N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 3, Number 435 (2019), 102 – 108 **https://doi.org/10.32014/2019.2518-170X.74**

UDC 621.9.1

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FORMATION MANAGEMENT IN PARTS PROCESSING REGENERATED BY SURFACING

Abstract. In this paper, we consider the control of the shape formation of the surface and the formation of specified properties, with the restoration of parts by overlaying. As an economically advantageous way of forming the re-welded part by the authors, a method of friction treatment is proposed. A mathematical model of thermal processes in the tool and part has been developed, which makes it possible to calculate temperatures in contacting bodies by calculation and to provide values close to optimal.

It has been experimentally established that the temperature field in the instrument is determined by a number of factors: the operating time, the thermos-physical and physic-mechanical characteristics of the instrumental and processed materials; intensity of heat release, dimensional characteristics of contacting bodies. In modelling, taking into account the schematization, the part is represented as a semispace, along the surface of which a linear thermal source of length B, intensity q_1, moves with speed S_m with boundary conditions of the second kind.

Also shown is a dependency of heating temperature of the disk from the distance to the heat source. It is established that a fairly sharp drop in temperature occurs as the heat source is removed. Relatively high temperatures remain at a distance R <10 mm, after which a sharp decrease is observed.

The maximum value of the instrument's heating temperature during the entire period of resistance did not exceed 90 °C. The average value of the disk heating temperature was 70÷75 °C.

Keywords: overlaying, friction treatment, temperature field, heat source, friction disk, thermal conductivity, thermo-friction cutting.

The relevance of research. Modern machine engineering constantly increases the requirements for the quality of the surface of critical parts, which entails the further development of new approaches and methods for controlling surface shaping processes.

At present, methods for multi-electrode welding and overlaying in protective environments are mainly used for the repair and restoration of engineering parts. The range of parts is quite diverse, starting from the cross-section of cardan shafts, hinges to tooling and stamps.

Methods combined with machining processes in the plastic condition, as well as methods for controlling the composition and structure of the overlayed metal by forming combinations of electrodes and filler materials, allow metal transfer through a concentrated energy flow (arc) during its deposition [1, 2]. Intensification of the above processes is achieved through the use of shock loads, the combination of different methods of processing by concentrated energy flows (CEF), the use of powder and nanomaterials as the main and filler materials. Electro-physical methods of processing are widely used, such as elastic vibrations of sound and ultrasonic frequency ranges, vibration processing, high frequency currents, laser and electron radiations. Despite the offered technologies, significant growth in the quality of the material structure, and therefore the level of the product properties complex, is not achieved due to a constant change in the parameters of the crystallization process associated with the dynamics of heat input and heat removal from molten metal, changes in the chemical composition of the melt, formed by the electrode material, filler material and the main metal of the product, which passes into the melt. The structure of the seam is formed as a result of a balance between the processes of heat transfer, diffusion, chemical reaction between the alloy components against the background of a rapid transition of the melt from overheating to supercooling. At the same time, the qualitative and quantitative indices of the crystallization process, even if expensive materials and equipment are used, can influence the results of the technological process in very wide redistribution, up to the point of putting the product into flaw. The most effective results can be achieved by using combined technologies, such as sonication, additional thermal effects on the melt during the treatment with concentrated energy flows (CEF), the use of forced shaping processes and combined machining (for example, frictionmachining).

Particular importance in welding and overlayinghas the formation of structure around the seam zone and the weld metal itself in connection with the periodicity of the thermal action on them during heating, cooling and crystallization [2, 3]. In most cases, the periodicity of the main technological effect on the product is compensated for by periodic auxiliary technological influences such as preheating the surface to reduce the temperature gradients in welding and surfacing in the base material, the subsequent heating or cooling in thermostats to reduce the cooling rate, the periodic thermal action on the molten metal in the process of its crystallization, periodic electromagnetic and ultrasonic effects e for the purpose of grinding the structure of the weld metal, using the vibrations of the welded article; impulse supply of electrodes and additives, etc.

On the basis of Prigogine principle – the minimum production of entropy applicable to non-equilibrium physical-chemical processes proceeding at a constant speed, we can speak of the predominance of heterogeneous sequential crystallization, which is energetically more advantageous than the bulk homogeneous solidification, and the existence of both mechanisms in competitive interaction and the dominance of heterogeneous crystallization.

