

# Thermal shock removal of defective glass-enamel coating from cast-iron products

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**Abstract.** A setup for light beam exposure has been developed. The setup was used to consider the technology of thermal shock destruction of the coating by pulsed-periodic exposure to powerful focused light from the xenon arc lamp DKsShRB-10000. It is shown that this type of exposure can effectively remove the glass-enamel coating from iron products. The optimal mode of setup operation to efficiently remove the defective glass-enamel coating is found: the diameter of the focused light beams is 2.5–3.5 cm; the lamp arc pulse current is 350–450 A; pulse duration is (0.5–1) s and pulse repetition frequency is (0.15–0.5) s<sup>-1</sup>.

## 1. Introduction

Glass-enamel coatings (GEC) for metal products are the most effective protection against corrosion and, in addition, they provide the metal surface with a number of useful properties inherent in oxide glasses such as hardness, smoothness, acid- and alkali-resistance and aesthetic appearance, and so on [1]. While being manufactured and operated, GEC on metal enameled products may contain different defects [1]. One of the stages to recover GEC is to remove its defective part from the surface of the enameled product. Steels can be treated locally with subsequent recovering or re-enameled the enamel coating on the top of the product defective part [2]. For cast iron products, the problem is fundamentally different. Due to specific properties of iron (high gas evolution rate upon heating) [2, 3], this technology can not be implemented. For cast iron products, recovery of the enamel coating should be performed after complete removal of the old. Conventional cleaning methods based on mechanical and chemical cleaning are labor-intensive and time consuming, and in addition, they are not environmentally friendly [3]. Thermal shock destruction of GAC with a powerful thermal effect can be suggested as an alternative method free of these drawbacks [4, 5].

The paper aims to study the features of pulse-periodic action of a powerful focused light of the xenon arc lamp on GEC on iron products.

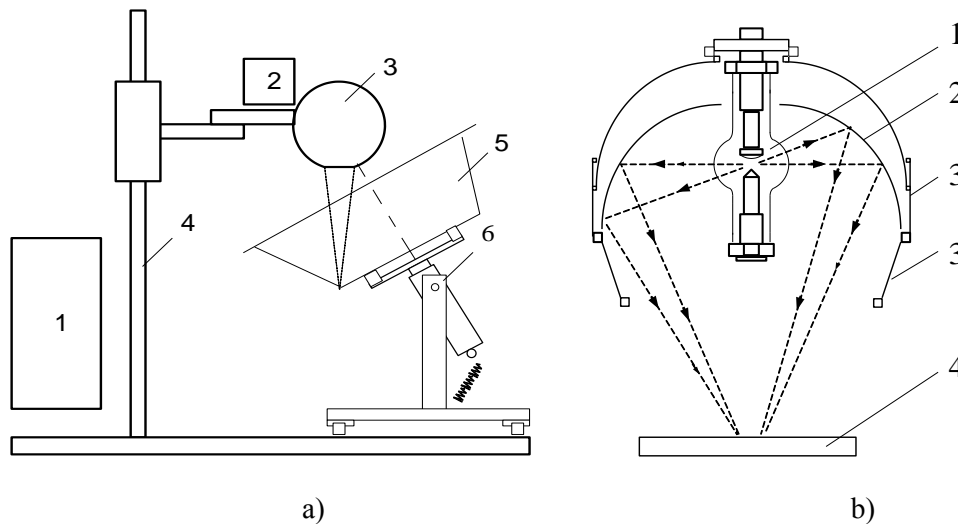
## 2. The experimental procedure

Xenon arc lamp DKsShRB-10000 was used as a light source. The configuration of the setup to implement a pulse-periodic action mode is shown in Figure 1. The apparatus comprises a switched power supply (1), radiant energy generator (3), ignition unit (2), column of "T-31021" type gun-welder (4), bogie (6) on which the workpiece to be treated is attached (5). The pulsed mode of the xenon lamp operation is achieved via switched power supply (1), which includes a three-phase transformer,



rectifier, the device to control the lamp current and reference generator to regulate the duration and repetition rate of current pulses.

