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Aluminum Profile Extrusion Simulation using “Comsol Multiphysics” Software Package

ADMIR ŠUPIĆ, ALMIR BEČIROVIĆ, ALDIN OBUĆINA

THE FACULTY OF TECHNICAL STUDIES, UNIVERSITY OF TRAVNIK, BOSNIA AND HERZEGOVINA

ABSTRACT

Global aluminium consumption in the last decade followed by an overview of deformation theory and extrusion process basics are presented in the Introduction of this paper. The components of the extrusion press with additional equipment and integrated systems are presented in the next chapter of this work. The extrusion die design is described in detail, from the designing to the manufacturing process of the extrusion die. This is followed by an introduction to the theory of the finite element method and numerical analysis. The extrusion process simulation represents the final part of this work; in this work, the “L” profile, manufactured by the German company “HUECK GmbH”, with the profile number P447937 is used for the simulation. The extrusion is simulated in the COMSOL software. Following the end of the simulation process, referent measurements like billet temperature, extrusion velocity, isothermal exchange of extrusion and deformation are presented. The simulation results are used to help in predicting die damage, so it could be eliminated and corrections could be made at the right time. In this way, it is possible to save time and money.

Keywords: Deformation, extrusion, simulation, COMSOL.

Introduction

Extrusion is a process of shaping where the material, most frequently cold, is, under the influence of a force, brought to a state of plastic flow and pushed through a gap between the press and die or through an opening in the die.

The plastic flow of cold metals is analogue to the flow of a viscous liquid and it is defined by the laws of hydromechanics.

In 2015, China was the largest manufacturer of raw aluminium (not including recycled aluminium), producing 31 million tonnes, that is, 55% of the world aluminium production.

Russian production amounted to 7% of the global production, Canada produced 5%, and the UAE 4%. Just like steel, aluminium production in China grew rapidly. In 2004, China produced 6.7 million tonnes of aluminium, which is an average annual growth rate of 16% over the decade to 2015. [5] Even though China is the world’s largest producer and consumer of aluminium, it is not a large exporter or importer of aluminium. Russia was the world’s largest exporter of aluminium, exporting 3.4 million tonnes, or 18% of world exports in 2015. In 2015, the world’s largest importer was Germany with 2.59 million tonnes, or 11% of the world’s total imports. [5]

Image 1. shows the world’s aluminium consumption growth for the last twelve years. During this period, the total aluminium consumption increased by 23 million tonnes or 68%.

The largest consumer is China, which currently accounts for more than 50% of the world’s consumption. In the course of the last decade, China’s aluminium consumption more than doubled, which represents an increase of more than 22 million tonnes. [5]

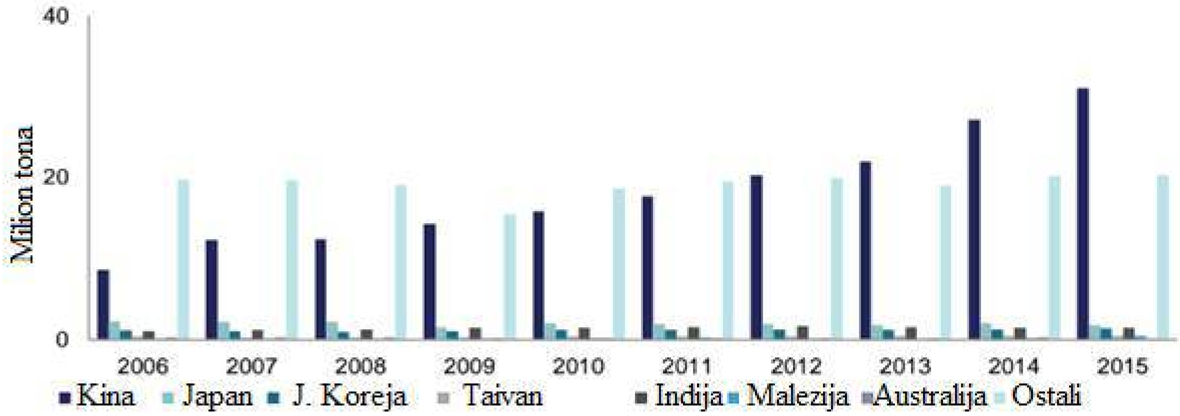

Image 1: World's aluminium consumption from 2006 to 2015 [5]

Numerical simulation

COMSOL is a powerful engineering software for running simulations by applying the finite element method whereby intended for solving problems ranging from primary linear analyses to extremely demanding nonlinear simulations. It has a large library of elements which enables the creation of different model geometries.