The dynamics of supercooling at the interface between the phases and in the melt volume of the welding-surfacing bath, as part of the process of cooling and crystallization of the welding or surfacing seam, can be different, due to a change in the chemical composition in the interphase boundary zone in the process of separation diffusion and supercooling degradation on one side and introducing, for example, filler material into the tail part of the bathtub on the other side. It should also take into account the release of heat in the latent heat of fusion during crystallization at the interphase boundary, which also reduces the actual supercooling of the melts in the active growth zone of the crystals. This is typical for both heterogeneous and homogeneous crystallization. A significant difference in the process of crystallization of the melt of a welding-surfacing bath is the instability of the chemical composition of the melt in the crystallization region, associated with the supply of filler materials, the transition of chemical elements from protective media, the burning out of the melt components during the transition through the arc, the incompleteness of the reactions of chemical interaction due to the short-term metallurgical processes in melt the bath. A number of melt components in the crystal growth zone change the position of the non-equilibrium liquidus, both toward its growth and decrease.

Thus, control of surface formation and formation of specified properties, when restoring parts by surfacing, is quite a complex and urgent task.

The advantages of the proposed technology. The technological process of machining parts after overlayingincludes, mainly, turning with tools with plates of superhard materials, as well as preliminary and final grinding operations. Typically, the processing of such parts is associated with certain difficulties due to the increased hardness of the material being processed. In some cases heat treatment (tempering) is applied, after which it becomes possible to turn or milling with sufficiently low resistance of cutting tools.

New technologies combining several types of energy [4, 5] may prove to be the most effective in solving such a complex multi-criteria problem. These methods include frictional processing combined with high-speed cutting. The friction disc is heated and the reduced surface of the part is pre-treated, after which the final processing is performed by the cutting tool at high speeds. Also perspective is the combined processing methods based on the mechanism of cutting thermo-friction cutting at low speeds [6-9], such as multi-blade rotational turning [10, 11], rotational-friction turning [12, 13], thermos-friction milling and of the interval [14, 15].

The main advantage of these processing methods is the provision of high accuracy and quality of processing at a lower cost of operations due to the use of cutting tools made of non-instrumental materials. And also, with the right choice of optimal cutting conditions, the treatment with the proposed methods eliminates the need for the finishing operation - grinding.

Mathematical modelling of thermal processes. To ensure optimal conditions and processing conditions, it is necessary to strive to ensure optimal temperatures in the cutting zone [16-18]. The proposed mathematical model of thermal processes in the tool and the part allows us to calculate the temperatures in the contacting bodies by calculation and to provide close values to optimal. In frictional processing, the thermal action process is characterized by two modes, such as unsteady and steady. The unsteady mode takes place at the beginning of the processing, when the part and the tool begin to interact. To develop a mathematical model of thermophysical processes, it is necessary to schematize the process.

Taking into account the schematization, the part can be represented as a half-space, on the surface of which a linear thermal source of length B, with an intensity q1, moves with velocity S_m with boundary conditions of the second kind [17, 19]:

$$q_1=\varphi(x,y,z,\tau)=0,$$

that is, the law of distribution of heat fluxes.

Initial conditions:

$$f_o(x,y,z)=\Theta_o\ ,$$

where Θ_o – the ambient temperature, (Θ_o=20°C).

Formula for calculating temperature:

$$\theta(x,z)=\frac{q_1}{\pi\lambda}\exp\left(-\frac{S\cdot z}{2\omega}\right)K_o\left(\frac{S}{2\omega}\sqrt{x^2+z^2}\right) \tag{1}$$

The friction disk is represented as a wedge with an angle of 90 °, on the edge of which there acts a fixed, linear, continuously operating thermal source with intensity q_2.

$$\theta(x,z,\tau)=\frac{q_2}{4\pi\lambda_1}\left(-E_i\left[\frac{R^2}{4\omega_1\tau}\right]\right) \tag{2}$$

where $R^2=x^2+y^2$; $\tau=L_\partial/S$.

where L_l – length of the surface to be treated, m; S – feed, m/sec; q_1- the heat release density of the source acting on the chips, W/m^2; E_i – Euler function; x, z – coordinates of the point under study, m; ω_1 – coefficient of thermal diffusivity of the material of the disk, m^2/sec; λ_1 – coefficient of thermal conductivity of the material of the disk, W/m°C; τ – time of action of the source, sec.

Since the heat source is located at the tip of the wedge, the thermal regime in it, taking into account the effect of the reflected sources, can be written as:

$$\theta(x,z,\tau)=\frac{q_2}{\pi\lambda_1}\left(-E_i\left[\frac{R^2}{4\omega_1\tau}\right]\right) \tag{3}$$

To determine the heat release density q_1 and q_2, it is necessary to solve the heat balance problem, which determines the amount of heat entering the workpiece and the friction disk. To solve the balance problem, boundary conditions of the fourth kind are used, according to which there exists an equality of the mean or maximum temperatures within the contact area of two bodies.

