Recenzované vědecké články

Numerical Simulations of Longitudinally Rolled Plates with Artificially Introduced Defects

Numerické simulácie pozdĺžne valcovaných plechov s umelo vnesenými chybami

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The paper presents numerical simulations of a longitudinal rolling process of the flat sheets with artificially introduced defects. The primary goal of the rolling process consists in ensuring production of a correct profile, free of defects, with good surface quality. The simulations were made in the DEFORM complex program. Low carbon steel grade S690Al was the target material used in this investigation. Defect formation is one of the problems that might occur during the rolling process. Defects of hole type (on the surface and below the surface) and U- and V-notch types were introduced to a steel specimen. The processes of longitudinal hot rolling and cold rolling processes were simulated on such prepared material. During the simulation process, the effect of heat-deforming parameters on the behaviour of different types of defects was observed.

Key words: *numerical simulations; surface and subsurface defects; hot rolling; cold rolling*

Článok prezentuje numerické simulácie pozdĺžne valcovanej plochej produkcie – plechov s umelo vnesenými chybami. Pozornosť je zameraná na sledovanie vplyvu zvolených režimov valcovania na vývoj zadefinovaných defektov, a teda v konečnom dôsledku na výslednú (predovšetkým povrchovú a podpovrchovú) kvalitu predmetných vývalkov. Chyby v liatych bramách môžu byť v princípe technológiami valcovania rozvíjané alebo obmedzované, čo závisí hlavne od druhu a veľkosti primárnych defektov a zvolených parametrov valcovania. Simulácie sa previedli v programe DEFORM; vo výskumných prácach sa uvažovala nízkouhlíková oceľ S690Al. Do zvoleného experimentálneho materiálu boli vnesené umelé chyby typu: diery a vruby tvaru V a U, ktoré mali rôzny tvar, veľkosť a polohu. Proces valcovania za tepla sa simuloval pri teplotách deformácie 1200 a 900°C, pričom pri daných deformačných teplotách sa aplikoval pomerný stupeň deformácie 10 a 50 %. Simulácia procesu valcovania za studena sa realizovala v podmienkach: teplota deformácie 23°C, pomerný stupeň deformácie 10 %. Pri uvedených simulovaných tepelne-deformačných podmiekach bol sledovaný ich vplyv na chovanie predmetných umelo vnesených defektov na povrchu a pod povrchom skúšaného – sledovaného oceľového materiálu pravouhlého prierezu. Dosiahnuté výsledky získané z numerickej simulácie boli konfrontované s reálnym valcovaním (fyzikálnou simuláciou) v laboratórnych podmienkach, ktoré sa realizovalo na laboratórnej valcovacej stolicu DUO 210.

Kľúčové slová: *numerické simulácie; povrchové a podpovrchové defekty; valcovanie za tepla; valcovanie za studena*

The rolling of flat products is a complex and challenging process as it is one of the initial metal-forming processes. The key to attaining a desired shape and properties consists in controlling the rolling process. With a simulation tool, the complex rolling process can be precisely simulated also for various production scenarios. It helps to quickly identify quality problems and to initiate effective processing improvements.

Recently, different numerical methods were used for the analysis of forming processes as follows: Sachs slab method – SLAB, upper bound element technique – UBET, slip-line field – SLF, finite element method – FEM [1] which were implemented to either special or universal software products. The FEM method has found the best application for the simulation of rolling processes, which is evidenced by a large number of publications: FEM

Hutnické listy č. 3/2019, roč. LXXII
ISSN 0018-8069

analyses of a rolling process with tracking process variables, the geometry of rolled products and defects generated during the production of steel products. The authors [2 – 4] analysed the geometry of a slab during the multi-pass V-H hot rolling process. The authors [5] present the metal flow during the rolling of bimetallic rods in the round–oval series. The thermomechanical analysis of the hot continuous rolling process was studied by SUI Feng-li [6]. The author [7] analysed the contact conditions where a layer of a thin friction element between the roller and the workpiece was introduced to consider the contact friction. In the article [8], the ALE formulation was used for the calculation of steady-state, which was applied to modelling slitting and shape rolling processes. An elastic-plastic finite element formulation was used by LIU Xiang-hua [9] to investigate the effect of the elastic deformation of rolls, the plastic deformation of a strip, and the pressure between the work roll and the backup roll. The authors [10, 11] analysed the cold rolling process of a thin sheet, which was simulated by a two-dimensional rigid-plastic finite element method [FEM] to find out local penetration of plastic deformation during thin sheet rolling. The material processing by an asymmetric rolling [ASR] technique from the point of view of numerical simulations was discussed in the paper.

YU Hai-liang simulated the behaviour of transversal cracks on the surface of a slab corner during vertical and horizontal rolling processes (V-H process) by an explicit dynamic finite element method where, in the paper [11, 12], he analysed the closure and the growth of a crack and the contact pressure on surfaces of the crack in the contact zone between the slab and the roll, and the author [13] watched the crack tip stress in the whole rolling process. The author [11] analysed the behaviour of a transversal crack notched on a slab corner during a vertical-horizontal rolling process where the crack tip stress in the whole rolling process was observed. In the articles [14, 15], a FEM method was used to analyse the crack propagation in terms of a wheel/rail rolling contact fatigue problem.

Defects of steel inputs for final forming operations are a source of reduced or poor quality of finished products. Surface and subsurface defects of continuously cast slabs intended for the rolling of sheets and strips affect their quality distinctly, in particular by preserving initial defects, or through the development of the initial defects in the forming process into a different defect type [16 – 20].

Sources of potential surface defects affect any point of the production cycle, namely at the level of steel making and casting, as well as at the level of rolling mill. The most important surface defects or initiators of superficial defects arising during the steel making and casting processes are: inclusions, bubbles, scars, lines of aluminium oxide, holes, longitudinal and edge cracks.

Defects in continuously cast slabs are mostly developed or restricted by rolling technologies, depending on the type and size of initial defects and used rolling parameters [20].

