of PP-AN 122 – quality and that of PP-AN 122 flux-cored tape [4, 8–10, 12].

Their properties and welding features are close. The only distinction consists in the shapes and dimensions of their cross-sections: the tape dimensions are 2.5×6.0 mm, and the wire is of a pipe-shaped cross-section with an outer diameter of 2.6 mm. Such a choice is caused by an intensification of the process of overlaying by means of a tape; however, the main technological restriction is the necessity of the application of special burners and tape-feeding mechanisms. As a result, for the chosen overlayed materials the following values of specific (per unit length) heat input (q_{sp}) have been obtained: 1.5993 kJ/mm for tubular cored electrodes; 1.8451 kJ/mm for strip electrodes. According to [15], the obtained results can be considered as maximal permissible ones for the case of overlaying the first bead in the restoration of the rim of a roller. There is no taking into consideration the influence of temperature caused by overlaying the rest beads, which causes extra heating of the roller structure being restored. Regarding the peculiarities of the design of the support roller, namely the ring-shaped curvelinear character of the rim to be restored, a verification of the lengths of weld pools for the determined values of specific (per unit length) heat input of the overlaying has been carried out. Here, recommendations from [15, 21] for the calculation of the length of the weld pool according to the corresponding isotherm of the temperature field in the weld zone are used:

$$L = \frac{q_{sp} \times V_{overlaed}}{2\pi\lambda \times T_{melting}},$$

where λ, $T_{melting}$ are the coefficient of heat conduction and the melting temperature, respectively.

For the calculated values of heat input, the following values of the lengths of the weld pools have been obtained for different types of welding electrode wires: 31 mm for strip-type electrodes, 27 mm for tubular electrodes. Thus, the calculated above specific (per unit length) heat inputs ensure the necessary dimensions of the weld pool at the surface of the rim of a roller of a tractor. There is no danger of the emergence of defects of the overlaying due to the spreading of the metal.

4. Establishing the optimal range and the permissible value of cooling rate for the material of a roller. Let us use the known from [11, 13, 16] recommendations concerning the determination of the cooling rate during welding the 45-quality steel. There it is asserted that such steel of a support roller belongs to the materials which during the manufacturing are to be thermally treated (normalization, hardening + tempering, etc.) to ensure the proper qualities. This is caused by the application of rollers under peculiar conditions: in this case, there are considerable impact and abrasive wear at high static loadings. Therefore, it is important to ensure the resistance of the overlayed rim connection of a roller against the actions of forces in a broad range of temperatures during operation. It is also important to resist brittle fracture, especially in the heat-affected zone. Such a zone occupies an inconsiderable part of the whole cross-section of the connection; however, it is just in it that britte overlayers which emerged in the course of the action of the thermal cycle of welding are observed most often; high residual stresses take also place there. In such steels [14, 16], it is important to ensure not only the crack-resistance but also the appropriate proportion in chemical composition as well as necessary mechanical properties of the rim of a roller of a caterpillar tractor. Thus, the establishment of parameters of the regime is of decisive influence on ensuring the operational characteristics. In the given case, it is necessary to combine the two important criteria: the optimal rate of cooling for ensuring the necessary structure and the permissible rate of cooling for preventing cold cracks during the overlaying of the rim of a roller.

In order to ensure the necessary weld structure of 45-quality steel in the heat-affected zone, the range of optimal rates (w_{opt}) must be rather small (from 2.0 to 4.0 ^{o}C/s) [16, 21]. This indicates the necessity of the creation of possibilities of slow, controllable cooling of the overlayed metal of a weld. Also important is the minimization of martensite-type hardening structure, which is permissible up to 5 %. Therefore, it is expedient to conduct pre-heating and concomitant heating of a support roller of a tracked vehicle during the overlaying. The permissible cooling rate (w_{perm}), as to cold-crack resistance, in this case, is greater than any possible within the optimal range (w_{opt}). At the same time, attention should be paid to the type of test welding, by which the cooling rate (w_{perm}) is determined [16, 22]. In particular, more “strict” conditions of the formation of a weld in cross-test welding restrict this value to 8 ^{o}C/s. Unlike this, the use of CTS-test welding enables us to establish apermissible cooling rate of up to 15 ^{o}C/s [16]. Analogically, these rates affect the permissible amount of martensite in the weld; in a less cooling rate (8 ^{o}C/s), the maximal permissible value amounts to 30 %, and the increase in such a rate almost twice (15 ^{o}C/s) permits the amount of martensite in the weld up to 80 %. Thus, the values of cooling-rates cooling-rates cooling-rates cooling rates depend on the established criterion and can differ considerably. Therefore, in this case, it is necessary to take into consideration the conditions of work of the restored support roller; there we should take into account the acting loads. This gives us the possibility to carry out the overlaying (surfacing) under more energy-saving and economically justified conditions.

