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Effect of Non-metallic Inclusion from the Continuous Casting Process on the Multi-Stage Forging Process and the Tensile Strength of the Bolt: Case Study

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Abstract : The paper presents the influence of non-metallic inclusions on the multi-stage forging process and the mechanical properties of the dodecagon socket bolt used in the automotive industry. The detected metallurgical defect was so large that it directly influenced the mechanical properties of the bolt and resulted in failure to meet the requirements of the mechanical property class. In order to assess the defect, an X-ray examination and metallographic examination of the defective bolt were performed, showing exogenous non-metallic inclusion. The size of the defect on the cross-section was 0.531 [mm] in width and 1.523 [mm] in length; the defect was continuous along the entire axis of the bolt. In analysis, a FEM simulation of the multi-stage forging process was designed, taking into account a non-metallic inclusion parallel to the sample axis, reflecting the studied case. The process of defect propagation due to material upset in the head area was analyzed. The final forging stage in shaping the dodecagonal socket and filling the flange area was particularly studied. The effect of the defect was observed to significantly reduce the effective cross-section as a result of the expansion of the defect perpendicular to the axis of the bolt. The mechanical properties of products with and without the defect were analyzed. In the first step, the hardness test confirmed that the required value for the mechanical class 8.8 of both bolt types was obtained. In the second step, the bolts were subjected to a static tensile test. The bolts without the defect gave a positive result, while all 10 bolts with the defect gave a negative result, achieving a tensile strength below the requirements. Tensile strength tests were confirmed by metallographic tests and FEM simulation with perpendicular inclusion spread in the area of the head. The bolts were damaged directly under the bolt head, which is inconsistent with the requirements of ISO 898-1. It has been shown that non-metallic inclusions with orientation in accordance with the axis of the bolt can directly cause loss of functionality and these defects should be detected even before assembling in the machine element.

Keywords : continuous casting, multi-stage forging, non-metallic inclusion, upset bolt head
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