**UNIVERSITY of MISKOLC**
**Faculty of Materials Science and Engineering**

**Antal Kerpely Doctoral School of Materials Science & Technology**

# Theory of metal forming

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**COURSE DESCRIPTION**

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## Lecturer

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## Recommendation

The lecture is proposed for all students of the Kerpely doctoral school, especially in the field of metal forming, physical metallurgy, heat treatment and casting.

## Language

Hungarian or English.

## Scope

The objective of the course is to teach the continuum mechanical basis of metal forming processes. Examination stress and strain state of the individual forming processes by various analytical and numerical methods. Analysis of deformability and damage of metal forming processes. The application of theoretical methods for process planning.

## Methodology

For larger student numbers, the course is held in contact lectures. The time of contact courses is based on agreements with the students. In case of 1-2 students, keywords are given of the corresponding block. Three blocks in total cover the whole course. Basic questions are also given for the blocks. 3 meetings are held during which answers for the basic questions, the students' questions and fundamentals are discussed.

## Topics

### 1. Topic

**Continuum mechanical basis of the stress and strain state of deformable body. Materials laws.**

Theory of large deformations, interpretation of strain rate. Lagrangian and Eulerian description of movement of body. Determination of stresses. Eigenvalues and eigenvectors for stress and strain tensors. Material laws for isotropic and anisotropic bodies. Characterisation of elastic, viscous and plastic continuum.

***Basic questions:***

1. Interpretation of the motion and inverse motion function. Determination of Lagrangian and Eulerian variables.
2. What do you mean the deformation gradient tensor?
3. How to determine the deformation tensors by the use of deformation gradient tensor?
4. How to determine the Hencky's deformation tensor. How about express the constant volume of the material with the deformation tensors?

5. Define the normal and shear stress.
6. Determine the concept of equivalent stress, equivalent strain, equivalent strain rate.
7. Write relationships for the incompressibility of the materials, using the velocity field or strain tensors.
8. Interpret the three basic properties (elasticity, viscosity, plasticity) of the material by simple rheological models
9. Determine the condition of plastic deformation. Mises and the Tresca yield surface.
10. Material law for elastic, viscous, rigid-plastic and elasto-plastic body.
11. What do you mean yield stress? What factors will depend on the current value? Describe the procedures for determining the yield stress.
12. What do you mean anisotropy, what is its relationship with the number Lankford?
13. What does it mean monotonous and non-monotonous deformation?

**2.Topic**

**Boundary conditions of forming problem, damage during the deformation**.

The behavior of materials in contact with each other. Various friction laws. Determination of the coefficient of friction. Damage processes during plastic deformation. (Gurson, Lemaitre theory). Ductile fracture of metal forming process. Formability of sheet material. Test methods for determining the parameters of formability

***Basic questions:***

1. Summarizes the role of friction on the metal forming.
2. Interpret the Stribeck diagram. Check the individual friction zones.
3. Interpret the Coulomb, the Kudo and Levanov friction equations. Determine the domain of the coefficients of friction.
4. Highlight the procedures for determining the friction parameters.
5. The main characteristics of the lubricants used in the forming process. Describe the theory of Bogatov's ductile fracture, monotonous and non-monotonous deformation process.
6. Describe the formability diagram, explain in detail the method of experimental determination.
7. What is the ductile instability? How to apply this criterion to determine the border of formability?
8. Describe the process of ductile fracture in a tensile test, including the development of cavities.
9. Summarize the basic equations of Gurson's damage theory. What is the impact of the development of the cavity on the changes of flow surface?
10. Describe the damage Lemaitre's theory. Show some examples for the application.
11. Which kind of theoretical and experimental methods used for the sheet material formability?

**3.Topic**

Methods for determining the stress and strain state of metal forming process.
Boundary value problem of metal forming task. Applying the material and friction laws in basic equations. Applying the kinematically admissible velocity field (displacement field) for the solution. Approximation methods for the forming analyses, slab and upper bound methods applying the finite element.

***Basic questions:***

1. Boundary value problem for rolling at isothermal conditions. Simplifying of the mathematical solution.
2. Describe the expression of upper bound theorem, explained the role of each terms.

3. What do you mean the kinematically admissible velocity field? How to apply it for the solution of the upper bound problem?
4. Summarise the steps of the application on the slab method.
5. Stream function for axysimmetrical extrusion and drawing on solid and hollow bodies.
6. Analyse the upsetting of cylindrical specimens, using the static equilibrium equation and the velocity field.
7. Describe the solution for drawing and extrusion using the upper bound and the slab method.
8. How to apply the upsetting of circular hollow disk for the determination of friction coefficient
9. Using the finite element method for the solving of metal forming problems.

## References


1. Henry S. Valberg: Applied metal forming. Including FEM analysis. Cambridge University Press.2010.
2. K: Lange, Handbook of metal forming, McGraw Hill 1985
3. B. Avitzur: Metal Forming: Processes and Analysis, McGraw Hill, 1968
4. R.H. Wagoner, J.L. Chenot: Metal Forming Analysis. Cambridge University Press. 2010


## Exam

Oral exam if basic questions are answered correctly.

## Complex exam questions

1. Application different tensors for the determination of stress and strain state of deformable body. Eigen values and eigen vectors of tensors.
2. Constitutive equations for the describing of the behaviour of materials. Summarize the properties of the elastic, the viscous and the plastic continuum.
3. The role of the tribology in the metal forming. Explain the various equations of friction. Application of different lubricant for hot and cold forming.
4. Damage during the plastic deformation. Application of various theories of ductile fracture for the formability of sheet and bulk material.
5. Methods of classical forming analysis for the process planning. Compare the finite element method.