The risk of occurrence of surface defects at the level of rolling mill is relatively high. While heating and rolling the slabs, the following typical surface defects may occur: gouges, thermal cracks, scales, roll marks, scratches, and others.

This paper is aimed at tracking and evaluating the behaviour of artificial defects introduced into a flat steel specimen (a simulated input representative – a continuously cast slab) during its plastic deformation (a simulation of rolling the slab) upon selected process parameters based on numerical simulations.

1. Simulations

The rolling process was simulated using the program DEFORM. Low carbon steel of a rectangular cross-section in the state after continuous casting (from the range of the DEFORM database: S690Al steel) was considered. Limits of significant alloying elements: Cr ≤ 0,30 %; Cu ≤ 2,0 %; Mo ≤ 0,5 %; Ni ≤ 2,0 %; V ≤ 0,1 %; Ti ≤ 0,10 %. Yield Strength: 690 MPa; Tensile Strength: 760 – 930 MPa. The simulations took place in two stages. In the first stage, the defects of the surface oval hole and surface round hole types were applied to the specimen. In the second stage, the defects of U- and V-shaped notches and subsurface round hole types were applied to the specimen. The position and shape of those defects are documented in Figs. 1 and 2.

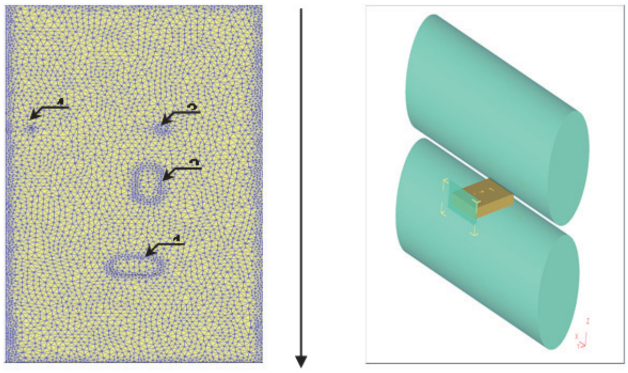

Fig. 1 Location of oval and round holes before the first simulation stage with the indicated direction of rolling

Obr. 1 Poloha oválnych a kruhových dier z prvej časti experimentu pred valcovaním a naznačený smer valcovania

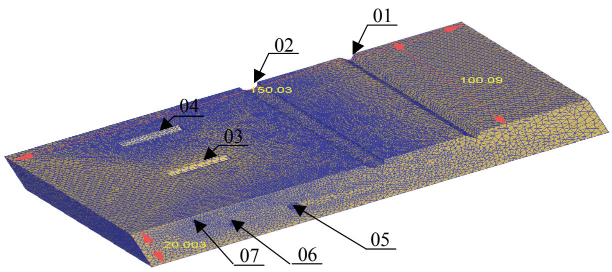

Fig. 2 Location of U- and V-shaped notches and subsurface round holes before the second simulation stage

Obr. 2 Poloha vrubov tvaru U a V a podpovrchových kruhových dier z druhej časti experimentu pred valcovaním

Fig. 3 indicates corresponding dimensions of the defects. During the rolling process simulation, changes in shape and size of defects occurred as shown in Tabs. 1 and 2. The round hole marked by the number 4 has not been evaluated, namely because of its small size.

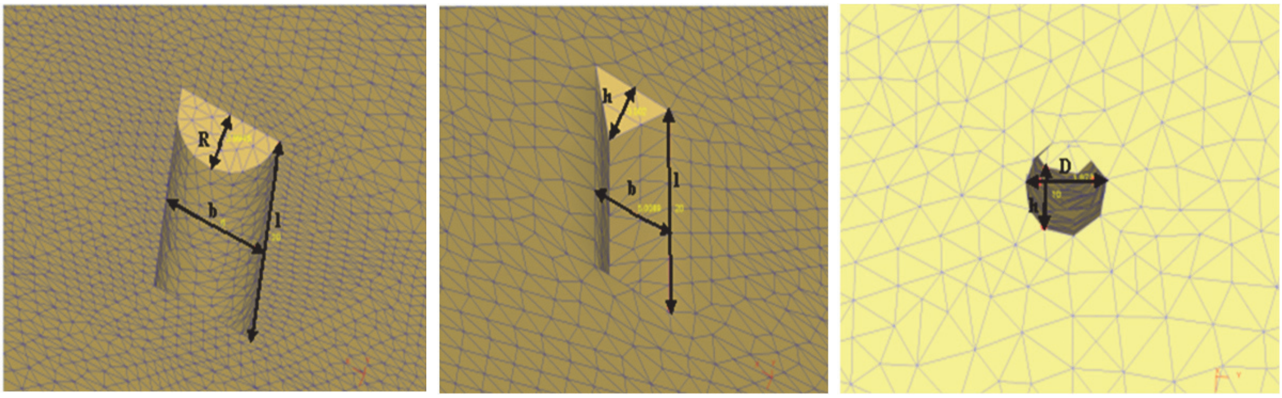

Fig. 3 A general indication of the dimensions of defects of U- and V-shaped notches and the round hole types

Obr. 3 Všeobecné naznačenie rozmerov chýb typu vruby U a V a kruhové diery

Tab. 1 Dimensions of defects of oval and round hole types in the first simulation stage before and after rolling at various temperatures of deformation and degrees of deformation

Tab. 1 Rozmery chýb typu oválne a kruhové diery z prvej časti experimentu pred a po valcovaní pri rôznej teplote deformácie a stupni deformácie

