COMPUTATION OF POWER DISSIPATION EFFICIENCY IN PLASTIC FLOW OF MATERIAL USING SERIES EXPANSION METHOD

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ABSTRACT

The efficiency of power dissipation (ij) is a criterion used by the metal architect for optimizing the efficiency of process and analyzing the metal forming problems like instabilities in a wide range of materials. Conventional way of obtaining the power dissipation is based on effective strain rate power law inculcating cubic spline method which is sometimes difficult to execute due to assumption of its piecewise continuity. The present article meets the expectation of obtaining the pon'er dissipation by modeling the effective stress of the series expansion method for defining the plastic deformation of the engineering work piece. This modeling phenomena is utterly expressible as a single formula unit and helps in resisting the superficial error due to inherent material defect in its bulk **as** *well as the eiror causing due to sudden throb in applied physical conditions. Different graphical* **as well as** *numerical results shows that the maximum value of power dissipation efficiency at each process zone of strain is obtained at s* **= 0.001** *& 773K temperature. Whereas***,** *under the whole regime, the best efficiency correspond toe* **— 0.5, £• = 0.001 ,** *T -773K.*

Key Words *- power dissipation,* **A12024 alloy***, Flow/True stress, True strain rate, Thermo- mechanical process, Material Modeling.*

I. INTRODUCTION

A revolution tendering the fair demanding engineering applications towards the critically designed parameters waiving various metals and alloys in a variety of aircraft and space works, lead to a thrust in the development of light weight alloys. The inclusion of high strength, good tolerance, super fracture toughness, corrosion resistivity and acceptable ductility is always in demand to work on such key applications [1, 2], All these aspects constitute the part of analyzing the workability of the material which in case of metallic alloy refers to the plastic deformation ability to withstand the failure in different cases of processing phenomena like forging, extrusion and rolling [3]. The efficiency of power dissipation is always used in reference for explaining the deformation ability and maximizing the efficiency of process for the analysis of metal forming problemsincluding instabilities in a wide range of materials. “Dynamic Materials Modeling” [4] is widely used to define these workable condition of a material which depends on the intensity of deformation with respect to the externally imposed stress level at particular physical circumstances.

The aim of the present investigation is to evaluate the deformation behavior of the metal or the alloy which accounts for the efficiency of power dissipation as the dynamic metallurgical processes occurring during hot deformation. The study will in turn enlighten the influence of flow stress at elevated temperature on other predefined or contingent external physical conditions. The approach of “Series expansion (8) method” [5] in combination with strain rate power law [6, 7] is used to reach the outcome. The results have been derived on the assumption of considering the testpiece as the inductive dissipater of power in the whole system.

II FUNDAMENTAL THEORY OF POWER DISSIPATION DURING HOT WORKING

Strain independent power law gives a direct dependency of flow stress on strain rate. According to it, the flow stress (<7) of a material under uniform plastic deformation can be expressed as the simple power relationship [6, 7]

$$a = ke^{m} \qquad (1)$$

Here, the Strain rate coefficient *“k”* is a constant for particular strain, strain rate and temperature. The strain rate exponent *“m”* is also constant at these particulars and is generally referred as “strain rate sensitivity parameter”. Its value always lies between 0 and 1. Mathematically “m” is determined by the slope of the plot
between 111 (*(j)* versus In (£').

However, on taking the natural logarithm of equation (1), we obtain

$$\text{In } a = \text{In } k + m \text{ In } s \qquad (2)$$

Now differentiating this expression w.r.t. logarithm scale of strain rate, the value of “m” can be alternatively expressed as following equation (3),

<i(lner) (3)

The basics of DMM have been adopted from [7], According to it, at particular strain and temperature, the power P (per unit volume) absorbed by the testpiece under plastic flow can be expressed as the sum of G (the dissipator content) and J (the dissipator co-content) i.e.

$$P = G + J \qquad (4)$$

Where, the value of terms in right side of equation (4) can be defined in terms of “m” as,

G = —rv, *14-m_ mP 14-m* (5)

Where, *P* represents the average power or say the average amount of work done or energy transferred per unit time. In modeling the dynamic response of the material, a zerodimensional efficiency index *rj* is generally used to represent the power dissipation. It is nothing but the ratio of the “J” value in equation (6) to its maximum i.e.

J1(')V (6)

But, in lieu of equation (6), the maximum value of “J” can be obtained at the unit of strain rate sensitivity parameter *“m”*. Thus,

j –L max ^ (7)

This is the factor that defines the optimum condition of processing with an alloy. Thus, it is useful for obtaining a good combination of the processing parameters temperature, strain & strain rate. On putting the different values in equation (7), we lead to give the efficiency of power dissipation as equation (8),

2m71 =m + *1* (8)

This mathematical expression is helpful in coding the experimental results to the numerical data.

