ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

IARJSET

International Advanced Research Journal in Science, Engineering and Technology

2nd International Conference on Advances in Mechanical Engineering (ICAME-2016)

Amrutvahini College of Engineering, Sangamner

Vol. 3, Special Issue 1, March 2016

A Review on Wear Analysis of Wire Drawing Die

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Abstract: The die is an important factor in the success of the drawing process. The influences of the die angle, reduction, aspect ratio of the die, interfacial friction and drawing velocity on the die geometry are studied. The study of die geometry is vital in determining the surface and mechanical properties of drawn wires, and consequently, their application. Drawing of wires is a well-known process and several manuscripts are recognizable looking at the scientific literature. Nevertheless many information are available from a mechanical point of view, today new needs related to process sustainability push toward a process redesign taking into account different criteria. Various factors affects the life of the die which includes drawing force, lubricant used, coolant used, preprocessing of wire rod, semi angle of die, die geometry, die material, die wear, material thinning and damage are considered building an optimization problem in which we can decide the role of each criterion in the operative scenario.

Keywords: Semi Die Angle, Tribology, Hardness, Wear, Friction

I. INTRODUCTION

Drawing is a process where usually cylindrical, material (wire, rod and pipe) is reduced in cross-section by being drawn through a so called drawing die. Changing the cross sectional area or shape of a solid rod, wire, or tubing by pulling it through a die Wire drawing is a metal-reducing process, in which a wire rod is pulled or drawn through a single die or a continuous series of dies, thereby reducing its diameter. [1]

A wire or rod of copper, steel other metals, or alloy enters into one side and is lubricated and reduced in size. The leading tip of the wire is usually pointed in the process. The tip of the wire is then guided into the die and rolled onto a block on the opposite side. The block provides the power to pull the wire through the die. [2]

The die is divided into several different sections. First is an entrance angle that guides the wire into the die. Next is the approach angle, which brings the wire to the nib, which facilitates the reduction. Next is the bearing and the back relief. Lubrication is added at the entrance angle. The lube can be in powdered soap form. If the lubricant is soap, the friction of the drawing of wire heats the soap to liquid form and coats the wire. The wire should never actually come in contact with the die. A thin coat of lubricant should prevent the metal to metal contact. [2]

For pulling a substantial rod down to a fine wire a series of several dies is used to obtain progressive reduction of diameter in stages. Standard wire gauges used to refer to the number of dies through which the wire had been pulled.

Figure 1 : Wire Drawing Process

Wire drawing is one of the most common plastic deformation processes. A wire rod is pulled or drawn through a die or a series of dies, causing a reduction of its diameter. In general, drawing is known as a process performed at room temperature. Drawing of low-carbon- content steel wires is generally conducted at room temperature employing a

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number of passes or reductions through several dies. Sometimes it may be performed at elevated temperatures for large wires to reduce drawing forces.

Figure 2 : Die Setup

The tribological properties are of utmost importance for the materials in contact and the system is sensitive to operating conditions and environment. To understand the tribological behaviour, knowledge in physics, chemistry, metallurgy and mechanics is necessary which makes the science interdisciplinary. By optimising the friction and wear in technological applications, such as machine components or in metal working systems, both environment and costs can be saved.