Defect No.	Change in dimensions of defects after rolling		Dimensions before rolling (mm)	Dimensions after rolling in (mm)				
				T_ε 1200°C, ε 10%	T_ε 900°C, ε 10%	T_ε 23°C, ε 10%	T_ε 1200°C, ε 50%	T_ε 900°C, ε 50%
1	Oval hole transversally	h_1	2	1.5	1.5	1.5	0	0
		b_1	10	10.72	10.7	10.5	14.7	15
		l_1	20	19.7	19.5	19.2	19.4	19.5
2	Oval hole longitudinally	h_2	2	1.5	1.4	1.5	0	0
		b_2	10	9.7	9.5	9	8.5	9
		l_2	20	22	21.6	21.4	27.5	33.6
3	Round hole	D_3	5	$axis_{longer}$ = 5.4 $axis_{shorter}$= 4.8	$axis_{longer}$ = 5.2 $axis_{shorter}$= 4.6	$axis_{longer}$ = 5.1 $axis_{shorter}$= 4.5	$axis_{longer}$ = 5.8‘$axis_{shorter}$= 3.4	$axis_{longer}$ = 6.5 $axis_{shorter}$= 3.3
		h_3	2	1.6	1.6	1.6	0	0
4	Round hole	D_4	2					
		h_4	2					

Tab. 2 The dimensions of defects of U-shaped or V-shaped notch and subsurface round hole types of the second simulation stage before and after rolling at various temperatures of deformation and degrees of deformation

Tab. 2 Rozmery chýb typu U a V vruby a podpovrchové kruhové diery z druhej časti experimentu pred a po valcovaní pri rôznej teplote deformácie a stupni deformácie

Defect No.	Change in dimensions of defects after rolling		Dimensions before rolling (mm)	Dimensions after rolling in (mm)		
				T_ε 1200°C, ε 10%	T_ε 23°C, ε 10%	T_ε 1200°C, ε 50%
01	V-notch transversally	h_{01}	3	2.2	2.3	0
		b_{01}	5	5.9	5.6	13
		l_{01}	100	100	100.1	100
02	U-notch longitudinally	R_{02}	3	h = 1.9	2	0
		b_{02}	6	6.4	5.8	15
		l_{02}	100	100	100	100
03	V-notch longitudinally	h_{03}	3	2.6	2.5	0.5
		b_{03}	5	5	4.6	1 to 2
		l_{03}	20	21.7	22.2	37
04	U-notch longitudinally	R_{04}	3	h = 2.6	2.5	0
		b_{04}	6	5.9	5.5	6.2
		l_{04}	20	21.9	22.2	37.7
05	Round hole	D_{05}	4	$axis_{longer}$ = 4.8 $axis_{shorter}$= 3	$axis_{longer}$ = 4.8 $axis_{shorter}$= 3	l = 8.6
		h_{05}	15	14.8	14.8	0
06	Round hole	D_{06}	2	$axis_{longer}$ = 2.3 $axis_{shorter}$= 1.5	$axis_{longer}$ = 2.5 $axis_{shorter}$= 1.5	l = 5.7
		h_{06}	10	10	9.9	0
07	Round hole	D_{07}	2	$axis_{longer}$ = 2.1 $axis_{shorter}$= 1.5	$axis_{longer}$ = 2.3 $axis_{shorter}$= 1.5	l = 6.6
		h_{07}	5	5	5	0

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ISSN 0018-8069

The process of hot rolling was simulated at heating temperatures of 1250°C and deformation temperatures of 1200 and 900°C. The relative degrees of deformation of 10 and 50 % were applied at the given temperatures. Subsequently, the process of cold rolling was simulated (temperature of 23°C) while applying the relative degree of deformation of 10%. The rolling speed of 1 $m{\cdot}s^{-1}$ was considered for the simulation. The strain rate $\dot{\varepsilon}$ varied at 50% deformation at those levels: at the entry end to the rolls – 60 s^{-1}, in the middle zone of deformation – 20 s^{-1}, at the exit end of the rolls – 10 s^{-1}, and at 10% deformation at the entry end to the rolls at a level of 20 s^{-1}, in the middle zone of deformation – 4 s^{-1}, at the exit end of the rolls – 2.5 s^{-1}. Those are the values, which are read directly from the simulation process in the program DEFORM. The simulation results at deformation temperatures of 1200 and 900°C and the degrees of deformation of 50 and 80 % were compared with the results obtained after the actual rolling under laboratory conditions on the two high rolling mill 210.

2. Results of experimental simulations

In general, the simulations of rolling showed a change in position and shape of defects, as well as the development of initial defects to another type. Further, specific cases are discussed corresponding to the given heat-deformation conditions of rolling.

2.1 The first simulation stage (surface defects of hole type – oval, circle)

2.1.1 Hot rolling (1200°C, 900°C) and cold rolling (23°C) at 10% deformation

In the simulation under the given conditions, only changes in shape and size of initial defects were observed (e.g. round holes were transformed into ellipses). Since the round holes indicated as No. 3 and No. 4 are deformed to ellipses, their diameters *D* as changes in the size of intersecting axes were tracked (indicated in Tab. 1 as axislonger and axisshorter), the size of which was shrinking by rolling. Since no significant deformation occurred, except for a change in shape (especially in depth) only, we did not introduce any visual documentation.

The simulation results show that the greatest deformation (effective-logarithmic strain) occurred in the oval hole No. 2 oriented in the longitudinal direction as it can be seen in Fig. 4.

Also, the value of the damage factor (Cockcroft-Latham fracture criterion), expressing the possibility of material rupture, was the highest for the hole given in Fig. 5.