Designed as a general simulation tool, COMSOL can be applied in researching not only structural problems.
It enables heat transfer simulations, mass transfer through diffusion, thermoelectric analysis, acoustics, soil mechanics, piezoelectric analysis, electromagnetic analysis and fluid dynamics. COMSOL software package has an environment that offers a simple, consistent interface for creating, monitoring and evaluating the results by using the COMSOL simulator. The package is composed of several modules where each one defines a logical aspect of the modelling process such as:
- defining geometry,
- specifying the properties of materials
- mesh generation.

Transitioning from module to module creates a model from which ABAQUS generates an input file necessary for performing the simulation process. Results analysis is performed in a separate module where COMSOL receives information that enable progress monitoring and output database creation. Reading output data, reviewing and correcting the results of the analysis are enabled by applying the module intended for visualisation. The entire COMSOL analysis consists of three phases: pre-processing, simulation, post-processing.

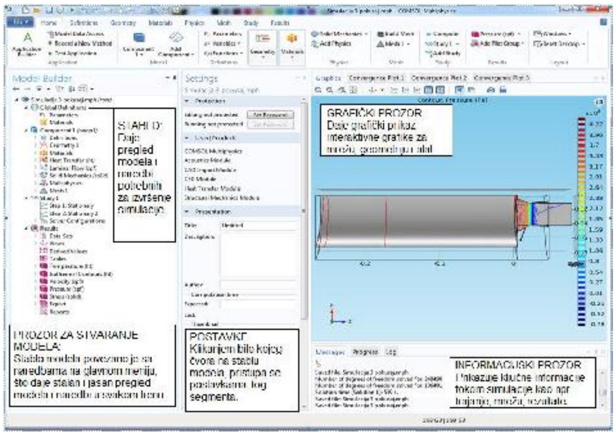

Image 2: The main functions of the COMSOL software

The produced profile has a composition of the AlMgSi0.5 alloy, where it is the most prominent one in the extrusion process when it comes to the profile extrusion.

The extruded profile sample along with the utilised documentation is shown in Image 3.

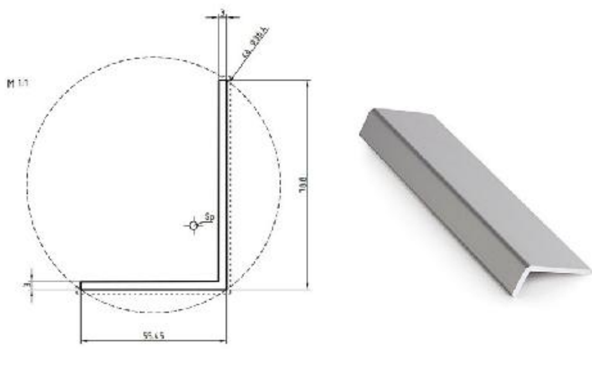

Image 3: An overview of the extruded profile dimensions and sample

By defining a mesh at the output cross section, we can see that there is a clear distinction that the mesh is properly distributed in relation to the die mesh, which means that there will be no mesh deviation, that is, profile deformation. On the other hand, there is a probability that deformation and die damage will occur. An overview of the die mesh and the extruded profile is presented in Image 4.

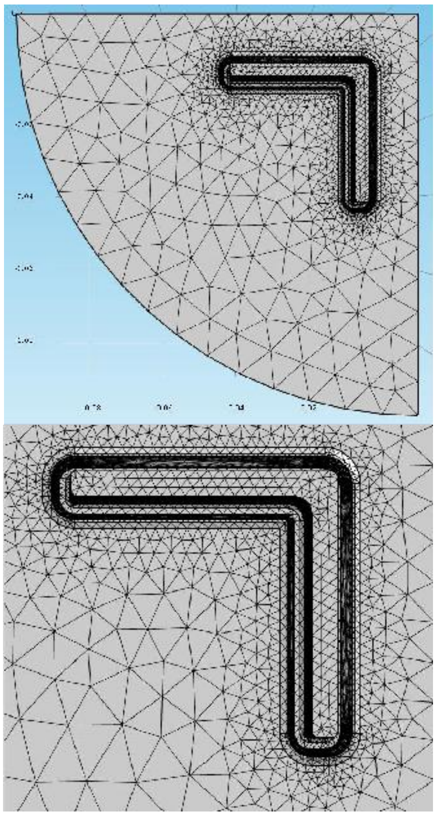

Image 4: A detail of the extrusion profile mesh and the extrusion zone

The appearance of a different mesh density can be noted on the lateral side of the model cross section and at the container and die inlets considering that billet heating starts at the inlet, while billet deformation and the process of shaping it into a profile that is extruded starts at the die inlet, so mesh thickening is expected to occur in those areas. The changes are shown in Image 5.