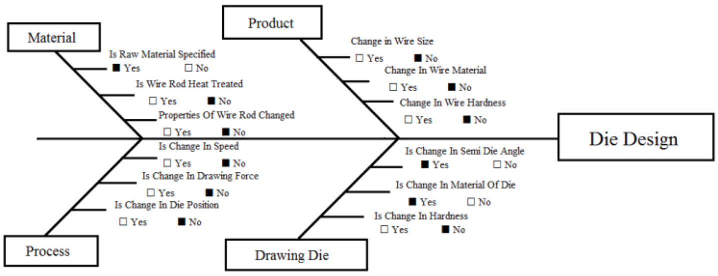

Figure 3 : Cause Effect Diagram

II. TERMINOLOGY OF WIRE DRAWING DIE[3]

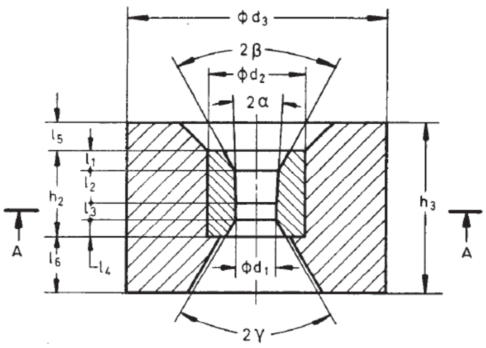

Figure 4 : Terminologies of wire drawing die[3]

Where,
d_l =diameter of bearing
d_2 = diameter of pallet
d_3 = diameter of case
h_2 = height of pallet
h_3 = height of case
L_I = length of entry angle
L_2 = length of drawing angle
L_3 = length of bearing

L_4 = length of exit angle
L_5 = length of entry opening of the case
L_6 = length of exit angle of the case
S= wall thickness of the pallet
a xb = bore dimensions across flat, a > b
2α = drawing angle
2β = angle of entry cone
2γ = exit angle

III. EXPERIMENTAL SETUP

Wear of the wire drawing die can be reduced by changing various die design parameter ranging from the Material, hardness, forces, operating time to die angle. To check the wear of the die the experiment is to be carried on pin and disc setup. The pin is manufactured of the die material and the disc of the wire material.

Experimental set up which is available in Amrutvahini College of Engineering, Sangamner is as shown in following photograph. Using pin-on-disc Tribometer (TR-20LE) readings will be taken.

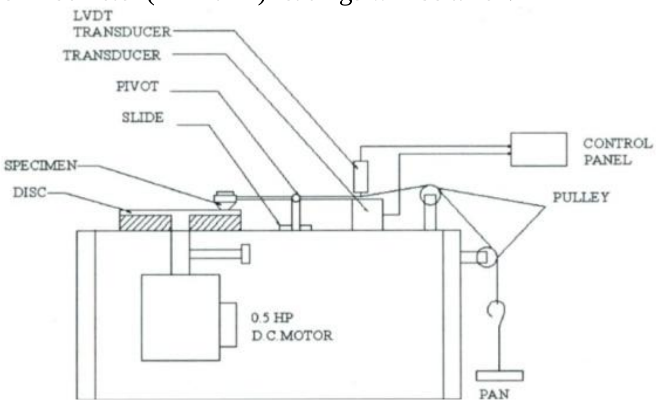

Figure 5 : Pin on Disc tribometer

Based on this experiment we can get a matrix. After obtaining the results the optimum result is selected for less wear of die. This is obtained by using taguchi method using software Mini Tab.

Constancy of Volume[1]

$$V_i \frac{3.14159xd_i^2}{4} = V_f \frac{3.14159xd_f^2}{4}$$

. (1)

Where,
V_i and V_f represent the wire velocities (meters per minute)
d_i and d_f are the wire diameters (millimeters) entering and exiting the die. For circular wire, Equation 1 can be simplified and reduced to:

$$V_i d_i^2 = V_f d_f^2$$

Eq. (2)

The velocity of the wire as it exits the last die can then be calculated by using Equation 2a as follows:

$$V_f = \frac{V_i d_i^2}{d_f^2} = \frac{1200 * 0.100^2}{0.090^2} = 1{,}481 \text{ feet per minute}$$

. (3)

Delta Factor[1]

$$\Delta = \sin \alpha \left(\frac{D_1 + D_2}{D_1 - D_2} \right)$$

Eq. (4)

Where,
2α is the included approach angle (α is the approach semi angle), D1 is the initial wire diameter, and D2 is the final wire diameter. For small approach semi-angles, sin α = α in radians, and by multiplying the right side of Equation (3a)

