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**THE INFLUENCE OF THE DIELECTRIC LIQUID TYPE ON THE  
SURFACE HARDNESS OF ELECTRICAL DISCHARGE-MACHINED  
STEEL 40KH (40X)**

*(Gyumri)*

The surface characteristics formed by electrical discharge machining in different type of dielectric liquids is presented. Three different dielectric liquids (de-ionized water, hydrocarbon oil and oil/water emulsion) were used during the electrical discharge machining. The influence of the dielectric liquid type on the hardness and recast layer properties of the machined 40KH (40X) steel is presented. The obtained results for different- type dielectric liquids are compared.

**Keywords:** electrical discharge machining, dielectric liquids, water, oil, oil in water emulsion, steel 40KH, hardness.

Electrical discharge machining (EDM) is a direct contact free machining process, with a wide range of use. The main advantages of EDM is that it enables to machine hard-to-cut, advanced materials, produce a difficult shape and high surface finish. EDM is widely used in material machining area.

At EDM, the material removal takes place when a discharge takes place in dielectric media between the electrode anode (work piece-electrode tool) couple. The dielectrics' type and properties influence the discharge impulse energy and duration. The dielectric medium plays an important role in the EDM process. The dielectric liquid is insulating and cooling machining zone-gap. The insulating, electrical and physical properties of the dielectric medium are key factors affecting EDM [1].

The main functions of a dielectric liquid are cooling down the gap and evacuating the eroded molted material particles and vaporized gases, debris. The dielectric liquids' properties generally influence the EDM productivity and cost, especially the material removal rate, electrode wear, machined surface roughness, surface hardness, etc.

The electrical properties of dielectric affect the pulse energy and duration, the breakdown current value, the breakdown gap size. An electrical breakdown spark brings about local high heating. Thermal energy melts a definite amount of work piece and thr electrode tool. The eroded, molted material particles and vaporized gases-debris gases evacuate from the gap with the dielectric fluid flow [1].

The dielectric liquid's flow cools down the machining gap as well. In this aspect, the electrical conductivity and viscosity of the dielectric liquid affect the eroded particles and debris evacuation and the gap cooling intensity. Some portion of the melted metal extremely cools down and re-solidifies. The rapid nature of temperature change and high temperature during machining forms a zone with alternate structure and properties to the main material. The zone with a re-solidified structure is called a recast structure or a white layer. Not only the heating value, but also the dielectric liquid type, properties and electrode tool material define the microstructure of the recast layer [2].

The higher is the thermal conductivity of the dielectric liquid, the better the liquid's flow cools down the gap. The viscosity value must be defined for the optimal flow speed and debris in catching property [3]. Therefore the choice of the dielectric liquid must be done, taking into account the importance of improving one or a group of parameters of EDM.

The widely used dielectric liquids are hydrocarbons (kerosene), tap and distilled water. Each of the mentioned liquid has advantages and disadvantages. Hydrocarbons have low viscosity, low flash point, but they can react with the skin and cause pollutions. Hydrocarbon allows for lower surface roughness, high machining surface quality, low material removal rate (MRR) and small heat affected zone. Machining in water produces high MRR and low electrode wear, high thermal stability due to good cooling properties of water. Water is environmentally friendlier than hydrocarbons. Water is more economical, safe and preferred to hydrocarbon [1].

The way to combine the positive properties of water and hydrocarbon is to combine these liquids. To get the combination (mixture) of water and hydrocarbons, it is necessary to emulsify them. In our earlier research, complex emulsion dielectric fluids were produced and implemented during EDM [4]. The produced emulsions were oil-in-water type with different concentrations of components. The estimated MRR shows the reasonable implication possibility of emulsions for EDM [4]. Therefore there was a need to estimate other EDM parameters as well, and surface properties in particular.

One of the important properties of EDM is surface hardness. Experimental investigation was carried out define the EDM surface hardness. Three types of dielectric liquids were used (water, hydrocarbon and water-in-oil emulsions) to define their influence on the EDM surface hardness.

As known, kerosene is a hydrocarbon liquid, so the use of kerosene as on EDM dielectric liquid, probably will lead to increase the EDM surface hardness, due to high temperature of the machining zone and presence of hydrocarbon. At

high temperature hydrocarbon (in kerosene and oil in water emulsion) can react with melted material and after cooling, expectedly, will make an alloy with high concentration of hydrocarbon.

The experiments were processed on the experimental EDM device [5]. A hardened steel 40KH bar (6x10x30 mm) was used as a work piece. After quenching at the temperature of 850°C it was tempered at about 200°C. After hardening, the hardness, was measured on PMT-3M, and was about HRC 55. The work piece was die-sink eroded with single sparks by a brass electrode tool with a 300 μm diameter, the discharge current was 2.2 A, and the gap voltage was 45 V.

The same work piece was machined in water, kerosene and emulsion. The formed craters after single sparks are presented in Fig. 1.