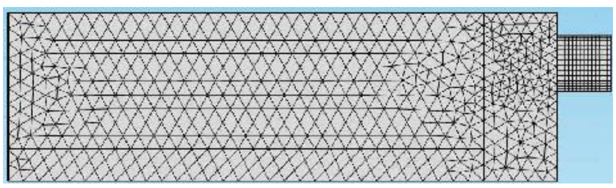

Image 5: Mesh thickening

Simulation results

The results obtained during the simulation give a clear overview of the tool and billet state after the simulation is finished where, based upon the results, we can see where it is necessary to perform tool corrections and correction in the extrusion process. Image 6. shows the billet temperature change where the lowest temperature is noted at the container inlet and the highest one at the die exit, that is, at the location where the profile is finally shaped.

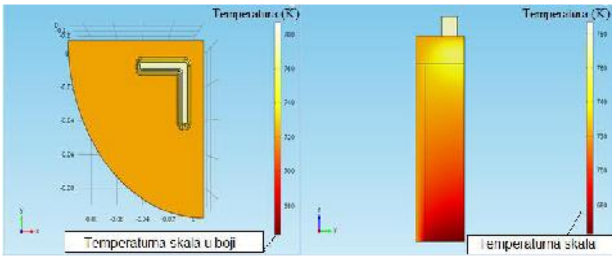

Image 6: Billet temperature change displayed in COMSOL

Images 7. and 8. display isothermal temperature changes where they completely correspond to the temperature growth shown in Image 6.

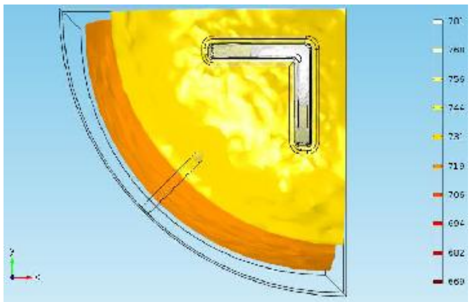

Image 7: Isothermal billet temperature change displayed in COMSOL on the x-y plane

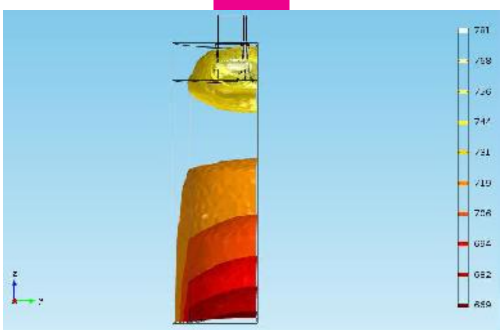

Image 8: Isothermal billet temperature change displayed in COMSOL on the y-z plane

Image 9. shows the speed of aluminium flow through the die where the maximum speed is noted in the middle of the aperture, while the minimum one is seen at the edges of the aperture. Image 10. displays die stress distribution where it can be noted that the stress expands towards the edges of the die, which leads to die deformation.

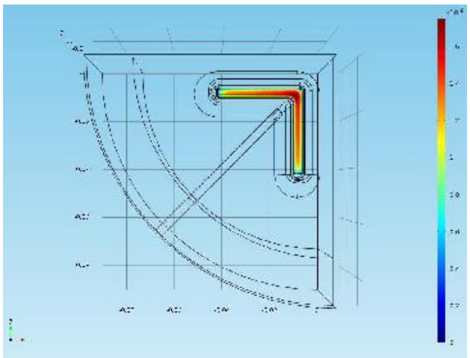

Image 9: Aluminium flow speed displayed in COMSOL on the x-y plane

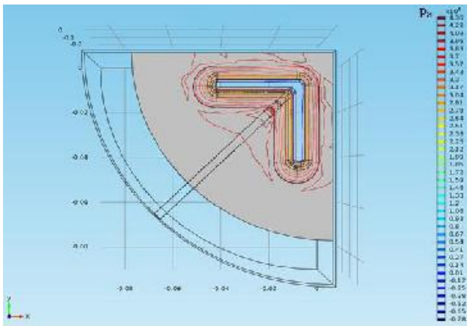

Image 10: Stress distribution in the cross section

Considering that extremely high temperatures and pressure are involved here, die strains can be detected by way of simulating the cross section, which is shown in Image 11.

