Analysis of Die Design and Other Process Parameters in Elevated Temperature Drawing and Extrusion Techniques

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الملخص

تم فى هذة الدراسة استخدام ثلاثة انواع مختلفة من المعادن كااسلاك سحب وهى (الحديد – النحاس – الالومنيوم) وقالب من نوع واحد مصنوع من كربيد التانجستن وتم استخدام اقطار مختلفة من الاسلاك ابتدا من 2 مم الى 12 مم وزوايا مختلفة لقالب السحب من الزاوية 2 الى 14 وبنسب مئوية مختلفة لتخفيض اقطار الاسلاك وايضا تم استخدام سرعات مختلفة لسحب الاسلاك ومعاملات احتكاك مختلفة مابين القالب والمعدن المسحوب وباستخدام مواد تزييت مختلفة .

وتم استخدام برنامج ANSYS WORKBENCH بتحليل متغيرات (السرعة – معامل الاحتكاك – زوايا القالب – درجة الحرارة – ومواصفات السلك المسحوب والقالب) وبعد الحصول على نتائج جيدة للاجهادات ودرجات الحرارة الناتجة من عمليات السحب .

تم استنتاج النسب المئوية المثلى لتخفيض قطر السلك المسحوب للزوايا المختلفة تتراوح مابين 33% الى 40%, و هذة النتائج موضحة فى مخططات (الاجهاد مع النسب المئوية لتخفيض اقطار الاسلاك) ولم نجد أية دراسات سابقة فى هذا المجال لمقارنتها معها .

Abstract

In this Study has been used three different types of pulling wire metal a (iron - copper - aluminum) ,and mold of one type made of tungsten carbide , has been used different diameters of wire starting from 2 mm to 12 mm and different angles of drawing mold from the angle 2 to 14 degrees and different percentages to reducing diameters of the wires, and also different speeds have been used to pull the wires and different coefficients of friction between the mold and drawn metal as a result of using different material lubrication.

The program used is ANSYS WORKBENCH ,to analyzes the variables , (speed - coefficient of friction - the angles of the mold - temperature - and specifications of the drawing wire and the mold), after good results were obtained for the stresses and temperatures, resulting from drawing process.

we obtained the optimal percentage of reducing wire drawing diameter in different angles of the mold and these percentages ranging from 33% to 40%, and these results are shown in (stress with percentages of reducing the diameters of the wires) diagrams. We did not find any previous studies in the field to compare them with these results.

1 - Introduction

Wire has been produced for thousands of years by a variety of methods. Strip and block twisting of silver and gold wire resulted in a high-quality jewelry wire, but the drawing process was developed as quantity and strength requirements increased. Historical documents are vague as to when this transformation occurred—the earliest concrete evidence of an accepted drawplate points to the Vikings, but telltale markings left on older wire will fuel the debate for years to come.

The history of wire drawing through dies is reviewed and the description of the process by The ophilus, dating from about 1100 A.D., is discussed. It can be assumed that the fact that this early metal worker did not mention a die angle was due to his lack of knowledge of its function. It is suggested that debarred holes, or holes in which the boring operation inherently produced conical surfaces possibly were sufficient to make the wire drawing process successful without the operator knowing the reasons for his success. The recent data presented by Okolo and Wistreich seem to confirm that wire drawing is possible over a wide range of operating conditions and die angles.

In 1726, the English satirist Jonathan Swift posed a question: How might a race of tiny creatures immobilize an enormously larger human being? The answer, as learned to his distress by Gulliver, was by binding him with a large number of thin cords; the miniature people were incapable of handling a single rope big enough to secure a human.

2 - Drawing processes

Drawing is one of the oldest metal forming operations and has major industrial significance. Drawing is the process of reducing the cross-sectional area and/or the shape of a bar, rod, tube or wire (cold or hot) by pulling through a die ,as shown in Fig.1.

This process allows excellent surface finishes and closely controlled dimensions to be obtained in long products that have constant cross sections. In drawing, a previously rolled, extruded, or fabricated product with a solid or hollow cross section is pulled through a die at relatively high speed. The die geometry determines the final dimensions, the cross-sectional area of the drawn product, and the reduction in area. Drawing is usually conducted at room temperature using a number of passes or reductions through consecutively located dies.

