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ADVANCED FORMING TECHNOLOGY

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Forming is usually the final stage of metallurgical production of steel (90 % of the 1,7 billion tons of total steel production in the world) and traditionally also largely of the products made of non-ferrous metals. Many procedures and methods exist and we will focus only on some of them. The aim is usually to achieve ultra-fine grained structure, the proper microstructure and (mechanical / electrical) properties in innovative materials. The presented article mentions only some examples.

Key words: forming technology, extrusion-rolling, slitting rolling, surface flexible rolling, flow forming

INTRODUCTION

The text of the article will be selected from the following as examples of just some of the modern, but also some lesser-known technologies such as hot and cold deformation, flat rolling, rolling in plate mill, superplastic deformation, rolling of sheet pile, slitting rolling, cold roll bonding of alloys / steel bimetal strips, drawing process of the wires made of copper and aluminum, drawing of sheets, bending of seamless tubes, sheet metal forming, stamping, forging, extrusion, deformation in semi-solid state with rapid solidification, high-rate plastic deformation, equal channel angular pressing (ECAP), severe plastic deformation (SPD), continuous extrusion of metals using Conform™, and other.

JOINT "EXTRUSION-ROLLING" PROCESS

Development of new technological processes aimed at obtaining metal of predicted structure is a very important and urgent problem because making high–strength metal by reduction of grains to nano–sized level scale is one of the issues of priority importance in the field of nano–science. One of the most promising and superior metal forming techniques is the joint "rolling–extrusion" process using the grooved rolls and equi-channel step die for extrusion (Figure 1). [1]. The advantage of this process in comparison with simple step extrusion consists in the fact that it provides continuity of deformation process and removes limitations imposed on the size of initial billets.

The billet preheated to the temperature of the beginning of deformation is fed to the rolls, which grip it and push it into the roll gap due to the contact friction forces and on leaving it they push the billet through the channels of the equi-channel step die. When the billet leaves the die channels completely, it is gripped by the second pair of rolls, which also due to the contact friction forces push the billet into the gap of the second pair of rolls and draw out the billet completely from the channels [2].

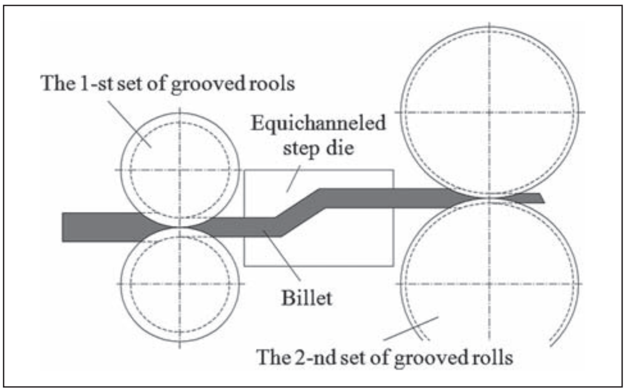

Figure 1 Joint "rolling – extrusion" process

Simulation of the "rolling–extrusion" process was made in 3D-DEFORM program.. After completion of calculations and checking the results the model was considered successful if the billet was gripped and rolled in the first pair of rolls, then pushed through all the die channels and at the exit from the die gripped by the second pair of rolls and completely drawn out from the die (Figure 2).

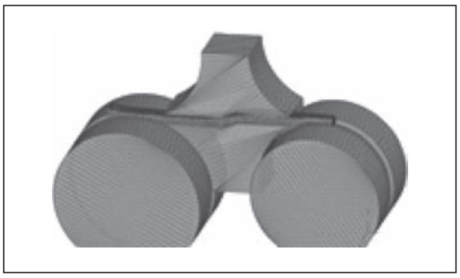

Figure 2 Middle part – Step 38

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The analysis of the distribution of the main stresses shows that on the whole compressive stresses predominate in the site of the strain. The scheme of all–round compression guarantees the absence of macro- and micro-cracks in the metal and promotes maximum ductility of the deformed billet.