However, the increase in heat input of the welding to the maximal permissible values can harmfully affect the mechanical properties. First of all, in operation under low temperatures, the value of impact strength decreases [17, 20].

5. Investigation of specific heat input based on the permissible cooling rate of the weld. In this case, we used a special nomogram, which is presented in the special literature [11, 15, 16]. They determine the dependence between the cooling rate of the weld and the heat input of the overlaying at different temperatures of heating of the base material. In the work [16], there is shown that these nomograms are obtained for the case of overlaying onto a plate of a given thickness at less depth of penetration, i. e. the penetration of the plate is not a throughout one. In our case, the process is implemented for the restoration of the rim of a roller of a tractor with a minimum thickness of 10 mm. According to this, we use the corresponding curve of the nomograms [16] determined the cooling rate of the material of a roller: 2 ^{o}C/s, 4 ^{o}C/s, 8 ^{o}C/s, and 15 ^{o}C/s. Taking into consideration the data on the recommended value of heating the 45-quality steel (which are obtained above), we used the following types of nomograms: without heating, with the value of heating of up to 100 ^{o}C and up to 200 ^{o}C, respectively.

The results obtained have indicated that in such a case the increase in the permissible rate of cooling the overlayed rim enables us to reduce the heat input of the overlaying. In the case when the criterion of control is the permissible rate (w_{perm}) only, we can make the overlaying without pre-heating at the aforesaid values of heat input.

However, in this case, the due properties of the heat-affected zone of the overlayed material of the weld are not ensured for the optimal range of cooling-rate, i. e. within the range of 2.0 through 4.0 ^{o}C /s. More favorable conditions of formation of the weld can be achieved by means of pre-heating the rim of a roller up to 100 ^{o}C. With this, it is practically possible to ensure the cooling rate of the weld of 4.0 ^{o}C /s by the determined above minimal heat-input (15.993 kJ/cm) of the overlaying. The heating of a roller up to 200 ^{o}C gives us the possibility to obtain a favorable structure of the overlayed weld as well the necessary cold-crack resistance.

6. Investigation of the temperature condition of overlaying a rim. The calculation for temperatures of the rim of a support roller was conducted for the case of “multiple passes” (in several runs) overlaying. For this purpose, there was used the technique which is in detail presented in [11] for the study of peculiarities of overlaying the cylindric elements in a helix line. Taking into consideration the possible rated dimensions of the roller in operation (diameter 330…350 mm), it is possible to consider that the effect of the curvature, in this case, is not essential. At the same time, the possibility of implementation of the conditions of superposition of heat fluxes of the neighboring beads is important. We consider the process of heat propagation in the cylinder as that for simultaneously mutually shifting the determined number of heat sources. Therefore, the temperature field can be studied in an individual interval, the heat forces being summed [10]. An important thing is the establishing of the initial conditions and restrictions concerning the given structure; in particular, concerning the rim of a roller of the tractor. Taking into consideration the diameter of the rim of a roller of the tractor, it should be noted that the duration of making a bead is rather great. Therefore, in the study of heat propagation, it is expedient to make analysis of the overlaying of several parallel beads. The heat inputs of overlaying which are determined above are taken as the initial conditions for implementing the overlaying process for a support roller. The results of the calculation for different values of effective energy, for the case of the overlay of six beads, are presented in Table 1. Here, the thickness of the overlayed rim (δ) is taken equal to 10 mm.

Table 1

The temperature at the distance of one turn relative to the sixth overlayed bead on the rim of the support roller

Effective energy of overlaying, q_s, W	7344	9722	11215
Heat input of overlaying, kJ/cm	12.074	15.993	18.451
Investigated temperature of rim, T_s, ^oC	236.52	313.11	361.19

Analysis of the obtained results indicates that the increase in the effective power of the electric arc ensures higher temperatures of heating of neighboring regions of the rim of a tractor roller. The obtained values indicate the possibility of achieving the established temperatures of heating for 45-quality steel at the expense of the choice of the necessary parameters of the overlaying regime. Thus, by means of variating the rate of overlaying, it is also possible to effectively regulate the process of auto heating. With this, it is important to control the length of the weld-pool, because the roller is of curvilinear shape. In order to determine the effect of the diameter of the roller upon the value of auto heating, there were conducted investigations for different values of the thickness (δ) of the rim, from 10.0 to 20.0 mm (Table 2).

