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Zbigniew Malinowski, Miroslaw Glowacki, Robert Szyndler
Bronislaw Hoderny, Jozef Kobic

STUDY ON RAILCAR WHEELS DIE-ROLLING WITH FINITE ELEMENT METHOD

Summary. This work presents results of thermic and mechanical modelling of die-rolling process of a railcar wheel forging by means of finite element method. The process features with a local spacial deformation zone what enforced using three -dimensional solution of finite element method.

ANALIZA METODĄ ELEMENTÓW SKOŃCZONYCH PROCESU MATRYCOWEGO WALCOWANIA KÓŁ WAGONOWYCH

Streszczenie. W pracy przedstawiono wyniki termo-mechanicznego modelowania metodą elementów skończonych procesu matrycowego walcowania odkuwki koła wagonowego. Proces ten cechuje się lokalną przestrzenną strefą odkształcenia, co spowodowało konieczność zastosowania trójwymiarowego rozwiązania metodą elementów skończonych.

1.INTRODUCTION

Railcar wheels manufacturing with die-rolling method requires numerous process engineering parameters influencing run of deformation process and eventually deciding a final product properties to be predetermined.
The basic citerion which is to be considered at each process of plastic working is conformity of a product shape to assumptions taken.
A lot of crucial factors influence a product shape, and among others one can name :
raw material shape applied and its temperature,
shape of a die impression, friction conditions and plastic properties of material being deformed as a function of changes in temperature due to deformation .
Railcar wheels manufacturing with die-rolling method , in view of factors influencing the run of plastic deformation in material , is reckoned as difficult one.
It is due to limited range of process engineering parameters accessible by which one could influence the run of deformation process.

Single-operational process of product shaping by use of the AGW rolling mill reduces time of production, however eliminates possibility auxiliary passes to be applied in order to alter the direction of material flow.
Thus, out of all geometric factors substantially influencing plastic flow of a material, only the shape of a preform remains crucial in the process of die-rolling.
Apart from the shape of a preform the run of deformation process is also influenced by : temperature of raw material, rotational speed of dies, inclination of the upper die, bite and friction.
Limited possibility to alter those parameters causes that the major factor the process engineer has to fit is a proper selection of a preform shape.

2. SIMULATION OF A WHEEL ROLLING PROCESS

A preform, whose shape and way of digitizing is shown in Fig. 1, was taken into modelling studies by means of finite element method of material flow in a process of die-rolling of a wheel, dia. 920.

It was assumed that in a result of press forging a wheel hub and lower portion of rim would be roughly shaped.

From the side of the lower die slight clearance was left to enable putting freely the preform into the die impression. Due to large area of friction as a result the preform contacts lower die throughout the entire circumference the radial flow of material from the lower die side is rendered difficult. Having considered foregoing it was assumed that the material could be relocated in the lower die mainly by bending and extrussion. At this zone, due to upper device inclined, the contacting area is narrow, and stiff parts of material beyond the contacting area enforce intensive, radial flow of material. Having considered foregoing a sidal surface of a preform was inclined into direction of wheel hub to delay relocation of material and to prevent forming a fin. A preform has a hub with raised upper portion due to ability of upsetting this portion of material as a result upper die moving downwards.

At calculations with finite element method it was assumed that dies of the rolling mill revolve at speed of 75 rpm and during one revolution height of the material is reduced by 2 mm. Friction at the area where dies contact the material was modelled by means of the friction ratio valued 0.3. Flow stress of R7 steel at conditions of hot forging was approximated with curves

$$\delta_p - \delta_o \ (1 + a\,\bar{e}) \qquad (1)$$

where $\bar{e}$ stands for intensity of logarithmic deformations. Values for coefficients δ_o and a are given in Table 1.