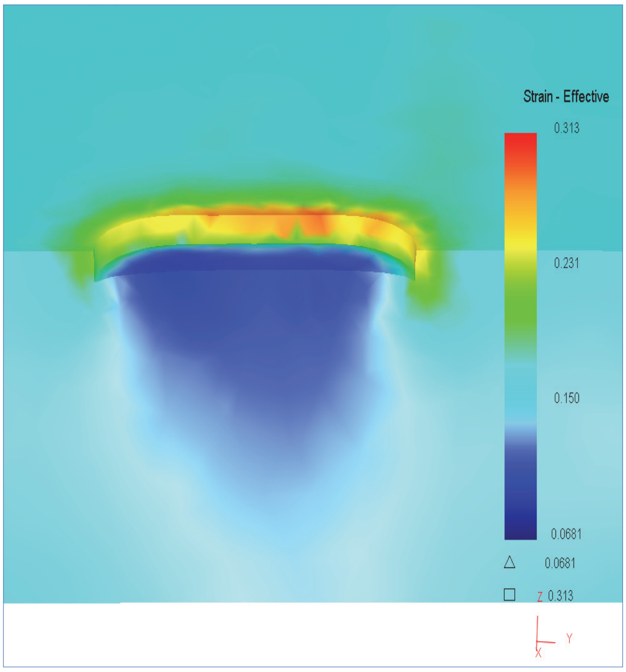

Fig. 4 Expression of the logarithmic deformation of the material in the area of the defect of the oval hole No. 2, longitudinally oriented, at deformation temperature of 1200°C

Obr. 4 Vyjadrenie logaritmickej deformácie materiálu v oblasti defektu typu oválna diera č.2, orientovanej pozdĺž, pri deformačnej teplote 1200 °C

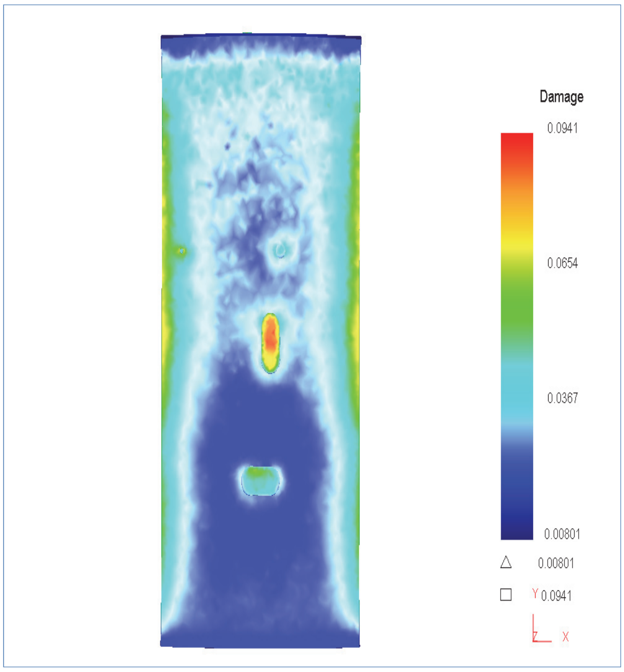

Fig. 5 Cockroft-Latham fracture criterion at deformation temperature of 1200°C

Obr. 5 Cockroft-Lathamove kritérium tvárniteľnosti pri deformačnej teplote 1200 °C

2.1.2 Hot rolling (1200°C, 900°C) at 50% deformation

In the simulation under the given conditions, in addition to the change in the size of initial defects, also their development was observed, namely irrespective of the deformation temperatures. The initial defects were rolled-in and defects of lap and scratch types occurred, which can be observed in Fig. 6. The visual documentation shows the simulation of deformation of the oval hole No. 1 as an example; for other holes, the course of deformation was similar. Figure 6 shows the cross-section of the oval hole No. 1 oriented transversely and its behaviour during the simulation process of rolling at a deformation temperature of 900°C and 50% deformation. We can see how the oval hole gradually disappears, and how, in the final stage of the simulated rolling, a lap arises and the hole loses its depth. The lap can give rise of scales in the further processing of the material. In the scale formation in the stage of hot-forming, oxidative processes play a significant role, originating in internal sources (oxides in initial defects, atomic oxygen in a solid solution of Fe) and external sources (oxygen from the contact atmosphere). During the hot-forming process, scales are mostly not observed, they appear only after an additional increase in the intensity of material stress (bending, cold rolling, pressing). The formation of scales on sheets after cold-forming is often accompanied by other surface defects, such as dark spots and strips with brown or black colouring. These defects also indicate the presence of latent scales. Compared to the rolling simulation at 10% deformation, a similar change in the size of the defects (*h*, *b*, *l*) occurs, but with lower values. The change in thickness, the value of which was zero after increasing the degree of deformation (rolling-in of the initial defect) was the most important.

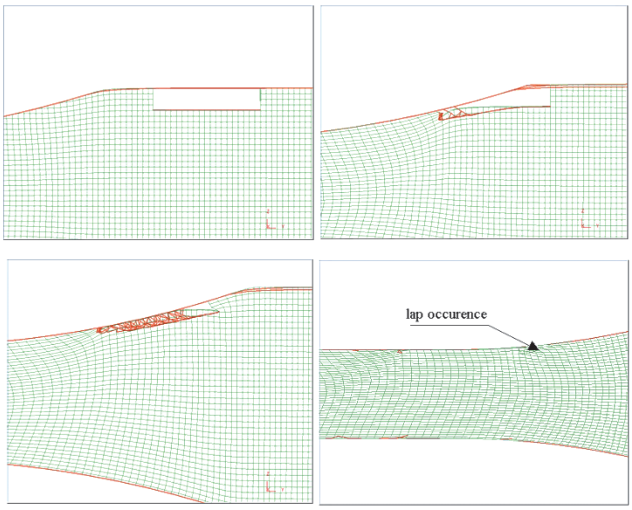

Fig. 6 The cross-section of the oval hole No. 1 oriented transversely, at deformation temperature of 900°C and its rolling-in at 50% deformation

Obr. 6 Priečný rez oválnej diery č.1 orientovanej priečne, pri deformačnej teplote 900 °C a jej zavalcovanie pri 50% deformácii

Fig. 7 shows the size of logarithmic deformation (effective strain) of material in the area of oval hole oriented transversely at deformation temperature of 900°C and 50% deformation. The highest values are located at the root of the defect and compared to the rolling simulation at 10% deformation the values are greater.