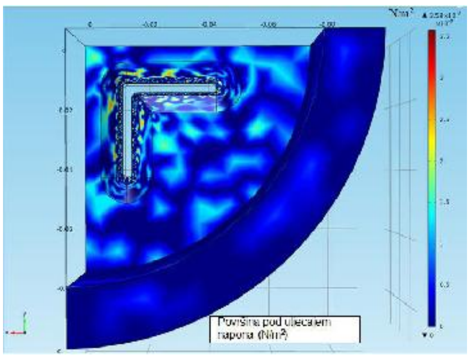

Image 11: Regular strain distribution

Image 12. displays the velocity fields and the aluminium flow patterns in the profile cross section.

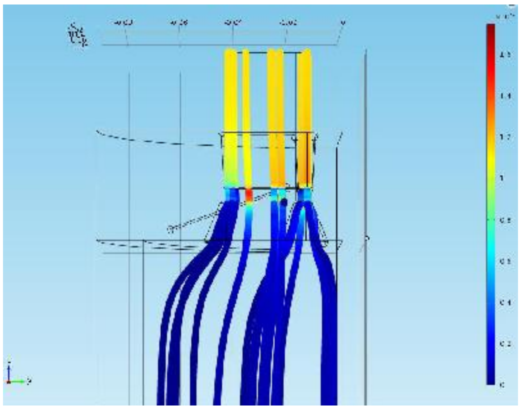

Image 12: Aluminium flow patterns and velocity fields

Image 13. shows the flow patterns, velocity fields and deformation of the profile during extrusion where red arrows represent the heat flux of the extruded aluminium.

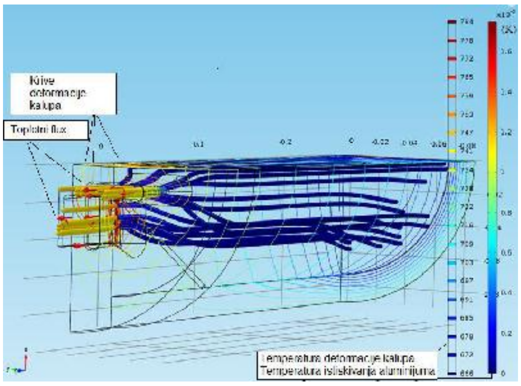

Image 13: Flow patterns, heat flux and profile deformation

Image 14. shows the mesh deformation under stress.

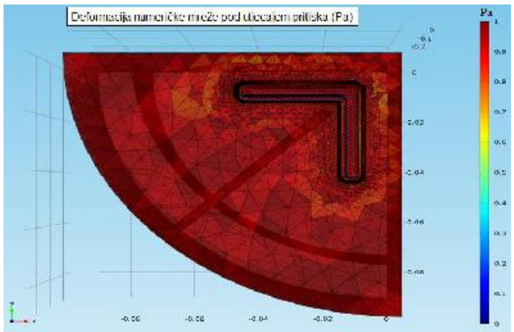

Image 14: Mesh deformation under stress

Conclusion

In many cases, software programmes for 2D and 3D modelling help in predicting how the processed item will behave thereby predicting and preventing potential mistakes, which automatically saves time and money. Automotive industries, aircraft industries and all the world's companies base their production on the usage of software packages because it is impossible to imagine product manufacturing without previous performance tests being made (even if it is theoretical, conducted under ideal conditions).

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Simulacija ekstruzije aluminijskih profila korištenjem softverskog paketa „Comsol multiphysics“

SAŽETAK
U uvodu ovoga rada predstavljena je globalna potrošnja aluminijuma u posljednjoj deceniji, nakon koje slijedi i prikaz osnova teorije deformacija i procesa ekstruzije. Komponente ekstruzione prese sa dodatnom opremom i integrisanim sistemima su predstavljene u sljedećem poglavlju ovog rada. Dizajn ekstruzionog kalupa je detaljno opisan, od projektovanja do njegove proizvodnje. Nakon toga uvodimo teoriju metoda konačnih elemenata i numeričku analizu. Simulacija procesa ekstruzije predstavlja završni dio ovog rada; u radu se za simulaciju koristi profil "L" proizveden od strane njemačke kompanije "HUECK GmbH", sa brojem profila P447937. Ekstruzija je simulirana u softwareu COMSOL. Nakon završetka simulacije, prikazane su referentne mjere poput temperature gredice, brzine ekstruzije, izotermne razmjene ekstrudiranja i deformacije. Rezultati simulacije se koriste kao pomoć u predviđanju oštećenja kalupa, kako bi se ista mogla ukloniti, te korekcije izvršiti u pravo vrijeme. Na ovaj način je moguće uštedjeti vrijeme i novac.

Ključne riječi: Deformacija, ekstruzija, simulacija, COMSOL.

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Correspondence to: Admir Šupić, Faculty of Technical Studies, University of Travnik (Bosnia and Herzegovina)
E-mail: admirsupic@gmail.com