Table 1

Coefficients of curves of steel R7 consolidation

Coefficient	Temperature °C							
	650	850	900	950	1000	1050	1100	1150
δ_o MPa	100	70	60	50	40	30	20	10
a	3.134	1.346	1.274	1.258	1.468	1.770	2.481	5.070

Because the process of a railcar wheel shaping by means of the AGW rolling mill is ipreceded by press forging of a preform distribution of temperature throughout a preform is designated what derives from changes in temperature of raw material during press forging and due to cooling between specific operations. Following parameters of forging were assumed:

diameter of the raw material : 420 mm,
height of the raw material : 450 mm,
temperature of the raw material after discharging: 1200 °C ,
time of transportation to the water jet descalling device : 3 s,
time of transportation to the press: 3 s,
time of forging and transportation to the rolling mill : 30 s .

Results of calculations, by a pack of E_p Forg, for temperature of a preform before a process of rolling were presented in the Fig.2.

Determined temperature distribution was assumed as initial area of a preform temperature in calculations simulating material flow at rolling.During a die-rolling process material temperature
changes occur what is caused by carrying a heat away into dies and environment . Also an inflow of heat takes place due to plastic deformation of a material .
Those factors were considered by adding to the pack the AGW-Roll sub-programmes determining the temperature area of material being deformed .Exhibits for material temparature distributions after 25 and 34 revolutions of dies at the process of a 920 dia. wheel rolling were shown in the Fig. Nos 3 and 4 . In a result material contacting dies significant cooling of surface layers occurs , locally to the temperature of ca. 800 °C at places material contacts dies. When the rolling process develops the gradual widening of cooled areas is noticable . At the central portions of hub and rim temperature drop is slight and equals to ca. 25 °C after 34 revolution of dies . Deatiled results of calculations of the temperature area of a wheel forging after the process of rolling are shown in the Fig. No. 4.

Simulation of material flow proved correctness of matching the shape of a preform relative to filling the dies impression in. Fig. 5 presents shape of material after 25 revolutions of dies . At the final stage of deforming the upper die contact s material at the zone from inner portion of hub to the wheel rim . Due to material upsetting and radial extrussion the filling of outer part of rim at the final stage is achieved , Fig. 6 .

Process of railcar wheel shaping by means of die-rolling features with great level of non-uniformity of deformation. It is connected with creation local zone of deformation at places where a material contacts a device, Fig. 7 .
While developing the contacting area of dies with material being deformed the relocation of deforming zone towards wheel hub is noticed , Fig.8 . However,new non-deformed zones at

the wheel rim have developed. Fig. 9 shows the distribution of deforming intensity after 25 revolutions of dies while shaping a dia. 920 wheel from a preform presented in the Fig. 1.

At the beginning of the process deformations are located at the wheel rim area ; wheel hub and central portion of wheel remain low-deformed.
Despite passing the deforming zone from a rim towards a hub , non-uniformity of plastic strains is great both radially and at the wheel thickness .
Layers of material contacting the inclined die are subject to intensive deformation whereas from the side of lower die , non-inclined one, deformations are much less.
Consolidation of superficial layers due to temperature drop and great plastic strains hinders filling wheel hub and rim corners in . Detailed results of calculations of distribution of deformation intensity in the wheel cross section after the process of die-rolling are shown in the Fig. 10 .

3 . CONCLUSIONS

Thermic and mechanical study on process of railcar wheel shaping by means of die-rolling shows great level of difficulties in engineering design of this process. The basic problem which ought to be uniformly solved during designing separately for each forging is the proper selection

of a preform shape .
In a process of die-rolling one can distinguish following crucial features of material deformation :

slight relocations of material from the side of non-nclined die, the lower one, due to large area material contacts the device and cooling the material down because of carrying the heat away to a die as a result the die fully circumferencially contacts the material,

intense radial flow of upper layers caused by the narrow deforming zone due to inclination of upper die and lesser cooling of material as a result the material contacts the device in shorter time,

local deformation of material and presence of low-deformed areas,

great level of non-uniformity of deformation in radial direction and at the forging thickness; material layers from the side of the inclined die are greatly deformed where intensity of logarithmic deformations values ca. 5 ; at the area of wheel hub and rim, from the side of non-inclined die, the low-deformed areas are present,

filling the die corners in is difficult to achieve due to intensive radial flow of material and substantial cooling the material surface down ; the temperature of surface drops locally down to ca. 800 ^{o}C.