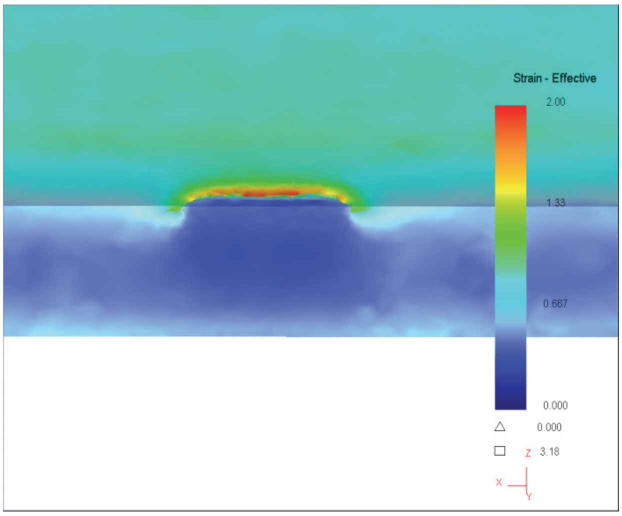

Fig. 7 Expression of the logarithmic deformation of the material in the area of the defect of the oval hole No.1, oriented transversely, at deformation temperature of 900°C and 50% deformation

Obr. 7 Vyjadrenie logaritmickej deformácie materiálu v oblasti defektu typu oválna diera č.1, orientovanej priečne, pri deformačnej teplote 900 °C a 50% deformácii

2.2 The second stage of simulation (defects of U-shaped, V-shaped notches; subsurface round hole).

2.2.1 Hot rolling (1200°C) and cold rolling (23°C) at 10% deformation

The rolling simulation results under the given conditions do not lead to significant changes in the morphology of defects as they remain more or less unaffected.

From Fig. 8, where the Cockcroft-Latham fracture criterion is expressed, it can be deduced that the maximum probability of material rupture and the possibility of developing initial defects consist in their root.

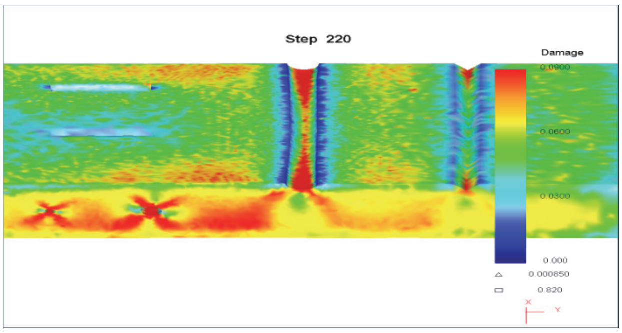

Fig. 8 Cockcroft-Latham fracture criterion

Obr. 8 Cockroft-Lathamovo kritérium tvárniteľnosti

2.2.2 Hot rolling (1200°C) at 50% deformation

During the simulation under these conditions, except changes in the size of initial defects, also their development occurs. The initial defects were rolled-in, which caused the emergence of new defects of lap and scratch types. The emergence of new defects during the rolling process and their final appearance are captured in the visual documentation.

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ISSN 0018-8069

The V-shaped notch No. 01 (Fig. 9) and U-shaped notch No. 02 (Fig. 10) oriented transversely were rolled out and after that edge corrugation remained. For the V-shaped notch No. 03 (Fig. 11) U-shaped notch No. 04 (Fig. 12), longitudinally oriented, a lap in the rear occurred. The final appearance of the V-shaped notch (No. 03), longitudinally oriented, after rolling-in, was in the form of a visible scratch along the whole length, but for the U-shaped notch (No. 04), oriented alike, a visible scratch remained only in the corners.

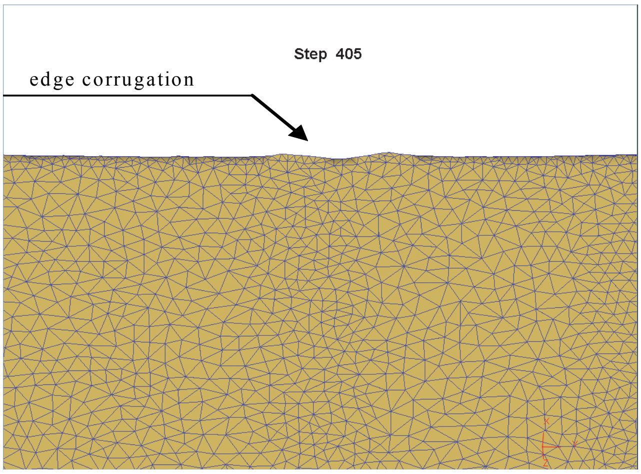

Fig. 9 The defect of V-shaped notch type (No. 01) oriented transversely, after hot rolling at deformation temperature of 1200°C and 50% deformation

Obr. 9 Defect typu vrub V (č. 01) orientovaný priečne, po valcovaní za tepla pri deformačnej teplote 1200 °C a 50% deformácii

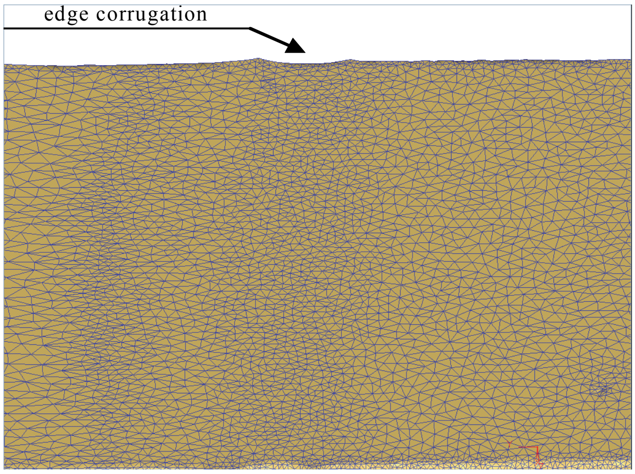

Fig. 10 The defect of U-shaped notch type (No. 02) oriented transversely, after hot rolling at deformation temperature of 1200°C and 50% deformation