We introduce the notation:

$$\psi_1=\frac{1}{\pi\lambda}\exp\left(-\frac{S\cdot z}{2\omega}\right)K_o\left(\frac{S}{2\omega}\sqrt{x^2+z^2}\right) \tag{4}$$

$$\psi_2=\frac{1}{\pi\lambda_1}\left(-E_i\left[\frac{R^2}{4\omega_1\tau}\right]\right) \tag{5}$$

The coordinates of points for which it is necessary to calculate the temperature lie on the surface, i.e. x = 0. At a point with the coordinate z = 0, the Euler and Bessel functions tend to infinity, therefore it takes z = 0.05.

Taking into account formulas (4) and (5), the system of equations will have the form:

$$\begin{cases} q_1 B + q_2 \pi D = P_z V \\ \psi_1 q_1 = \psi_2 q_2 \end{cases} \tag{6}$$

Solving the system of equations, we calculate accordingly the values of q_1 q_2, which determine the heat fraction for calculating the temperature of the part and the friction disk:

$$q_1 = \frac{P_z V}{\left(B + \dfrac{\psi_1 \lambda_2}{\psi_2 \lambda_1} \pi D_{фр} \right)} \tag{7}$$

$$q_2 = q_1 \frac{\psi_1}{\psi_2} \tag{8}$$

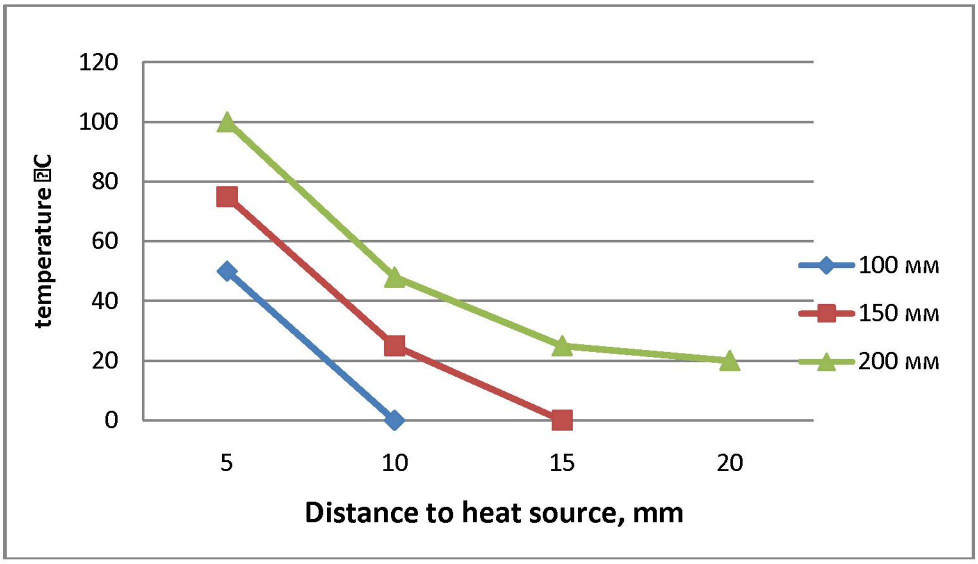
With tool diameter D = 500 mm with cutting modes V = 10 m/s, S = 60 mm/min, the heat balance was 93% and 7%, respectively. 93% enters the body of the friction disk and dissipates in it by thermal conductivity. The remaining 7% of the heat goes to the heating of the part. Knowing the ratio of the amount of heat entering into the contacting bodies, it is possible to determine the surface temperature of the workpiece and, through changing the cutting conditions, ensure the optimum temperature in the contact zone.

It has been experimentally established [17, 20] that the temperature field in the instrument is determined by a number of factors: the operating time, the thermo-physical and physical-mechanical characteristics of the instrumental and processed materials; intensity of heat release, dimensional characteristics of contacting bodies.

The operating time of the friction disc determines the length of the machined surface and the cutting modes.

Figure shows the plot of the heating temperature of the disk from the distance to the heat source.

The graph (see the figure) characterizes quite a sharp drop in temperature as you move away from the heat source. Relatively high temperatures remain at a distance R<10 mm, after which a sharp decrease is observed. The maximum value of the instrument's heating temperature during the entire period of resistance did not exceed 90°C. The average value of the disk heating temperature was 70÷75°C.



Dependence of the heating temperature of a disk from the distance to the heat source

Conclusions.

