ABSTRACT

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„Development of a high-performance technology for the production of a chromium-nickel steel engine valve for trucks"

The dissertation concerns the development of an improved technology of valves production for trucks from chrome-nickel steel. This type of forging is produced in two operations, i.e. co-extrusion of a long stem and then forging of the valve head in closed dies. The difficulty in the charging material processing (Nireva steel) comes from the presence of numerous chromium carbides occurring on the austenite grain boundaries and primary carbonitride precipitates evenly distributed in the austenitic matrix. Plastic forming is difficult to control, mainly due to the increased adhesion of the charging material to the tool base and the blocking of the forging preform in the forming area of the preliminary forging die. Lack of repeatability in the operation of the forging die from the first operation, ranging from 1 piece to approximately 2,500 pieces of forgings. A significant problem in the production process is also the relatively low durability and lack of repeatability in the operation of the punch used in the second forging operation, in which the key element determining its further use is the so-called "calotte", in which the material is tempered, causing its plastic deformation, loss of height and finally removal from the process. Low tool durability results from very difficult operating conditions in the forging process (cyclic, high mechanical and thermal loads, long friction path, etc.). Based on the carried out research, including: technology analysis, numerical modeling, macro tests combined with 3D scanning of tools forming shapes and microstructural tests, hardness measurements, it was found that the correct selection of process parameters is crucial (holding time of the charging material in the inductor, tools, working conditions), because their slight changes significantly affect the working life of forging tools. There are two tools which are crucial in the analyzed process: the forging die from the first operation and the punch from the second operation. A detailed analysis of the preliminary forging die wear was performed. Tests showed the presence of traces of abrasive wear, a highly developed network of thermal and mechanical fatigue cracks and traces of adhesive wear and plastic deformation on the surface of the forging dies. Then, an analysis of punch wear was performed. Fatigue cracks at the base of the calotte, the effect of sticking the forging material to the tool surface, and, above all, plastic deformation of the calotte were observed. Based on this and after a complex process analysis, the following thesis was made: "by using selected methods of durability improvement, such as: increasing the thickness of the nitrided layer on the preliminary forging die, initial creation of the calotte and cooling of the punch in the second operation, as well as extending the heating time of

the charging material, it is possible to significantly increase the durability of forging tools, which will contribute to improving the current technology and increasing the efficiency of the forging process of valves made of chrome-nickel steel”. Knowing the wear mechanisms occurring on the tested tools, the following methods were proposed to improve the durability of the preliminary forging die: selection of tool material with a nitrided layer thickness of 0.2 mm, use of surface engineering techniques (lasing, PVD coating, nitriding), selection of the forging die shape using numerical modeling, heating of the charging material. For the punch the following methods were analyzed: selection of tool material, change the production technology of calotte and cooling of the punch. The tests carried out in industrial conditions have shown that among these methods in mass production, the best will be: for the forging die in the first operation, the use of QRO90 Supreme hot work steel with a nitrided layer thickness of 0.2 mm, for the punch in the second operation, its cooling and initial creation of the calotte in the first operation. The implementation of the research results into the production process allowed to increase the durability by 60% for the punch and by 100% for the preliminary forging die, thus proving the thesis of the dissertation. Additionally, a new technology for heating the charging material in an induction heater will be launched, including heating and annealing the batch. The direction of further research will be the use of tools made of sintered carbides in the production process. Carbide tools will be tested again after starting the forging press equipped with sensors confirming the correct position of the forging preform in the second forging cavity. Some of the solutions implemented in the production process significantly improved its efficiency and improved the quality of manufactured components.