Table 2

The temperature in overlaying rollers' rims of different thicknesses

δ, mm / q_s, W	12	14	16	18	20
7344	227.79	217.75	207.45	197.44	187.94
9722	301.56	288.25	274.63	261.38	248.45
11215	347.87	332.52	316.81	301.51	287.00

Thus, the increase in thickness of the overlayed rim leads to the reduction in heating temperature. This dependence holds for all three cases of the taken values of the effective power of the electric arc discharge. The increase in the power of the electric arc naturally ensures an increase in the observed temperature of heating.

Analysis of the obtained values of heating temperature indicates that within the investigated range of effective power of the electric arc and of the taken rated dimensions of the support rollers there is achieved the necessary value of heating temperature. In this case, this temperature can range from 218 to 348 ^oC.

The overlaying onto a roller can be implemented in a helix line or in ring-shaped beads with the transverse movement of the welding electrode. In literature [10, 11, 13], both these technological schemes are recommended. However, rather a great radius of the roller requires the use of a reduction gear of great gear ratio for smooth movement of the welding head. At the same time, inconsiderable variations in the width of the bead lead to the emergence of such a defect as non- overlap of the neighboring beads. Therefore, there is recommended a shift of the welding head with a help of a special mechanism. Thus, it is possible to regulate the overlaps of the beads more completely and to control the quality of overlaying. The small width of the rim ensures minimization or even the absence of temperature deformations (because of non-symmetry of the temperature field) caused by the non-uniformity of overlaying the restored layer.

Taking into consideration the obtained above results, it is expedient to recommend the use of flux-cored welding wires of the tubular cross-section. Such a choice is also caused by their greater wide-spreading as compared to strip materials as well as in comparison with simple equipment of a welding head. The increase in the number of turns also ensures a better process of auto heating of the roller being restored as well as the necessary value of the temperature of the overlayed surface of the rim.

According to the aforesaid, we use flux-cored self-protected electrode wire of PP-AN 122 – quality [4, 8–10, 12]. It is intended for machine elements that work under the conditions of “metal-on-metal” friction; rollers of tracked vehicles are also included here: i. e. such a wire ensures the possibility of work in alternating and impact loads. The wear-resistance of the layer overlayed is increased, and the resistance to impact loads is satisfactory. It should be also noted that the formation of the overlayed bead is good, the slag is separable from its surface. The tendency of the overlayed metal to crack formation is moderate.

Having established the parameters of overlaying close to the recommended above values and having carried out preheating up to 100 ^{o}C, it is possible to approach the structure to optimal characteristics in the heat-affected zone. Heating up to 200 ^{o}C ensures the optimal structure of the heat-affected zone as the necessary crack-resistance of the support roller of tracked vehicles.

At the same time, the value of the recommended heat input of overlaying the roller does not exceed the recommended range [17–19] for the streets of the given class of strength.

Conclusions

The analysis of weldability of the material of a support roller of a tracked vehicle has shown that the metal is “sensitive” to the thermal cycle of welding and requires welding with heating. With this, it is necessary to take into account the peculiarities of the technique of overlaying. A calculation of specific (per unit length) heat input of overlaying of the first bead of the rim of a roller has been carried out for a given cross-section of the electrode wire.

A verification calculation of the length of the weld-pool well pool for established values of the heat input (per unit length) has been carried out.

It is shown that the length of the weld-pool does not exceed its permissive values and ensures the necessary formation of an overlayed layer on the surface of the rim. Formation of the necessary structure of the weld in the heat-affected zone (from 2.0 to 4.0 ^{o}C/s) , as well as cold-crack resistance (from 8.0 to 15.0 ^{o}C/s), are taken into account. It is shown that the increase in the permissible cooling rate of overlaying gives the possibility to reduce the heat temperature for the process of overlaying.

The temperature conditions of heating a roller at the expense of making several parallel beads have been investigated. It is shown that for the established values of the effective power, it is possible to achieve a value of auto heating temperature over 200 ^{o}C.

The peculiarities of conducting the overlaying onto the cylindric surface of a roller by means of a flux-cored welding wire have been investigated.

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