The features of arcing in the xenon lamp do not allow implementation of the pulsed mode with completely interrupted glow between pulses, since DC is required to provide stable arcing. In this setup, the pulsed mode of lamp operation can be achieved via pulse-periodic energy supply of the lamp with direct background dark current therein. The dark current was regulated in the range of 15–200 A.

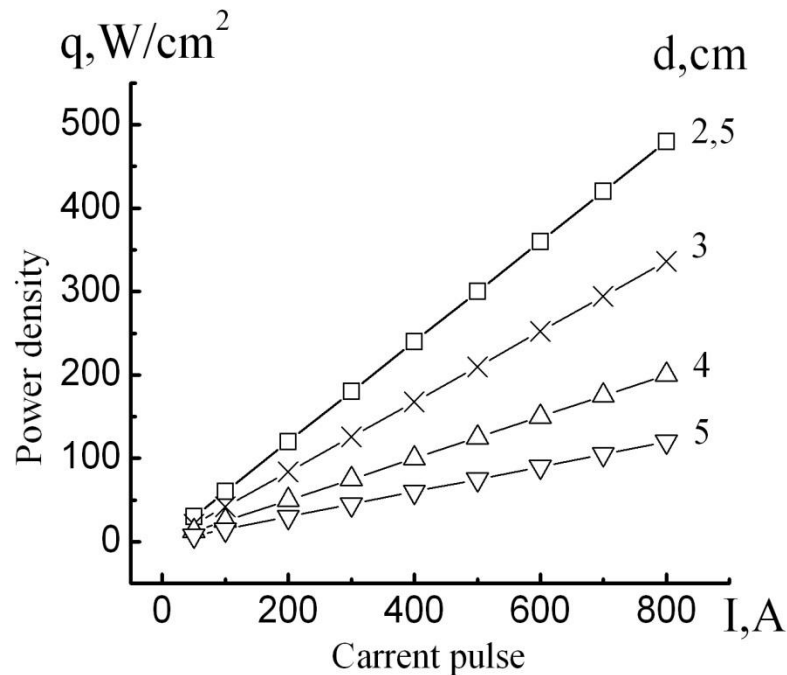


**Figure 1.** The configuration of the setup (a) and (b) are the radiant energy generator (3): 1 is a xenon lamp; 2 is a reflector; 3 is a protective casing; 4 is the target.

The power density applied to the target in the light spot is directly proportional to the current through the lamp and is inversely proportional to the squared diameter of the light spot (the area of the latter). The valid estimated values of the power density in the treatment region for the setup are shown in Fig. 2. It should be emphasized that the current exceeding 250 A is permissible only under pulsed mode. The integral power dissipation for the lamp should not exceed the maximum rated capacity of the arc source.

The heat flow from the radiant energy generator with the xenon lamp DKsShRB-10000 has lower and upper bounds. The lower bound is due to the minimum current for steady lamp arcing (dark current  $I_0$  is 15–20 A), and the upper bound is determined by the capacity of the power supply and current capacity for the lamp.

For the lamp DKsShRB-10000, the maximum permissible mode to maintain its performance is as follows: pulse current  $I$  of 750 A, pulse duration  $\tau$  of 0.5 s, pulse repetition rate  $\nu$  of  $0.5^{-1}$ . The luminous flux is directly proportional to the lamp current. In terms of the rated conversion efficiency, the light flux per pulse is 2.25 kW, and if the exposed area is  $5 \text{ cm}^2$ , the power density of light exposure (per pulse) will be  $450 \text{ W/cm}^2$ .



**Figure 2.** The estimated pulse power density of the light output in the exposed area versus the pulse current amplitude and the spot diameter. The diameter varies in the range of (2.5–5) cm.

A measure of exposure effectiveness was chosen the rate of GEC removal (destruction), i.e. the area of the surface region of the cast iron product with GEC removed within one minute (the area of the light spot being fixed). In the experiment, the dependence of the rate of GEC removal on the thickness of the coating, pulse current, duration and pulse repetition rate was investigated. The dark current was maintained at a minimum level. The diameter of the light spot was 3 cm.

