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The extrusion process towards *Industry 4.0*: a multi-objective simulation approach

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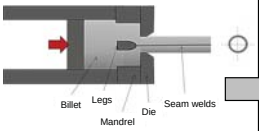
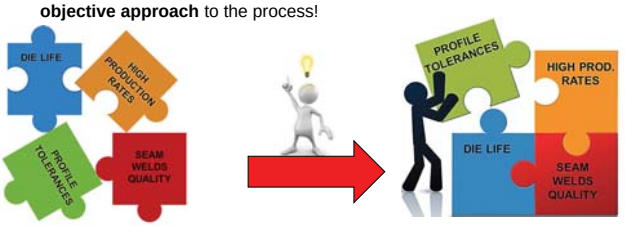
Background & Motivation

The **hot extrusion of aluminum profiles** is a manufacturing process able to achieve tight tolerances and high mechanical properties. However, due to the high number and complexity of the phenomena involved in the process, it emerges the difficulty in meeting all the set-out requirements that are very often **conflicting** one each others. The solution can only be find in a **multi-objective approach** to the process!



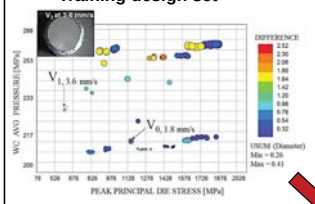


Conflicting objective functions — Multi-objective optimization

Aim of the work is to perform, for the first time, a **comprehensive multi-objective optimization** of the extrusion process. Three **industrial** validation cases of the proposed approach are presented

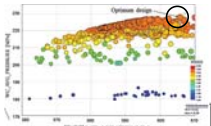
1st Case study – a round tube profile

Training design set



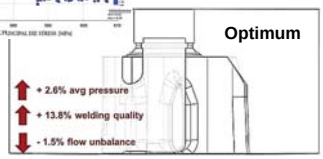
144 configurations (changed geometrical parameters and ram velocity) run on the basis of the FE model (each circle is a different configuration)

Set of final virtual models



Final optimal solution

Optimum



Meta models (mathematical relationships)

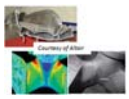
Reggiani et al., 2016, Int J Adv Manuf Technol (2017) 88:3281–3293

Material & Methods

For each of the three investigated test cases, this optimziation procedure has been followed

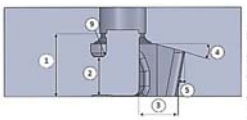
Output variable selection (objective functions)

1. Pressure in the welding chamber (increase seam weld quality)
2. Temperature in the welding chamber (increase seam weld quality)
3. Seam weld criteria (reduce dead metal zones) $\int_A \left(\frac{P_i}{\sigma_i} \cdot \frac{v_i}{v_{max}} \right) \cdot dA$
4. Amount of die deflection
5. Exit flow unbalancing (avoid profile distortions)
6. Peak principal stress in the die (extended die life)
7. Peak ram speed
8. Peak extrusion load



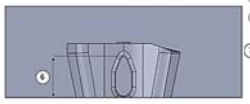
Input variable selection

The input variables were selected among the geometric and process parameters mostly affecting the previously defined objective functions (example of the 1st test is reported on the right)



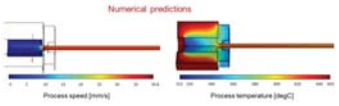
Geometry parametrization

The CAD model was specifically built-up in order to allow the variables modification within the ranges set by the user without alter undesired geometric variables (example of the 1st test is reported on the right)



FE code selection & model definition

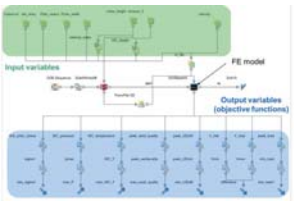
COMSOL Multyphiscs has been selected to perform the FE simulations and validated against experimental data



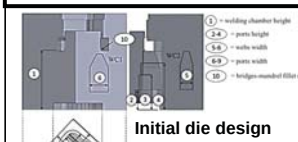
	Experimental	Numerical	%Error
Profile temperature [°C]	380	413	8.7
Die temperature [°C]	382	375	1.8
Ram load [MN]	4.2	4.1	1.7

Optimization workflow

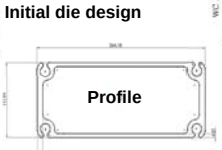
Multi-objective optimization by *means of meta-models* perfomed by means of ***modeFRONTIER (ESTECO)***



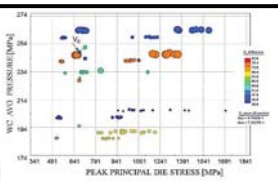
2nd Case study – a rectangular profile



Initial die design

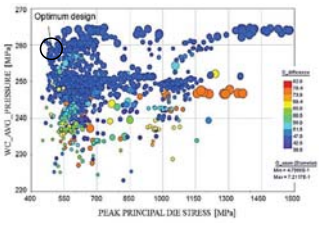


Profile

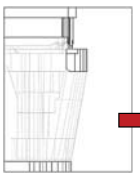


Training design set

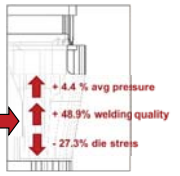
Meta models (mathematical relationships)



Set of final virtual models

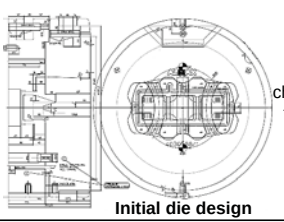


Starting configuration



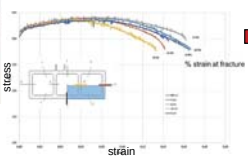
OPTIMAL configuration

3rd Case study – Seam welds optimization (work is in progress …)

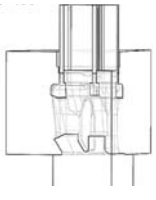


Initial die design

Experimental characterization of the seam welds quality of the starting configuration



CAD model parameterization



Computation is in progress

Conclusions

Presented a **comprehensive** approach for multi-objective optimization of the extrusion process by means of meta-models

Validation of the optimization procedure performed on 3 **industrial** cases (one is work in progress) that allowed to account for the complex design and operating conditions

For the 1st and the 2nd cases, the optimized configuration allowed to increase **both** the profile quality (seam welds) and the die lifetime (lower peak stress) without worsen the others objective functions