Obr. 10 Defekt typu U vrub (č. 02) orientovaný priečne, po valcovaní za tepla pri deformačnej teplote 1200 °C a 50% deformácii

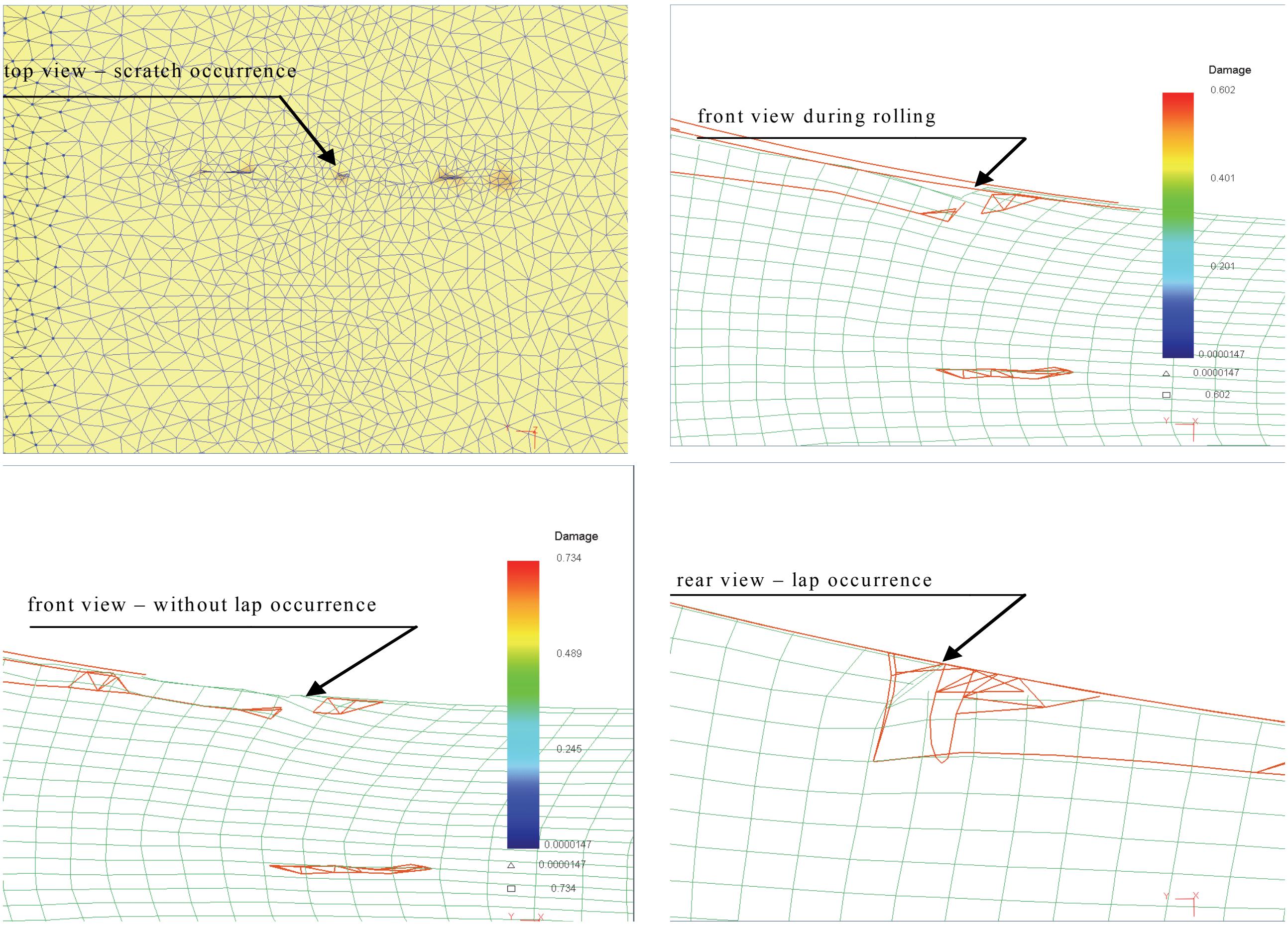

Fig. 11 The defect of V-shaped notch type (No.03) oriented longitudinally, after hot rolling at deformation temperature of 1200°C and 50% deformation; top view

Obr. 11 Defekt typu vrub V (č. 03) orientovaný pozdĺžne, po valcovaní za tepla pri deformačnej teplote 1200 °C a 50% deformácii; pohľad zvrchu

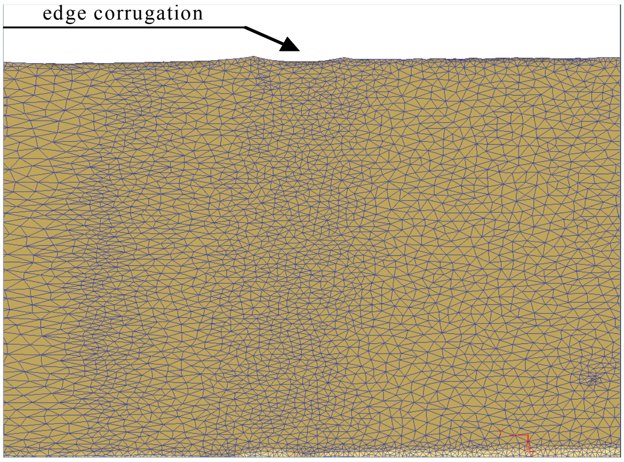

Fig. 12 The defect of U-shaped notch type (No. 04) oriented longitudinally, after hot rolling at deformation temperature of 1200°C and 50% deformation

Obr. 12 Defekt typu U vrub (č. 04) orientovaný pozdĺžne, po valcovaní za tepla pri deformačnej teplote 1200 °C a 50% deformácii

2.3 Subsurface round holes

2.3.1 Hot rolling (1200°C) and cold rolling (23°C) at 10% deformation

Under the mentioned simulation conditions, regardless of the deformation temperature, rolling-in of defects does not occur, subsurface holes changed their shape from a circle to an ellipse, another significant change, in addition to reducing their depth, did not occur.