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by (D1 + D2)/ (D1 + D2) and substituting reduction in area [r = 1-(D2/D1)2] in place of the initial and final wire diameters, Δ can be written as [4]

$$\Delta = \frac{\alpha}{r}\left[1+\sqrt{1-r}\right]^2$$

Eq. (5)

Table 1. Delta parameter values for various approach semi angles and reductions in wire drawing [4]

	Percent Reduction in Area							
	5	10	15	20	25	30	35	40
Semi-Angle (degrees)								
2	2.72	1.33	0.86	0.63	0.49	0.39	0.33	0.27
4	5.44	2.65	1.72	1.25	0.97	0.78	0.65	0.55
6	8.17	3.98	2.58	1.88	1.46	1.18	0.98	0.82
8	10.89	5.30	3.44	2.51	1.94	1.57	1.30	1.10
10	13.61	6.63	4.30	3.13	2.43	1.96	1.63	1.37
12	16.33	7.95	5.16	3.76	2.92	2.35	1.95	1.65
14	19.06	9.28	6.02	4.38	3.40	2.75	2.28	1.92
16	21.78	10.60	6.88	5.01	3.89	3.14	2.60	2.20
18	24.50	11.93	7.74	5.64	4.38	3.53	2.93	2.47
20	27.22	13.26	8.60	6.26	4.86	3.92	3.25	2.75

Drawing Force Calculation[1]

$$F_i = 1.6\,(TS_{i-1} = TS_i)\left[\frac{(3.14159)d_i^{\,2}}{4}\right] ln\,\frac{d_{i-1}}{d_i}$$

Eq. (6)

Where,
TSi-1 is the tensile strength of the wire entering the die at the ith stand TSi is the tensile strength of the drawn wire di-1 and di are the corresponding wire diameters.

Advanced Drawing Force Calculation[1]

$$\sigma_d = \sigma_{average}\left\{\left[\frac{1+\Theta}{\Theta}\left(1-\frac{d^2_{i-1}}{d_i^{\,2}}\right)^{\Theta}\right]+\frac{\sigma_{backpull}}{\sigma_{average}}\left(\frac{d^2_{i-1}}{d_i^{\,2}}\right)\right\}$$

Eq. (7)

Where,
Θ = μ.tan α
σd is drawing stress, σ backpull is the stress generated by any backpull,
μ is the Coulomb coefficient of friction,
α is the die semi angle in degrees or radians.

Die Pressure[1]

$$P_{average} = \sigma_{average}\left(\frac{\Delta}{4}+0.6\right)$$

Eq. (8)

IV. CONCLUSION

In this review paper, wear characteristics of the die is observed as well as the factors influencing die life such as semi die angle, die geometry and hardness are also studied.

1) The drawing conditions; if we change die geometry we can reach more than twice lower dies consumption
2) From experiment it is followed that the dies consumption can also be influenced by the quality and accuracy of dies geometry making up.
3) It was also demonstrated if we change dies geometry we can achieve better workability in the wire.
4) Based on mentioned in this experiment can be globally evaluated as experiment with an enormous benefit because it demonstrated a way for the next routing at the steel wires production. The main direction should be focused on the drawing angle decreasing, accuracy of die geometry making up and correction of calculated reductions for new die geometry.

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5. Further the effect of other parameters such as coolant used, lubricant used, preprocessing of wire rod, die material on the drawing die can be evaluated.

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ACKNOWLEDGMENT

During the course of writing this thesis, assistance was never in short supply. Without this the completion of this thesis would not have been possible. There are numerous individuals that deserve to be acknowledged, including, but not limited to **Prof. Harne M.S.**, for heading my thesis, for trusting me to work on this project throughout the process and for his constant suggestions and advice, **Prof. Aher V.S.** for pushing me to expand my thinking and time spent helping with the analysis. **Prof. Mishra A.K.**, for the time he spent reviewing my thesis and work, for the time he spent helping with report programming and for spending the time on my thesis.

All my friends, family and others who helped or simply tolerated the hours spent at the computer to finishing this thesis.