INFLUENCE OF MEFASS ROLLING PARAMETERS ON TEMPERATURE OF FORMED STRIP

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VPLYV PARAMETROV MEFASS VALCOVANIA NA TEPLOTU TVÁRNENÝCH PÁSOV

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Abstrakt

Cieľom práce bolo určiť hodnotu ekvivalentnej deformácie a vplyv teploty v skúšobných materiáloch po procese valcovania s dodatočným cyklickým, axiálnym pohybom valcov. Tento druh valcovania sa nazýva MEFASS (Metal Forming Aided by Shear Stresses). Výskum bol realizovaný na Katedre modelovania procesov a lekárskeho inžinierstva Sliezskej technologickej univerzity, kde bola navrhnutá a postavená laboratórna valcovacia stolica s možnosťou cyklického axiálneho pohybu valcov. Uvedená je matematická závislosť pre výpočet hodnoty ekvivalentnej deformácie vo valcovacom procese MEFASS. Bolo pozorované, že zmena toku deformácie pri valcovaní MEFASS spôsobuje výrazné zvýšenie hodnoty ekvivalentnej deformácie. Bolo tiež pozorované, že časť z celkovej ekvivalentnej deformácie spojenej s axiálnym pohybom valcov je značne väčšia ako celková ekvivalentná deformácia spojená so zmenou výšky pásu. Práca sa venuje aj vplyvu ekvivalentnej deformácie pri valcovaní MEFASS na teplotu valcovaného pásu. Teplota valcovaného pásu bola meraná termovíznou kamerou IR Snapshot 525. Predmetom analýzy boli termovízne obrázky vzoriek po sekundárnom priebehu nekonvenčného valcovania. Bolo pozorované zvýšenie teploty pásu po valcovaní MEFASS v porovnaní s konvenčným valcovaním. Hodnota teploty závisí od parametrov valcovacieho procesu MEFASS: veľkosť úberu, valcovacia rýchlosť, amplitúda a frekvencia dodatočného cyklického axiálneho pohybu valcov.

Abstract

The aim of this work was to evaluate the value of equivalent strain and also the temperature effect in tested material after rolling process with additional, cyclic, axial motion of the rolls. This type of rolling is called MEFASS (Metal Forming Aided by Shear Stresses). Research were conducted in Department of Process Modelling and Medical Engineering of Silesian University of Technology, where laboratory rolling mill with possibility of cyclic, axial rolls motion was designed and built. The mathematical relation for calculating the equivalent strain value in MEFASS rolling process is presented. It is observed that change of the strain path in MEFASS rolling causes significant increase of equivalent strain value. It is also observed that part of total equivalent strain connected with rolls axial motion is considerable larger than total equivalent strain connected with change of strip height. The equivalent strain influence in MEFASS rolling on temperature of rolled strip was also discussed in this paper.

Temperature of rolled strip was measured by thermovision camera IR Snapshot 525. Thermovision pictures of samples after second pass of non-conventional rolling were the subject of analysis. Increase of strip temperature after MEFASS rolling was observed in comparison with conventional rolling. The value of temperature depends from parameters of MEFASS rolling process: draft quantity, rolling velocity, amplitude and frequency of additional, cyclic, axial rolls motion.

Keywords: MEFASS process, rolling, change of the strain path, temperature

1. Introduction

Research in area of non-conventional metal forming processes are conducted in many of research centers. Very promising results are obtained in research of metal forming processes characterized by non-proportional and non-monotonic strain course. This type of strain course develops interesting effects: in structure of deformed metal [2] and its reaction for deformation expressed by force-energy parameters of forming process [3]. First industrial applications of this forming methods e.g. rod extrusion with reverse matrix KOBO [4], which is conducted in INMET Gliwice, shows rising interest of industry for this type of forming processes.

In Department of Process Modelling and Medical Engineering Silesian University of Technology are conducted research of two non-conventional metal forming methods: compression with oscillatory torsion and rolling with cyclic, transverse rolls movement. Characteristic feature both of these metal forming methods is significant part of share stresses in whole process of metal deformation, caused by additional tolls movement. In this connection the processes were called MEFASS processes (Metal Forming Aided by Shear Stresses).

2. Calculation of strain value in MEFASS rolling process

First research results of rolling process with cyclic, axial rolls movement were presented in some articles [5,6]. Research program is conducted at this time, in which main objectives are:

- determining of the most favourable conditions for conduct MEFASS rolling process,
- analysis of effects in metal after metal forming with cyclic change of load scheme.

Research are conducted on laboratory rolling mill with possibility of cyclic, transverse rolls movement – Fig. 1a. Maximum displacement of working roll is amount ± 2mm, which allows to reach maximum relative rolls displacement at 8mm. Frequency of transverse rolls movement is regulated and can be changed from 0 to 3Hz. Rotational speed of rolls is regulated in range from 0 to 20 r.p.m.