1. Friction machining is the most effective and economically profitable way of forming a part that has been repaired by overlaying, ensuring uniform heating of the surface and at the same time removing the defective layer.
2. Heating the surface takes place in two modes: stationary and non-stationary. The non-stationary mode takes an insignificant period of time and depends on the cutting regimes, thermo-physical and physical-mechanical characteristics of the contacting pair.
3. As a tool material for the friction disk, it is recommended to choose materials with a high coefficient of thermal conductivity, as they increase the heat flow into the body of the tool and actively exchange heat with the environment. It is also necessary to take into account the thermo-physical characteristics of the material being processed to ensure the optimum temperature in the disk-part pair.

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БАЛҚЫМА ҚАПТАУМЕН ҚАЛПЫНА КЕЛТІРІЛГЕН ТЕТІКТЕРДІ ӨҢДЕУ КЕЗІНДЕ ПІШІНҚАЛЫПТАСТЫРУДЫ БАСҚАРУ

Аннотация. Берілген жұмыста бөлшекті балқыма қаптаумен қалпына келтіру кезіндегі бет пішіннің жасалуын басқару және берілген қасиеттерді қалыптастыру сұрақтары қарастырылған. Балқыма қаптаумен қалпына келтірілгенбөлшектің пішінің жасаудың экономикалық тиімді әдісі ретінде автормармен фрикциялық өңдеу әдісі ұсынылған. Құрал мен бөлшектергі жылулық үрдістердің математикалық үлгісі даярланды, ол түйісуші денелердегі температураны есептік жолмен анықтауға және онтайлыға жақын мәнді қамтамасыз етуге мүмкіндік береді.

Құралдағы температуралық өріс бірқарат факторлармен анықталатыны тәжірибелік анықталды, ол факторларға: жұмыс уақыты, құралдық және өңделуші материалдың жылулық-физикалық пен физикалық-механикалық сипаттары, жылу бөлінудің қарқындылығы, түйісуші денелердің өлшемдік сипаттамалары жатады.

Сұлбалауды ескеріп үлгілеу кезінде бөлшек жарты кеңістік түрінде болады, оның бетімен ұзындығы В, қарқындылығы q_1, жылдамдығы $S_м$ екілік типті шекаралық жағдайға ие болатын сызықтық жылу көзі орын ауыстырады.

Сонымен қоса, дискінің қызу температурасының жылулық көзге дейінгі арақашықтыққа тәуелділік графигі келтіріледі. Температураның айтарлықтай тез төмендеуі жылулық көзден алыстауына байланысты болатыны анықталды. Салыстырмалы жоғары температура R<10 мм қашықтықта сақталады, содан кейін тез төмендеу байқалады. Құралдың қызу температуасының ең көп мәні тұрақтылықтың барлық кезең барысында 90°С аспады. Дискінің қызу температурасының орташа мәні 70÷75 °С құрады.

Түйін сөздер: балқыма қаптау, фрикциялық өңдеу, температуралық өріс, жылулық көзі, фрикциялық диск, жылуөткізгіштік, термофрикциялық кесу.

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УПРАВЛЕНИЕ ФОРМООБРАЗОВАНИЕМ ПРИ ОБРАБОТКЕ ДЕТАЛЕЙ, ВОССТАНОВЛЕННЫХ НАПЛАВКОЙ

Аннотация. В данной работе рассмотрены вопросы управления формообразованием поверхности и формирования заданных свойств при восстановлении деталей наплавкой. В качестве экономически выгодного способа формообразования восстановленной наплавкой детали авторами предложен способ фрикционной обработки. Разработана математическая модель тепловых процессов в инструменте и детали, которая позволяет расчетным путем определять температуры в контактирующих телах и обеспечивать значения, близкие к оптимальным.

Экспериментально установлено, что температурное поле в инструменте определяется рядом факторов: временем работы, теплофизическими и физико-механическими характеристиками инструментального и обрабатываемого материалов; интенсивностью тепловыделения, размерными характеристиками контактирующих тел. При моделировании с учетом схематизации деталь представлена как полупространство, по поверхности которого перемещается линейный тепловой источник длиной B, интенсивностью q_1, со скоростью $S_м$, с граничными условиями второго рода.

Также приводится график зависимости температуры нагрева диска от расстояния до теплового источника. Установлено, что достаточно резкое снижение температуры происходит по мере удаления от теплового источника. Относительно высокие температуры сохраняются на расстоянии R<10 мм, после чего наблюдается резкое снижение. Максимальное значение температуры нагрева инструмента в течение всего периода стойкости не превышало 90°C. Среднее значение температуры нагрева диска составило 70÷75 °C.

Ключевые слова: наплавка, фрикционная обработка, температурное поле, тепловой источник, фрикционный диск, теплопроводность, термофрикционное резание.

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