### 3. Results and discussion

The experimental results obtained for the light beam exposure by means of the designed setup are shown in Table 1.

As can be seen from the Table, for the area of the focused light emission with a diameter of 3 cm, the maximum removal speed is achieved within the following modes: the pulse current of the arc lamp  $I$  of (350–450) A; pulse duration  $\tau$  of (0.5–1) s, and pulse repetition rate  $\nu$  of (0.15–0.5) s<sup>-1</sup>.

Under the focused incoherent light of the arc source, the coating on the cast iron product absorbs radiation and heats up. Due to the temperature difference between the GEC and cast iron, significant thermal stresses arise and cause separation of the coating. Under exposure with the designed parameters, the destruction occurs at the coating-iron interface which is the optimal solution for the problem of GEC removal from the cast iron product surface.

The destruction of GEC on cast iron under intense heating by light flux can occur under continuous exposure mode, however, it is typically followed by microcracks, exfoliation and fusion of small enamel fragments. In the concave parts of the surface, fusion may not be followed by further destruction of the coating.

**Table 1** Parameters for glass-enamel coating removal

Coating thickness mm	Pulse current I, A	Pulse duration $\tau$ , c	Pulse repetition rate $\nu$ , c <sup>-1</sup>	Removal speed cm <sup>2</sup> /min	Effect
1–1.5	400	1.5	0.15	160	GEC partial fusion
	450	1.5	0.15	200	
	450	1.0	0.25	300	Shearing
	500	1.0	0.25	320	
	500	0.5	0.5	320	
	550	0.5	0.5	140	GEC partial fusion
	600	0.5	0.5	80	
2.5–3.5	400	1.5	0.15	60	Shearing
	400	1.5	0.25	80	Fusion
	450	1.5	0.15	120	
	450	1.0	0.25	140	Shearing
	500	1.0	0.15	145	
	500	1.0	0.25	140	
	500	0.5	0.5	140	
	550	0.5	0.5	80	Partial fusion
	600	0.5	0.5	30	GEC fusion
	400	1.5	0.15	80	Partial fusion
1.5–2.5	400	1.5	0.25	120	GEC fusion
	450	1.5	0.15	200	Partial fusion
	450	1.0	0.25	240	Shearing
	500	1.0	0.25	260	
	500	1.0	0.5	280	GEC fusion
	500	0.5	0.5	280	Shearing
	550	0.5	0.5	150	Partial fusion
	600	0.5	0.5	80	GEC fusion

The pulsed mode allows significant increase in the exposure effectiveness without fusion of the surface, as it enables to implement the greatest thermal-gradient tensions on the GEC-cast iron boundary. In addition, this boundary, apparently being the tension concentrator, will inevitably accumulate microdamages induced by repeated propagation of thermal deformation waves which finally result in separation of the coating. Thus, removal of an old or defective GEC from cast iron products with pulse-periodic heating by the focused radiation of the arc source is, apparently, fatigue destruction.

It should be noted that increase in the pulse repetition rate (if the duration is maintained or insufficiently reduced) not specified in the above table, is unpractical, since this results in overheating of the surface which causes or may cause not shearing but fusion.

Based on the experimental data, the technological procedure to recover the defective GEC for cast iron products can be as follows: complete removal of the glass-enamel coating through exposure to the light-beam and subsequent enameling of the cast iron products according to the proven conventional technology: treatment of the surface, application of the ground enamel slip; base coat drying, ground layer sintering, powdering and sintering of the enamel coating.

It should be noted that the setup can be successfully applied for local restoration of the defective glass-enamel coating on cold steel products.

#### 4. Conclusions

The developed setup for light beam exposure allows effective removal of enameled cast iron products.

The process modes for thermal shock destruction of the glass-enamel coating on cast iron by pulse-periodic action of the powerful focused light flux from a xenon arc lamp.

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