III. PROPOSED MODEL

According to "Series expansion method" [5], the flow stress with comparatively lesser number of coefficients can be defined by the following equation, <w) Or, /^/o 'X ') (9)

Where, *X*= *In s*, *Ay* are the functions of *T*. In order to go to its experimental counterpart the alloy taken under study is Al-2024 and the study data were collected from "HOT WORKING GUIDE" [4], The value of different parameters in equation (9) by the process of series expansion is described in Table-1.

Aj	*Value of Ay*
A_n	2367.5/T +0.921
A12	0.0002T-0.0249
Al3	-112420/T-^{2} +338.5/T -0.2513
A_{21}	-275.5/T +0.3235
$A_2$2	-0.026
A23	9620/ T^2 -5.4/T-0.0195

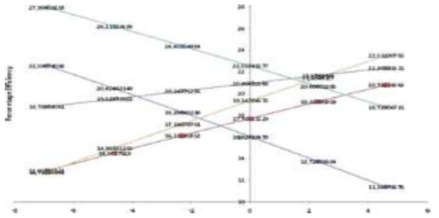
Table1-Value of Aij

The percentage efficiency of power dissipation is obtained through equation (9) by using the following equation,

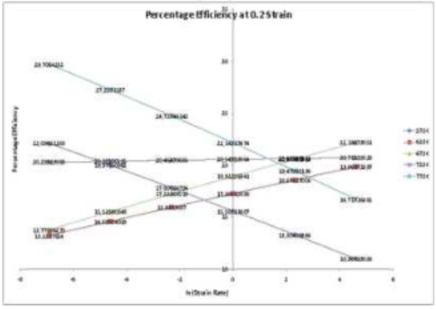
2m 1 m x1OO
m +1
V = (10)

IV. RESULT & DISCUSSION

Different plots for obtaining percentage efficiency of power dissipation by equation (10) at various strains are shown in Fig. (1). It can be easily analyzed from these plots that the maximum value of efficiency at each process zone of strain is obtained at *s* = 0.001 & 773K temperature. Whereas, in the whole regime the best efficiency correspond to £' = 0. 5, *s* = 0. 001, T=773K.



(a)



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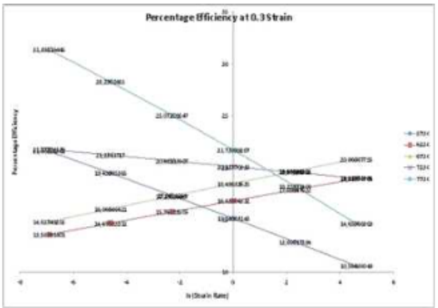

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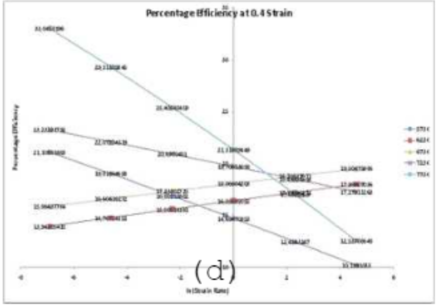

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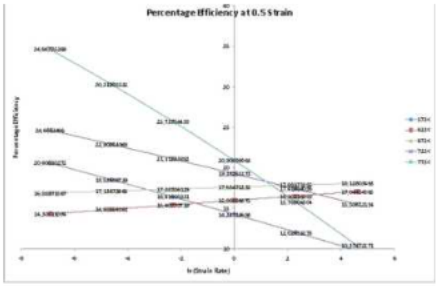

(e)

Fig-1: *Percentage Efficiency - ln(Strain Rate)* plot at *(a)£*= 0.1 (b) *s*= 0.2 (c) *s*= 0.3 (d) *s*= 0.4 (e) *e* = 0.5

V. CONCLUSION

Analysis carried out in this research article reflects the dependency of the Power dissipation efficiency during the plastic flow of the material under a deforming process on strain, strain rate & temperature. Various graphical and numeric results lead us to reach the following outcomes,

1. The maximum value of efficiency at each process zone of strain is obtained at £' = 0.001 & 773K temperature. Whereas, under the whole regime the best efficiency correspond to £' = 0.5, *s* = 0.001, T=773K.
2. Values of power dissipation efficiency can be obtained at many stringent experimental conditions by simply using the extrapolation or interpolation
3. This model may be used to eliminate the efficiency calculation at those points of experimental error where sudden changes in physical conditions like voltage fluctuation occurs.
4. The proposed model can ably covers a wider range of materials exhibiting the similar compressive behavior under the deforming compressive load.

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