SLITTING ROLLING

Modern technology of bar rolling is in many cases based on the application of single or multiple longitudinal slitting, the so-called Slit Rolling (SR). The slitting process uses special passes and guides to prepare, shape and separate the incoming billet into two or more individual strands, which will then be further rolled into finished sizes. The essence of this method is the application of two or three consecutive cutting-in passes, in which deformations of metal considerably differ from those occurring in conventional stretching passes [3]. In order to assess deformations in the slitting passes, finite element method was applied in the essential part of the analysis. The computations were based on the assumption of thermo-mechanical model of deformation.

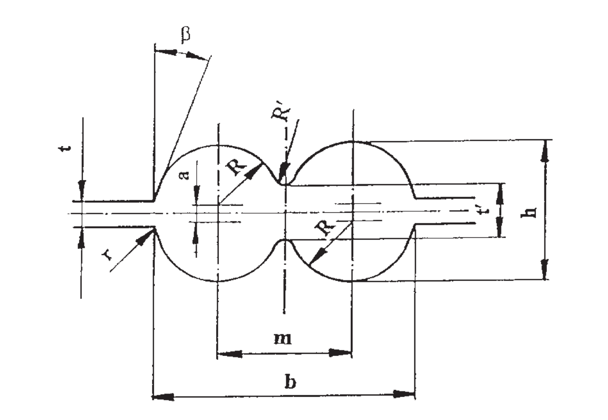

Figure 3 Design of dog bone and slit grooves

The analysis (finite element method) of the influence of shape and width of slitting "knives" was performed with varying technological parameters. The essence of the method is the application of two, more rarely three, consecutive shaping passes, in which deformations of metal considerably differ from those occurring in conventional stretching or forming passes.

Example distributions of effective stress and effective strain on a cross section of the bar rolled in a dog bone pass are shown in Figure 4. Distinct differences can be seen at the exit plane in the dog bone pass, concerning stress, as well as effective strain – reaching the value up to 1,8. The highest temperatures and the largest stresses took place in the zone between the slitting knives of the dog bone and slit grooves, where the largest effective strains were acting.

The next step of analysis dealt with the influence of shape and width of the slitting knives on metal flow in the roll gap [4]. As an example, the effect of the shape

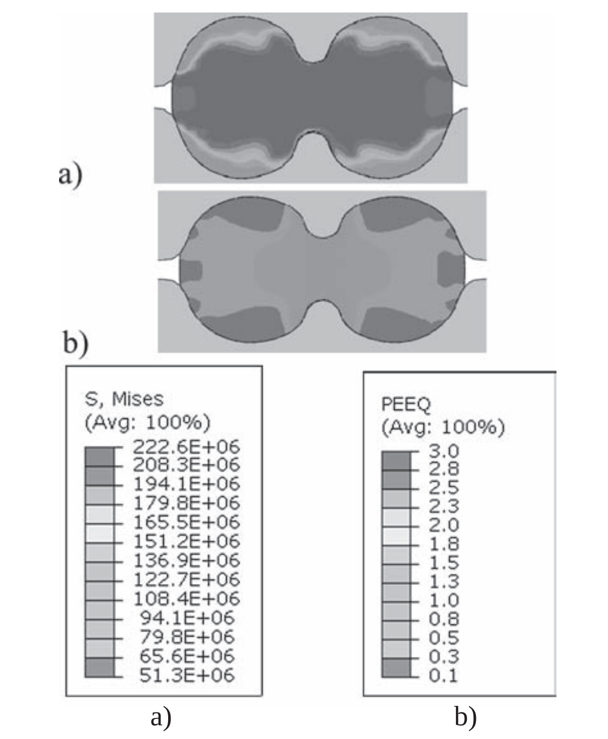

Figure 4 Example distribution of: a) effective stress in Pa, b) effective strain in exit plane in dog bone groove