Rolling mill is equipped with measurement system, which allows to measure and recording the most important parameters of rolling process – Fig. 1b. This measurement system also allows to follow measurement data in actual time, record data on hard drive of computer as well as analysis and processing of data.

Literature review [2,7] as well as conducted metallographic research for material after non-conventional metal forming proved large size reduction of grains in metal structure. This phenomenon is probably a result of strain value gained during deformation. Since existing relations for equivalent strain can be apply only for conventional metal forming processes, it is necessary to derive new relations. By assumption of strain macro-homogenity the following relation was derived for MEFASS rolling process

$$\varepsilon_{ic} = \frac{4 \cdot f \cdot a \cdot \sqrt{(h_0 - h_1) \cdot \frac{D}{2}}}{\sqrt{3} \cdot v_w \cdot (h_0 + h_1)} + \left| \ln \frac{h_1}{h_0} \right| \quad (1)$$

where: ε_{ic} - total equivalent strain in one pass of rolling,
h_0, h_1 – strip height before and after the pass, [m]
v_w – rolling velocity, [m/s]
D – diameter of rolls, [m]
f – frequency of rolls transverse movement, [s^{-1}]
a– amplitude of material axial displacement, [m]

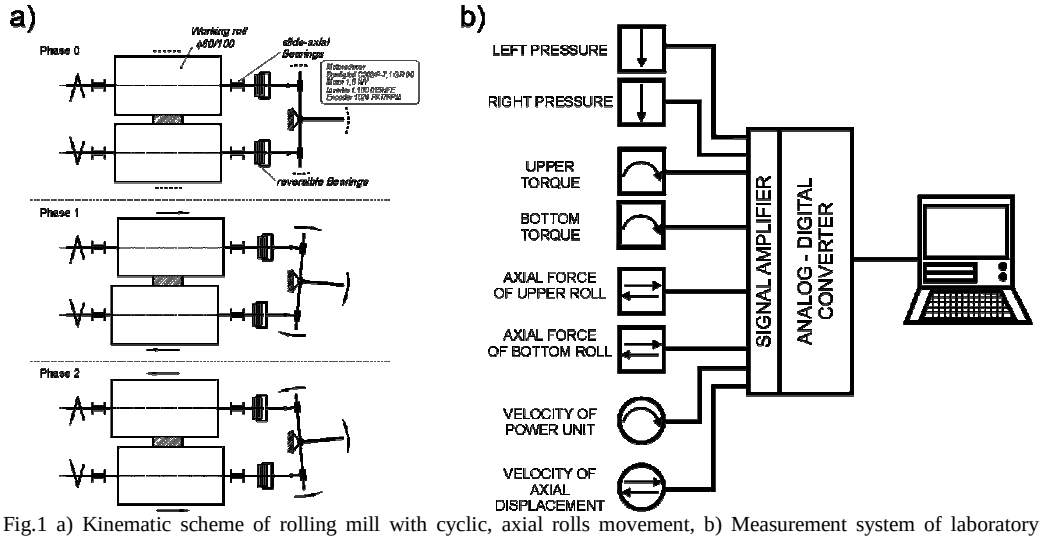


Fig.1 a) Kinematic scheme of rolling mill with cyclic, axial rolls movement, b) Measurement system of laboratory rolling mill [6]

Using relation (2.1) total equivalent strain for three pass of rolling was calculated. Influence of process conduct parameters i.e. draft quantity, rolling velocity, frequency and amplitude of transverse rolls movement on total equivalent strain value was analyzed. Results for example were presented in Fig.2.

Significant increase of total equivalent strain value with increase of axial motion parameters was observed. Part of total equivalent strain connected with rolls axial motion is definitely larger than total equivalent strain connected with change of strip height. This difference can reach six times. Similar differences were calculated for total equivalent strain in conventional rolling in comparison with total equivalent strain in MEFASS rolling. E.g. comparable total equivalent strain value in conventional rolling for relative draft about 20% would be reach after 21 passes of rolling, by assumption that strain hardening isn't present.

3. Course and results of temperature research rolled strip by MEFASS method

Characteristic property of metal forming processes with cyclic change of load scheme is performing additional work of deformation. This additional work of deformation is converted to heat in some areas of formed material called macro- and micro-shear bands [8].