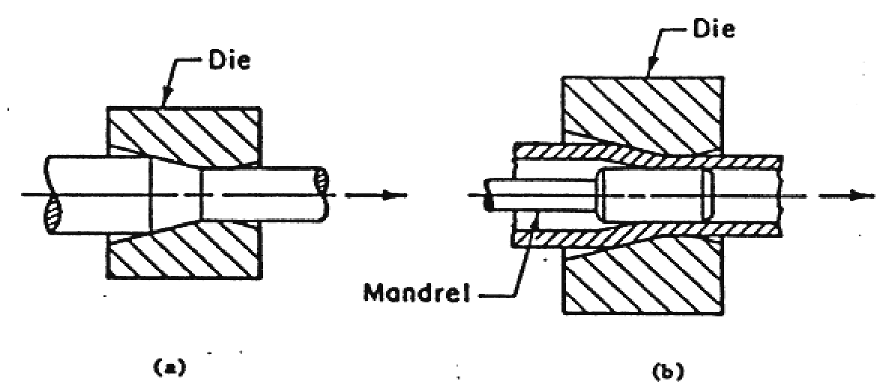
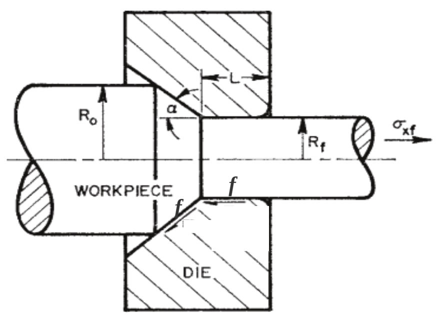


Fig.1 Drawing process of (a) rod or wire & (b) tube or hollow, Source [3]

At times, annealing may be necessary after a number of drawing passes before the drawing operation is continued. The deformation is accomplished by a combination of tensile and compressive stresses that are created by the pulling force at the exit from the die, by the back-pull tensile force that is present between consecutive passes, and by the die configuration.

There are mainly two type of drawing processes ``solid and Hollow``. Solid products are Rods and wires, as shown in Fig.1. Wires are used in many products, from musical instrument strings to cable supports in suspension bridges. Wire is produced by a drawing process, in which a cylindrical ingot of metal is drawn through a cone-shaped die, reducing the diameter.

The schematic-pertinent parameters of a wire drawing process. These parameters are the design keys to optimize the extrusion- and wiredrawing processes and Dies as shown in Fig.2.



2 α: Die angel
D_0 =2 R_0 : Inlet Diameter mm
D_1 =2 R_1 : Outlet Diameter mm
***f*: Friction coefficient**
L: Bearing length mm
σ_x : Axial Stress

Fig.2. described the schematic-pertinent parameters of a wire drawing process.

3 - Objective of this study

The aim of this work is to perform a computer simulation of the drawing process for Copper, Aluminum and Steel (C1018) wires. The research considers an estimation the optimal percentage of reduction of wire diameter .

4 - Literature review

By searching in available databases, libraries of graduate studies or on the web, researchers found that the optimal percentage of reduction of wire diameter in general did not receive much attention from specialists, and we did not find research in this regard.

5 - Methodology(Reduction of area (r))

For any given reduction of area r, the contact length L between the die and the deforming metal increases as α is lowered, and the contact area goes up. Since the compressive stress between the die and the material is not altered, the force along his interface must increase as α decreases. If the friction coefficient f is relatively constant, then the friction energy Wa will be higher as α goes down, as described in [13]. To a first approximation the process may be described in terms of bulk plastic deformation only, whereby a section with initial length L0 and diameter D0 is drawn into length L1 and diameter D1 undergoing an average strain $\varepsilon_{avg} = 2 \ln (D0/D1)$.

Owing to radial compression stress originated at die wire interface, no necking nor plastic instability may develop within the die, as opposed to the case of the common tensile test. An upper limit to drawing ratio.