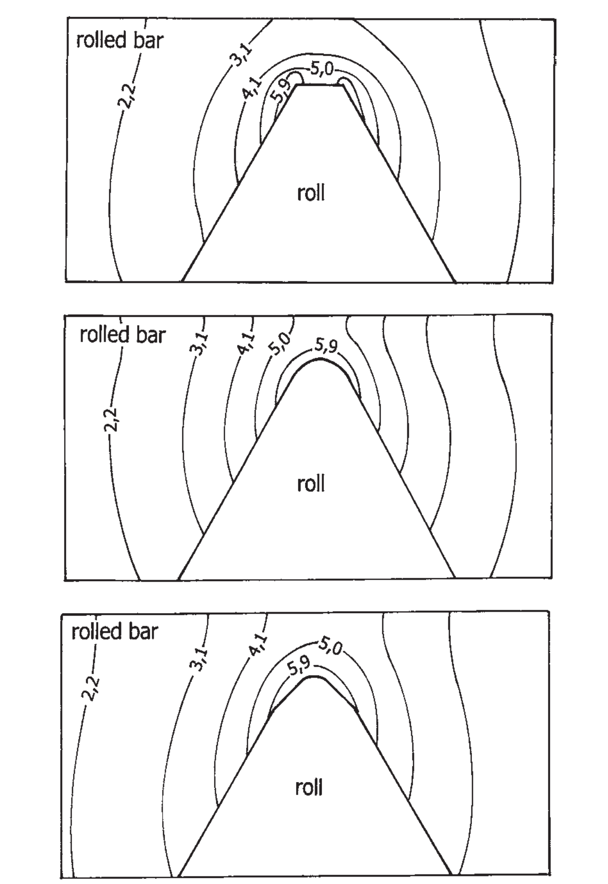

Figure 5 The effect of shape of slitting "knife"on the distribution of effective strain

of slitting knife with rounded corners and 0,8 mm width in a dog bone pass on the distribution of effective strain is presented in Figure 5.

As a result of calculations, the complete metal flow patterns in the slitting passes were determined. The graphs presenting the distributions of stresses and strains in the deformation zone allow direct analysis, which gives better information about the phenomena in the roll gap.

SURFACE FLEXIBLE ROLLING

Continuous roll forming (CRF) is an effective process for manufacture of the swept surface parts made of sheet metal [5, 6]. The forming tool in the CRF process is a pair of small-diameter bendable forming rolls, the swept surface is formed continuously after the rotating rolls sweep out the whole sheet metal blank.

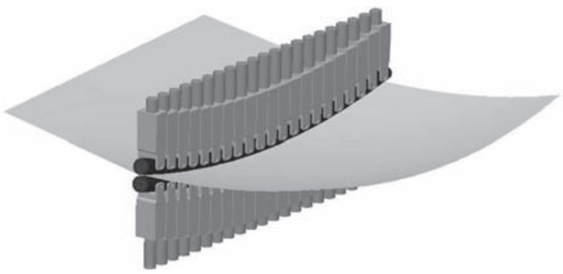

Figure 6 Schematic illustration of continuous roll forming process

Continuous working processes, such as rolling, are characterized by high productivity and low cost, since they do not require any dedicated dies and time-consuming setup operations.

Two bent rolls and the non-uniformly distributed roll gap along the rolls' length make the sheet metal bent simultaneously in longitudinal and transverse directions, the cross-section curve of the formed swept surface is controlled by the curved profile of the forming rolls and the spine curve is controlled by the differential elongations of sheet metal generated by the roll gap.

The rolling deformation of sheet metal produced by two rotating rolls decreases the thickness and increases the length of metal fibre. The elongation percentage of material depends on the gap between the two rolls.

The longitudinal curves of the formed surface result from the longitudinal bending deformation of the deformed sheet metal, as shown in Figure 7.

Numerical simulations and analyses of the CRF processes demonstrate the validity of the presented theoretical models. The experimental and measured results show that the formed surfaces are in good agreement with the desired surfaces, and it is possible to obtain with use of the CRG process swept surface parts with good forming precision.

Figure 7 Swept surface formed by CRF

FLOW FORMING

Flow forming is a plastic deformation process for production of thin-walled and high-precision cylindrical components. A hollow metal blank, a disc or a tube is mounted on a rotating mandrel and the material is made to flow axially along the rotating mandrel by one or more rollers [8-10]. Magnesium alloy is an important and lightweight alloy, which has the potential to be widely used in the automotive industry due to its low density, high specific strength, good castability and excellent machinability.