2.3.2 Hot rolling (1200°C) at 50% deformation

The increase in the deformation to 50 % caused, similar to the previous types of defects, except for a change in their dimensions, also their development.

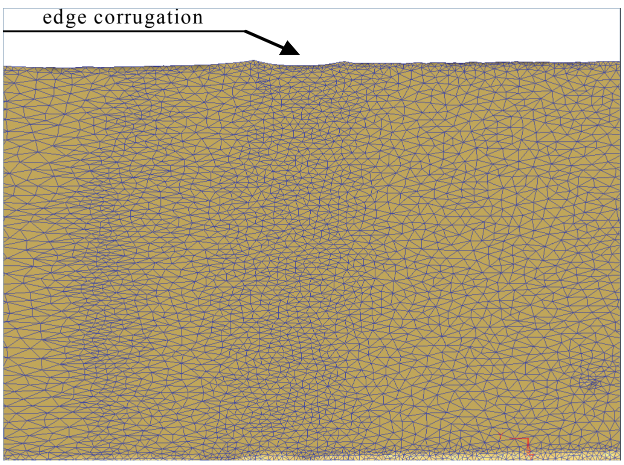

Fig. 13 The defect of round hole type (No. 05) located sideways, after rolling at deformation temperature of 1200°C and 50% deformation

Obr. 13 Defekt typu kruhová diera (č. 05) umiestnená zboku, po valcovaní za tepla pri deformačnej teplote 1200 °C a 50% deformácii

The round hole No. 05 (Fig. 13) was rolled in, which was reflected in the form of minor scratch formation, analogous to the round hole No. 06 (Fig. 14), which touched the surface. Conversely, the round hole No. 07 (Fig. 15) was completely rolled in and lost its height, which did not cause any secondary defect formation also thanks to the small size.

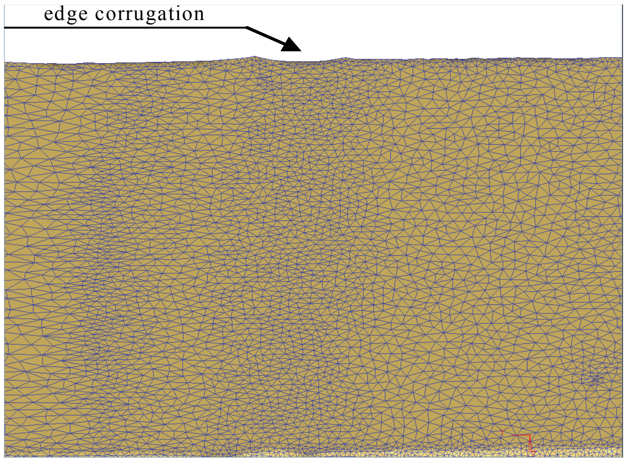

Fig. 14 The defect of round hole type (No. 06) placed sideways, after rolling at deformation temperature of 1200°C and 50% deformation

Obr. 14 Defekt typu kruhová diera (č. 06) umiestnená zboku, po valcovaní pri deformačnej teplote 1200 °C a 50% deformácii

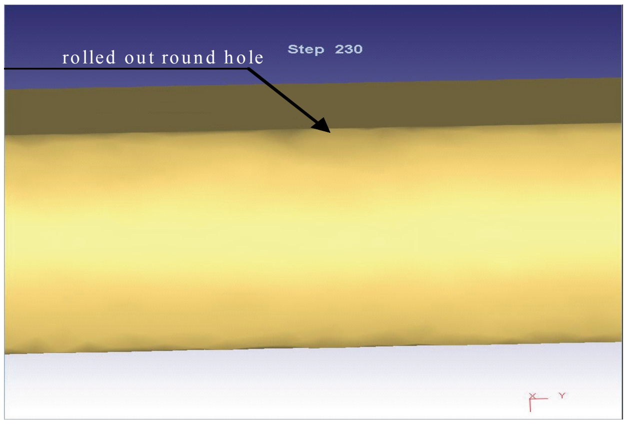

Fig. 15 The defect of round hole type No. 07) located sideways, after hot rolling at deformation temperature of 1200 °C and 50% deformation

Obr. 15 Defekt typu kruhová diera (č. 07) umiestnená zboku, po valcovaní za tepla pri deformačnej teplote 1200 °C a 50% deformácii

After completing the simulation of the selected rolling process in the DEFORM program, the physical lab rolling simulation of a steel specimen of coincidence quality was performed and the results compared. We have chosen the case corresponding to the high-temperature austenitic area and the degree of deformation corresponding approximately to the first stage of rolling, so the real conditions of rolling sheets and strips were approached. The mentioned comparison is documented in Fig. 16.

Hutnické listy č. 3/2019, roč. LXXII
ISSN 0018-8069

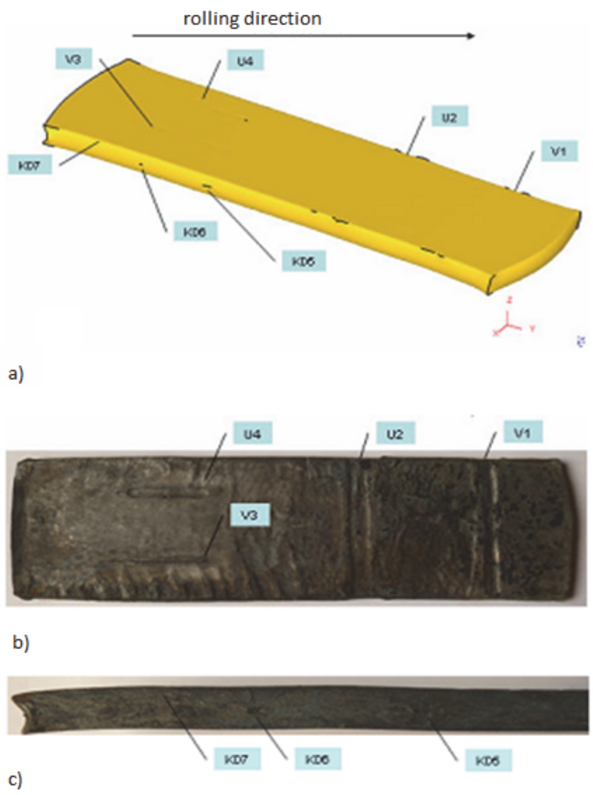

Fig. 16 Comparison of numerical and physical simulations
Obr. 16 Porovnanie numerických a fyzikálnych simulácii