$r = \Delta A / A0 = 1\ (D1/D0)2$ ………......................................(3)

is however set by drawing force, which may not reach wire's resistance; accordingly, rmax< 2/3 approximately for annealed copper, much lower values being currently adopted in production. Besides reduction in cross section, a more comprehensive model must account also for redundant deformation due to deviation in direction respectively at die entrance and exit, and for friction effects at die wire interface, both affected by die angle 2α.

According to Avitzur's classic analysis, the stationary velocity field may be assumed as uniform before and after die, and converging within die's active taper portion, limited axially by two concentric, spherical surfaces S0 and S1, as shown in Fig.3.

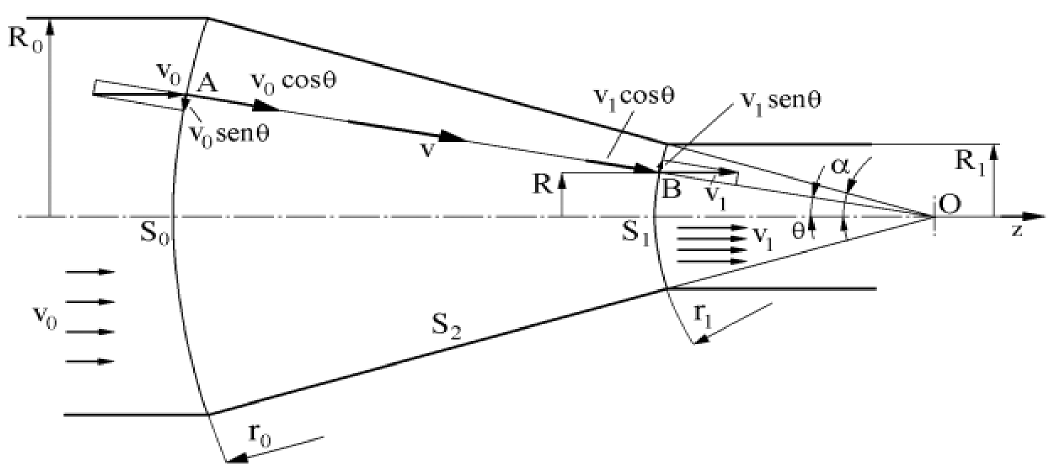


Fig. 3. Velocity field assumed in Avitzur's theoretical model of drawing wire process; Source [30]

Based upon this model, a more refined estimate of average strain is derived as:

$$\bar{\varepsilon}_r = \varepsilon_{avg}[f(\alpha) + \frac{\frac{1}{\sqrt{3}}(\frac{\alpha}{sen^2\alpha} - cot\alpha)}{ln\,(D_0/D_1)}]$$

………..……............ (4)

where α is the semi-cone angle of the die and , function of cone angle f(α), is given by:

$$f(\alpha) = \frac{1}{sen^2\alpha}[1 - cos\alpha\sqrt{1 - 0{,}9167\,sen^2\alpha} + 0{,}087\,ln\frac{1{,}957}{0{,}957\,cos\alpha + \sqrt{0{,}0833\,sen^2\alpha}}] \quad \text{...........(5)}$$

The above mentioned parameters control the material deformation during the wiredrawing process, and consequently, the stress distribution through the cross section of the drawn wire, as given in [30]. as shown in Fig.4 .With the correct parameter control, increased productivity and die life expectancy, as well as the wire breaking reduction will take place throughout the process. The parameter control also defines the wire properties such as good torsion resistance, tensile strength and rupture resistance.