The Mg–8.5Al–0.5Zn–0.2Mn (AZ80) alloy cylinder billets with the diameter of 200 mm acquired by semi-continuous casting were used as the initial material. The billets were homogenized by solid solution treatment at 413 °C for 10 h and quenched in hot water at 100 °C. After heat treatment, the billets were machined into some tubular specimens with a bottom as the blanks for

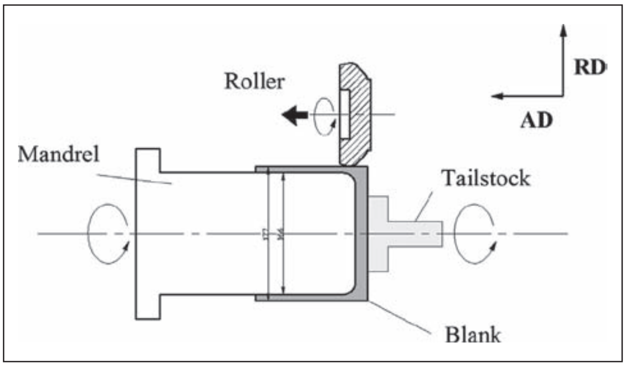

Figure 8 Schematic diagram of hot flow forming. The blank, mandrel and tailstock rotates along TD and the roller feeds to the mandrel along AD.

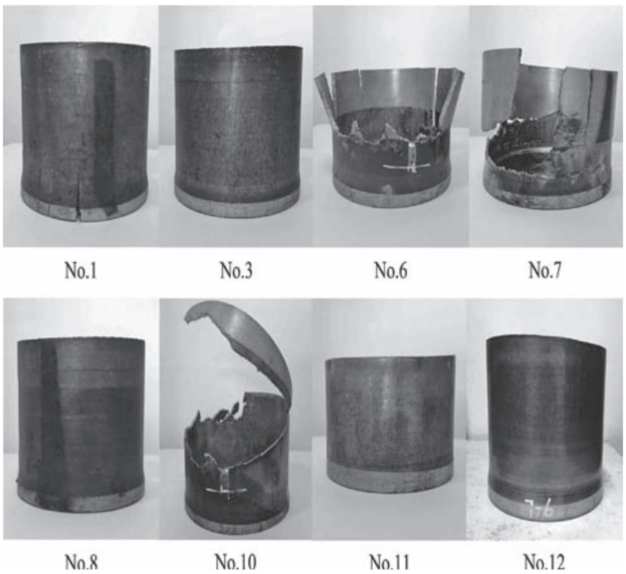

Figure 9 Lateral view of AZ80 Mg alloy tubes after hot flow forming.

hot flow forming. The wall thickness was 5,5 mm and the inner diameter was 166 mm, as shown in Figure 8. Before hot flow forming, the blanks were preheated in an electric induction furnace.

Forming ability shows in Figure 9 the appearance of some sound blanks and some cracked blanks after hot flow forming.

It can be seen that when the blank (No. 1) was flow-formed at 300 °C, it slightly cracked at the bottom. When the forming temperature was elevated to 350 °C and 420 °C (Nos. 2 and 3), AZ80 Mg alloy had so much better flow forming deformation ability that good surface finish was obtained in both outer and inner surfaces without any crack. The spindle speed from 200 rev/min to 400 rev/min did not cause cracks. The results indicate that the AZ80 Mg alloy blank has a good flow forming workability as long as it is processed under suitable process parameters.

The variation of spindle speed and feed ratio had a slight influence on the microstructure, but an obvious influence on the tensile properties, particularly on the elongation. With increasing reduction of the thickness, the grain size decreased, while the micro-hardness increased significantly.

SUMMARY

It is not entirely a coincidence the processes, which are in principle based on a rolling (almost 90 % of the world steel products are initially hot and cold rolled), were chosen as modern forming processes. The paper is gradually based on articles published in the world literature, from which only the essential part was chosen, and then some procedures were briefly introduced. The extrusion method (ECAP) has currently many variants, one of them, JOINT-ROLLING EXTRUSION is introduced as the first one. SLITTING ROLLING is still an underestimated rolling process, which in modern rolling trains substantially increases productivity without significant and costly investments. SURFACE FLEXIBLE ROLLING method is certainly rather marginal at present, but it shows the direction for production of spatially complex shaped plates. Finally FLOW FORMING shows a back path for production of cups and cans in different way than traditional pressing.

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