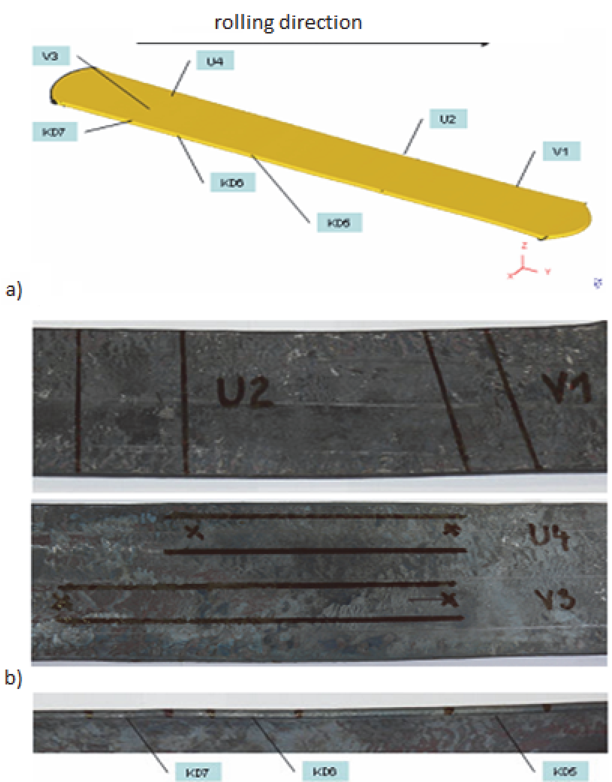

Fig. 17 Comparison of numerical and physical simulations when increasing the degree of deformation from 50 to 80 % while maintaining the thermal mode of simulation
Obr. 17 Porovnanie numerických a fyzikálnych simulácii pri zvýšení stupňa deformácie z 50 na 80 % pri zachovaní teplotného režimu simulácie

The mentioned documentation shows that under the given thermal-deformation conditions, conformity was achieved between mathematical and physical simulations in the case of the notch-shaped defect No. 04 and in the case of the subsurface defects No. 05 and No. 06. In a total number of defects, this conformity, expressed as a percentage, represents less than 50 %. In respect thereof, retaining the thermal mode of rolling, an increase in the relative degree of deformation from 50 to 80 % was considered. By increasing this deformation parameter, a 100% conformity occurred between the mathematical simulation in the DEFORM program and the physical simulation on the lab two high rolling mill 210 as documented in Fig. 17.

The simulations in the DEFORM program were performed with two fundamental goals:

a) Follow the course of development (evolution) of defects introduced into a virtual steel specimen; evaluate the course and compare it with real rolling conditions through physical simulations under laboratory conditions on a real steel specimen rolled on the two high rolling mill 210.

b) By the simulations, create a base for elaborating the algorithms by machine learning methods to predict the behaviour of a studied defect. The results from the DEFORM program are inputs to the algorithm. The attributes, which can be used for predicting the defect development are as follows: type of defect, length of defect, width of defect, depth of defect, rolling process (hot, cold), heating temperature, time of cooling (the difference between the heating temperature and the temperature of deformation), temperature of deformation, degree of deformation, orientation of the defect to the direction of rolling.

Examples with the described attributes may be classified into four classes:

- rolling-in of the defect,
- defect persists with retaining the shape,
- defect persists in a transformed shape (e.g, the transformation of a circle to an ellipse),
- defect persists in a transformed shape (e.g. creation of a recess).

Examples of forming the so-called training tables (training sets) taking into account the considered attributes, and based on them, elaborating the algorithms for predicting the behaviour of observed defects are mentioned by us in literature [21]. The results obtained from the numerical simulations of longitudinal rolling along with the use of machine learning methodologies [22 – 24] form the base for elaborating the algorithms; the C4.5 algorithm, which can handle a large number of variables, appears to be suitable for processing the data of this type, and the training set can be extended to cover other types of defects.

It results from the discussion of the obtained results that in order to eliminate initial surface and subsurface defects, a certain degree of deformation is required, which is in this respect a crucial technological parameter. With the growth of the degree of deformation depending on the morphology and dimensions of initial defects, the likelihood of their elimination increases. In order to refine the size of deformation (mainly in terms of subsurface discontinuities), the so-called shape factor by Okumara can be contemplated [25]. Within our observations, the simulated temperatures of deformation did not show a significant, or rather any effect on the behaviour of the examined defects. An identical finding was reached for example by the cited Okumara who watched the effect of rolling temperature in a range of 1250 – 860°C on the core porosity of continuously cast slabs.

Conclusions

On the basis of the theoretical studies and of our experiments the following results were achieved:

- The simulations of rolling showed a change in position and shape of studied defects, as well as the development of initial defects to another type.
- The relative degree of deformation of 80% regardless of the thermal mode of rolling can be considered as reliable for eliminating the monitored surface and subsurface defects adequately.
- The results obtained from the numerical simulations of longitudinal rolling along with the machine learning methodologies form a base for elaborating such algorithms, on the basis of which it will be possible to predict the evolution of initial surface and subsurface defects in rolling of sheets and strips.

Acknowledgements

This research has been elaborated in the framework of the project RMSTC No. LO1203.

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