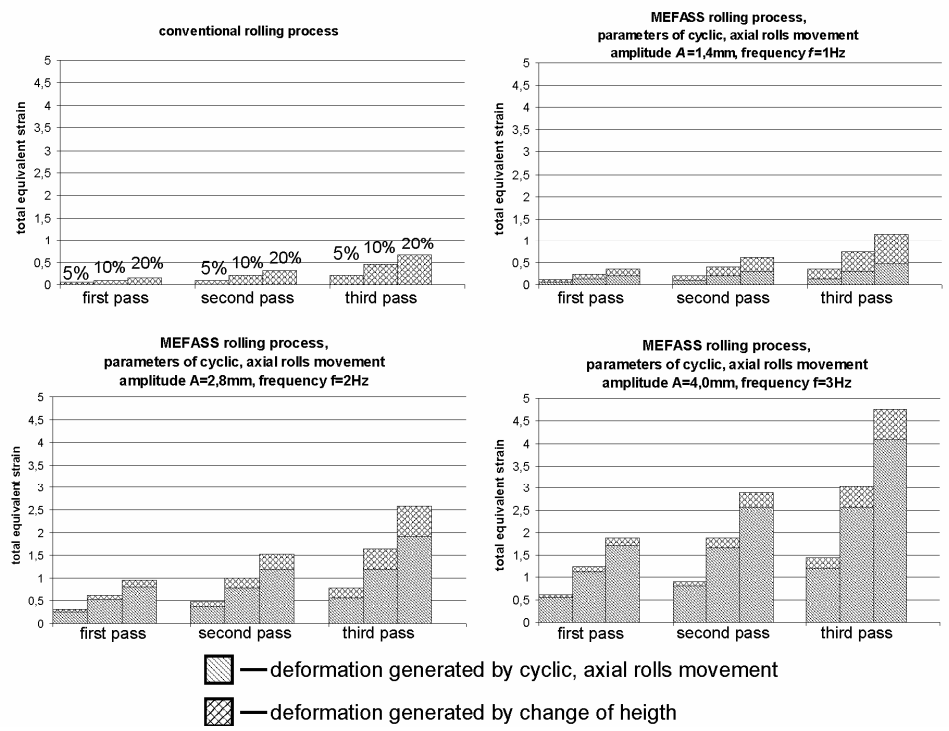


Fig.2 Total equivalent strain calculated in rolling process with cyclic change of load scheme for different parameters of process conduct – rolling velocity 7 r.p.m

For this phenomenon evaluation thermovision research of rolled strip in MEFASS rolling second pass were conducted. Strips were done from electrocopper M1E. Initial dimensions of strips amounted 8×8×100mm (w×h×l). Parameters of rolling process conduct were changed in range presented in Table 1.

Table 1 Parameters of process conduct for MEFASS rolling in presented research

draft quantity- ε_h , [%]	**rolling velocity - v_w, [r.p.m.]**	**frequency of rolls axial motion - f, [Hz]**	**amplitude of rolls axial motion - A, [mm]**
5	7	1	0
10	14	2	1,4
20	20	3	2,8

Temperature distribution on rolled strip surface was recorded after strip left the rolling gap by thermovision camera IR Snapshot 525 – Fig.3a. Recorded images were transferred to personal computer and were processed in program SNAPVIEW 2.1 – Fig.3b. SNAPVIEW 2.1 permit to:

- recorded thermovision images processing,
- change of emissivity coefficient and environment temperature,
- calculate minimum and maximum temperature of measured object,
- data export to different programs e.g. Microsoft Excel.

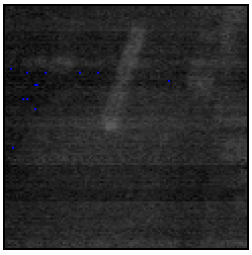
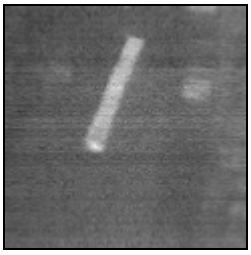
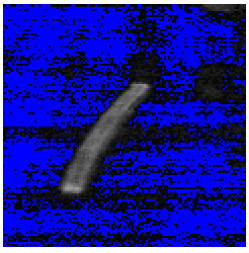
a) b)

Fig.3 a) Laboratory stand for thermovision tests of strips after MEFASS rolling, b) SNAPVIEW 2.1 software for thermovision images processing

Emissivity coefficient for electrocopper M1E was calculated during tests, which were conducted in laboratory heat furnace. Temperature of material sample measured by thermovision camera was compared with temperature measured by thermocouple. Emissivity coefficient amounted 0,38 and for range of temperatures, which were obtained during rolling i.e. 20÷120°C, allowed to precise measurement of rolled strip surface. Environment temperature during research was 19°C.

The highest temperature of sample surface after conventional rolling was obtained for draft value ε_h=10% and rolling velocity v_w=14 r.p.m., as described by Table 2. Temperature increase in this case was 19°C in comparison with sample before deformation.