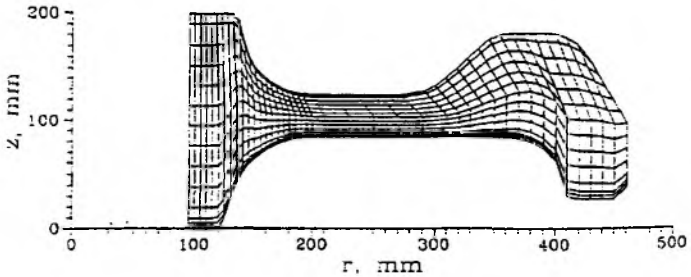

Fig. 1. Shape of a preform assumed at calculations of material flow in a process of die-rolling of an UIC Φ920 mm wheel

Rys. 1. Kształt przedkuwki przyjęty do obliczeń płynięcia materiału w procesie walcowania matrycowego koła UIC Φ920

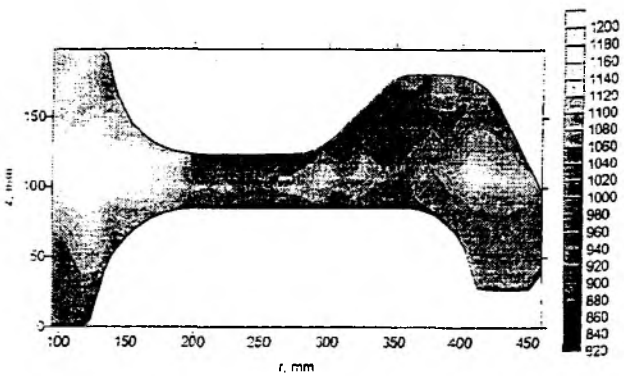

Fig. 2. Temperature distribution in a forging cross-section before die-rolling process

Rys. 2. Rozkład temperatury w przekroju poprzecznym odkuwki przed procesem walcowania matrycowego

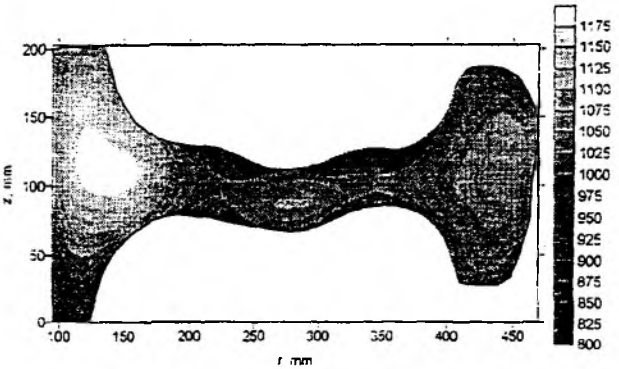

Fig. 3. Temperature distribution in the wheel cross-section after 25 revolutions of dies
Rys. 3. Rozkład temperatury w przekroju poprzecznym koła po 25 obrotach matryc

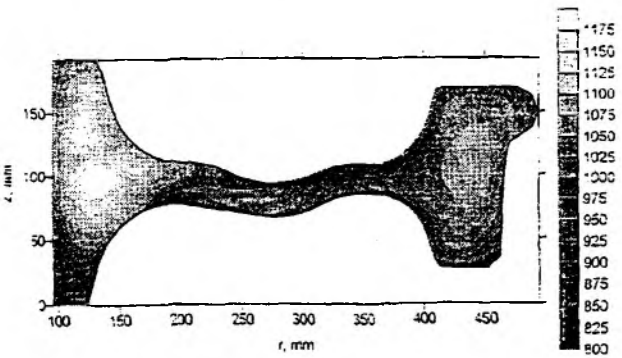

Fig. 4. Temperature distribution in the wheel cross-section after 34 revolutions of dies
Rys. 4. Rozkład temperatury w przekroju poprzecznym koła po 34 obrotach matryc

