able to fill the die cavity. In case of study 3 (Fig. 9), the load reached the value of 11.6 tons at the stroke of 13.6 mm, and the load had tended to go to infinity, which proves that the material was no longer available the ability to fill the die cavity. In case 4 (Fig. 11), the load reached the maximum value was 16.5 tons at the end of the forging process, and the stroke position was 10.8 mm. The load also had tended to go to infinity, showing that the material data reached the filling limit, and the process of load variation shown in the graph is appropriate. Simulation and experimental loads of case study 4 were 17.8 tons and 17.2 tons, respectively, so these results had not much error. The biggest difference between load theoretical and simulated loads was 7.3%.

The simulation and experimental results as studied above showed that case study 4 had optimized the process parameters and the ability to fill the material into the die cavity. The damage factor distribution in the sample was less than the critical value. The effective stress distribution was uniform in the specimen. The effective strain distribution and the material flow velocity were also increased. The cold forging process of straight bevel gears was successful.

IV. Conclusion

In this work, the cold-forging process of a straight bevel gear in a closed die was analyzed by numerical simulation and experimentally with four case studies to optimize the workpiece and tool design. Research results have shown that the shape of the workpiece and the tool have an important influence on the quality of cold forging products. Optimizing the geometry parameters of the workpiece and tool helped optimize metal flow fill velocity and reduce the risk of failure when cold forging straight bevel gears from A5052 aluminum. Research has shown that the most reasonable geometry of the workpiece to ensure the ability to fill the die cavity without destruction is the workpiece with a cylindrical body and a taped end with suitable dimensions. The tool profile is suitable when lifting the ejector from the bottom of the die to ensure that the metal is filled in the tooth grooves. The results of this study can be applied to the manufacture of similar machine components and help technicians have a better insight into the influence of the geometrical parameters of the workpiece and tools on the results of cold forging in a closed die.

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