Table 2 Thermovision images recorded for samples surface during conventional rolling

rolling parameters	**ε_h=5%,** v_w=14r.p.m.	**ε_h=10%,** v_w=14r.p.m.	**ε_h=20%,** v_w=14r.p.m.
εic	0,103	0,211	0,446
			
average temperature	26	38	28
maximum temperature	31	47	39

Thermal effect in material develop by additional deformation work, which was introduced by cyclic, axial rolls movement, can be observed in Table 3. Increase of strip surface temperature was followed by increase of parameters connected with additional tools movement i.e. frequency and amplitude of rolls axial movement. MEFASS rolling with amplitude of axial rolls movement A=1,4mm and frequency f=2Hz was develop average temperature increase ca. 10°C in comparison with sample surface after conventional rolling while for amplitude of axial

rolls movement *A*=2,8mm and frequency *f*=3Hz average temperature was higher about ca. 30°C. Differences for maximum temperatures were significantly higher.

Table 3 Thermovision images recorded for samples surface during MEFASS rolling. Temperature of samples surface for different parameters of cyclic, transverse rolls movement

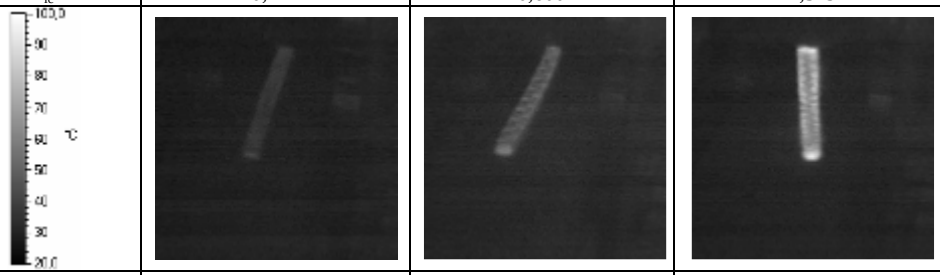
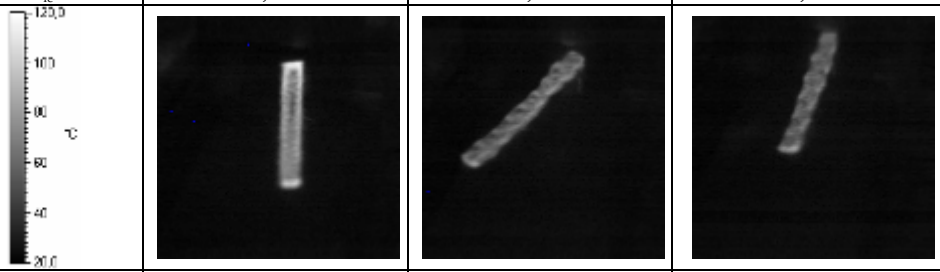
rolling parameters	ε_h=10%, v_w=7r.p.m. ***f*=1Hz, *A*=0mm**	ε_h=10%, v_w=7r.p.m. ***f*=2Hz, *A*=1,4mm**	ε_h=10%, v_w=7r.p.m. ***f*=3Hz, *A*=2,8mm**
ε_{ic}	0,211	0,600	1,379
			
average temperature	38	47	65
maximum temperature	46	62	94

Table 4 Thermovision images recorded for samples surface during MEFASS rolling. Temperature of samples surface for different values of rolling velocity

rolling parameters	ε_h=20%, ***v_w*=7r.p.m.** *f*=3Hz, *A*=2,8mm	ε_h=20%, ***v_w*=14r.p.m.** *f*=3Hz, *A*=2,8mm	ε_h=20%, ***v_w*=20r.p.m.** *f*=3Hz, *A*=2,8mm
ε_{ic}	2,244	*1,345*	*1,076*
			
average temperature	66	53	51
maximum temperature	115	84	84

Opposite influence on quantity of emitted energy in material was observed with change of rolling velocity – Table 4. The highest thermal effect (i.e. the highest temperatures) was observed for rolling velocity v_w=7 r.p.m. With increase of rolling velocity lower temperatures of strip surface were observed. But average temperatures difference between rolling velocity 14 and 20 r.p.m. was marginal – ca. 2°C. For rolling velocity v_w= 7 r.p.m. high homogeneity of temperature distribution on strip length was also observed in contrast to strips, which were rolled with higher rolling velocities.

4. Conclusions

Based on results of conducted thermovision research affirm, that:

- low values of rolling velocity v_w allow to gain homogeneous strain and temperature distribution on length of rolled strips,
- in MEFASS rolling cyclic, axial rolls movement develops additional thermal effect in deformed material, which depends from additional work of deformation connected with this rolls movement,
- increase of rolling velocity v_w causes decrease of additional deformation work and quantity of emitted heat in consequence,
- increase of parameters connected with additional rolls motion i.e. frequency of rolls transverse movement f and amplitude of rolls displacement A cause increase of additional deformation work and quantity of emitted heat in consequence,
- temperatures level, which were determined by thermovision measurements on surface of rolled samples, are significantly lower than expected values, which were calculated from relations formulated to change work of deformation on heat.

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