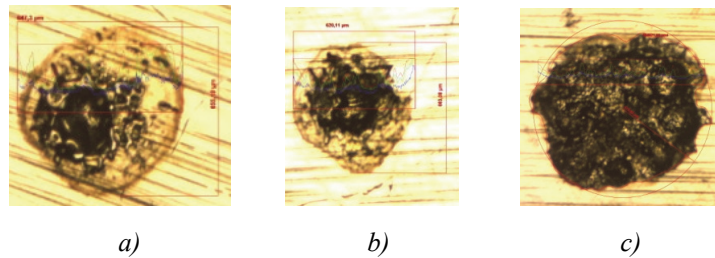


Fig. 1. The crater machined in a) kerosene, b) emulsion, c) water

As seen, the finest machining is in kerosene. The eroded surface is rather small, point shape and the crater is deep. The intermediate results are for emulsion and the worst, when the spark impulse eroded wider surface.

The hardness alters depending on the distance from the crater center and the depth of the recast layer. Only the micro hardness of the crater center and the recast layer surface was measured. The micro hardness of craters was measured for three work pieces and the average value was calculated. The results are presented in Fig.2.

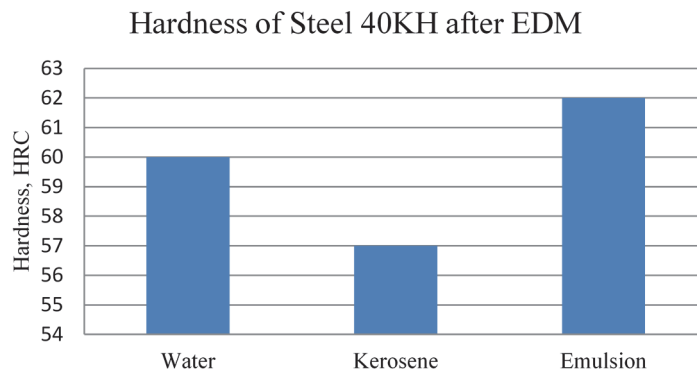


Fig. 2. Hardness of craters eroded in different dielectric liquids

The lowest hardness was in kerosene, the highest in emulsions. The hardness of the recast layer eroded in water is between the water and emulsions. Though the concentration of carbon in kerosene is high, the hardness was lowest. No carbon-containing alloys formed. The explanation can be the low temperature conductivity of kerosene. The cooling of the gap in kerosene goes on slowly. The analog of the tempering process takes place with the following hardness decrease. The rapid cooling of the gap in water, due to the high temperature conductivity, forms a recast layer with higher hardness compared to the initial hardness of the work piece surface. The hardness of the crater eroded in the emulsion was unexpectedly high. Disperse phase (water) rapidly cools the machining zone, and carbon contained in the oil under high temperatures reacts with the melted material, forming a carbon-rich alloy in the recast layer with high hardness.

In conclusion: if no finishing operations are required after EDM, the desired surface hardness can be achieved by means of the dielectric liquid choice.

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**ԴԻԵԼԵԿՏՐԻԿ ՀԵՂՈՒԿԻ ՏԻՊԻ ԱԶԴԵՑՈՒԹՅՈՒՆԸ ԷԼԵԿՏՐԱԷՐՈԶԻՈՆ  
ԵՂԱՆԱԿՈՎ ՄՇԱԿՎԱԾ 40X ՊՈՂՊԱՏԻ ՄԱԿԵՐԵՎՈՒՅԹԻ  
ԿԱՐԾՐՈՒԹՅԱՆ ՎՐԱ**

Ներկայացված են տարբեր տիպի դիէլեկտրիկ հեղուկներում էլեկտրաէրոզիոն մշակմամբ ձևավորված մակերևույթների հատկությունները: Էլեկտրաէրոզիոն մշակման դեպքում երեք տարբեր տեսակի հեղուկներ (ապաիոնացված ջուր, ածխաջրածնային յուղ, յուղը ջրում էմուլսիա) են կիրառվել: Ներկայացված է դիէլեկտրիկ հեղուկի ազդեցությունը մշակված 40X պողպատի կարծրության և սպիտակ շերտի հատկությունների վրա: Համեմատվել են տարբեր տիպի դիէլեկտրիկ հեղուկներում ստացված կարծրության արդյունքները:

**Առանցքային բաներ.** էլեկտրաէրոզիոն մշակում, դիէլեկտրիկ հեղուկներ, ջուր, յուղ, յուղը ջրում էմուլսիա, պողպատ 40X, կարծրություն:

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**ВЛИЯНИЕ ТИПА ДИЭЛЕКТРИЧЕСКОЙ ЖИДКОСТИ НА  
ТВЕРДОСТЬ ПОВЕРХНОСТИ СТАЛИ 40Х, ОБРАБОТАННОЙ  
ЭЛЕКТРОЭРОЗИОННЫМ МЕТОДОМ**

Представлены характеристики поверхностей, обработанных в разных диэлектрических жидкостях электроэрозионным методом. Во время электроэрозионной обработки были использованы три типа диэлектрических жидкостей (деионизированная вода, углеводородное масло, эмульсия масла в воде). Представлено влияние типа диэлектрической жидкости на твердость и белый слой обработанной поверхности стали 40Х. Проведено сравнение полученных результатов твердости для разных типов диэлектрических жидкостей.

**Ключевые слова:** электроэрозионная обработка, диэлектрические жидкости, вода, масло, эмульсия масла в воде, сталь 40Х, твердость.