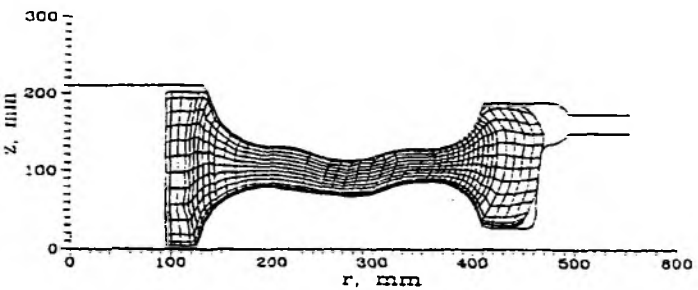

Fig. 5. Shape of a preform ofter 25 revolutions of dies in a proces of an UIC Φ920 mm wheel die-rolling
Rys. 5. Kszrtałt przedkuwki po 25 obrotach matryc w procesie walcowania matrycowego koła UIC Φ920

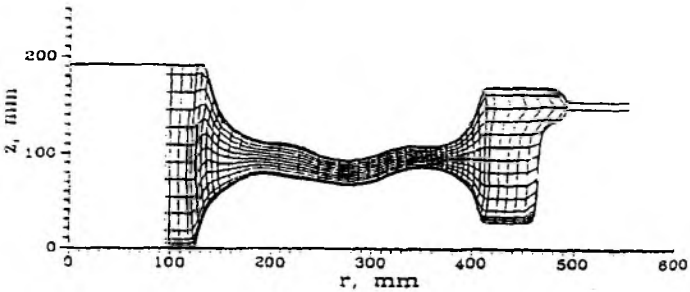

Fig. 6. Shape of a preform ofter 34 revolutions of dies in a procces of an UIC Φ920 mm wheel die-rolling

Rys. 6. Kszrtałt przedkuwki po 34 obrotach matryc w procesie walcowania matrycowego koła UIC Φ920

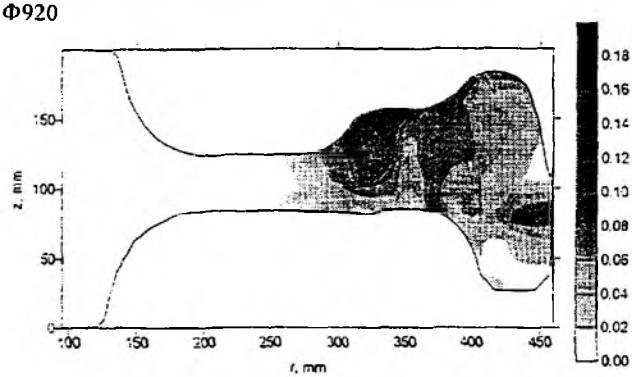

Fig. 7. Distribution of deformation speed intensity in the wheel cross-section after 10th revolution of a die

Rys. 7. Rozkład intensywności prędkości odkształcenia w przekroju poprzecznym koła po 10 obrocie matryc

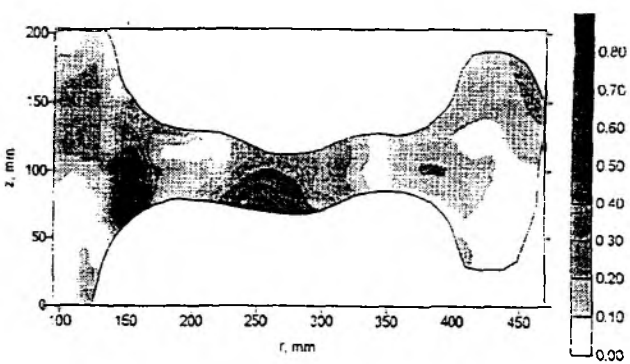

Fig. 8. Distribution of deformation speed intensity in the wheel cross-section after 25th revolution of a die

Rys. 8. Rozkład intensywności prędkości odkształcenia w przekroju poprzecznym koła po 25 obrocie matryc

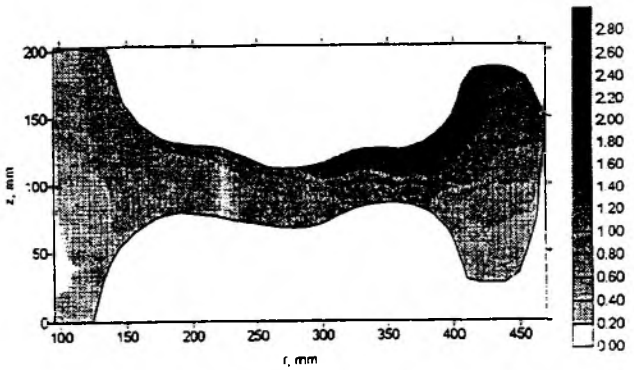

Fig. 9. Distribution of deformation intensity in the wheel cross-section after 25 revolutions of dies

Rys. 9. Rozkład intensywności odkształcenia w przekroju poprzecznym koła po 25 obrotach matryc

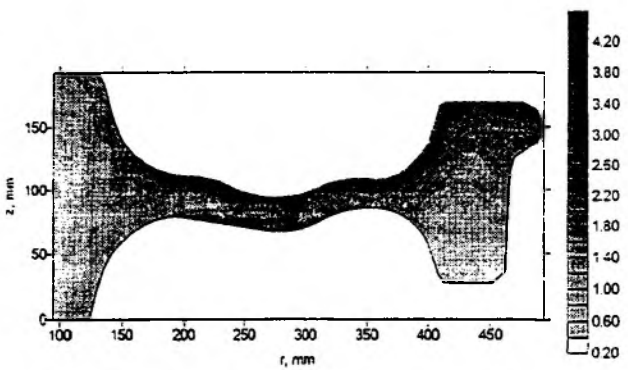

Fig. 10. Distribution of deformation intensity in the wheel cross-section after 34 revolutions of dies

Rys. 10. Rozkład intensywności odkształcenia w przekroju poprzecznym koła po 34 obrotach matryc

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Streszczenie

W pracy opisano czynniki wpływające na kształt wyrobu w procesie walcowania matrycowego oraz przedstawiono wyniki termomechanicznego modelowania metodą elementów skończonych procesu matrycowego walcowania odkuwki koła wagonowego.

Wytwarzanie kół wagonowych metodą walcowania matrycowego wymaga ustalenia szeregu parametrów technologicznych, mających wpływ na przebieg procesu odkształcenia i decydujących o końcowych własnościach wyrobu. Podstawowym kryterium, które musi być spełnione przez każdy proces przeróbki plastycznej, jest zgodność kształtu wyrobu z przyjętymi założeniami. Na kształt wyrobu ma wpływ szereg czynników, a do najważniejszych należy zaliczyć: kształt wsadu, temperaturę wsadu, kształt wykroju matryc, warunki tarcia oraz własności plastyczne odkształcanego materiału w funkcji zmian temperatury materiału powodowanej odkształceniem. Z punktu widzenia możliwości oddziaływania na przebieg plastycznego odkształcenia materiału, wytwarzanie kół wagonowych metodą walcowania matrycowego należy uznać za proces trudny. Związane jest to z ograniczonym zakresem parametrów technicznych, za pomocą których można wpływać na przebieg procesu odkształcenia. Jednooperacyjny proces kształtowania wyrobu w walcarce AGW skraca czas produkcji, eliminuje jednak jednocześnie możliwość stosowania wykrojów pomocniczych do zmiany kierunku płynięcia materiału. Tak więc, z czynników geometrycznych, mających zasadniczy wpływ na płynięcie materiału, pozostaje w procesie walcowania matrycowego jedynie kształt przedkuwki.

Proces walcowania matrycowego odkuwki koła wagonowego cechuje się lokalną przestrzenną strefą odkształcenia, co spowodowało, przy termomechanicznym modelowaniu metodą elementów skończonych procesu walcowania, konieczność zastosowania trójwymiarowego rozwiązania metodą elementów skończonych.