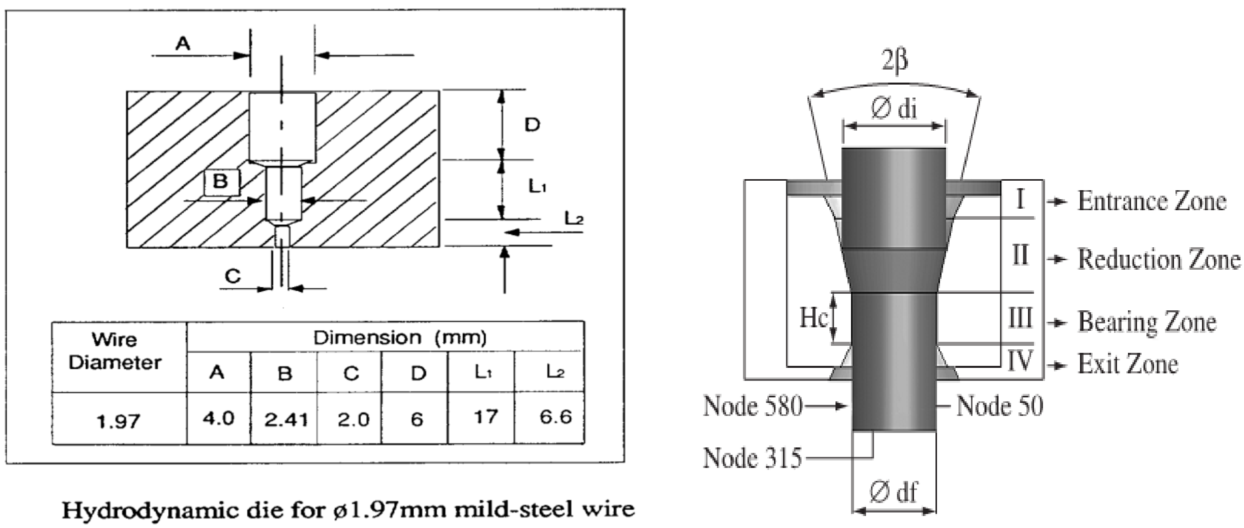


Fig.4. Scheme of internal die geometry, Source [11]

6 - Experiments

Table 1 shows stresses variation against different percentage reduction of wires diameters with different wire materials at 4 and 6 degree die angle at different speed and friction factor.

Table 1 Experiment (1)

periment (21)						utputs analysis	
		eed=	ferent	/min)	Friction= different		
	re iterial			duction of D %			
esses	uminum			0	6	8	4
[pa.)	pper		3	7	6	3	8
6°	eel	3	1	5	6	3	01

esses	uminum		1	0	6	6	1
pa.)	pper		8	9	5	5	1
8˚	eel	8	2	9	1	6	81

stresses variation with different percentage reduction of dimeter and different wire materials at 6 degree die angle shown in Fig. 5 .

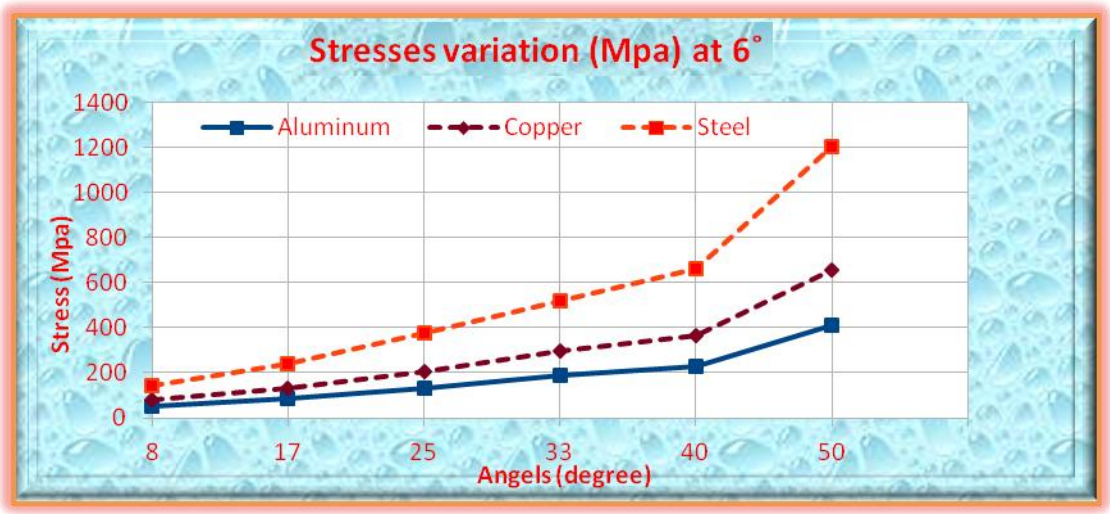


Fig. 5 stresses variation with different percentage reduction of dimeter and different wire materials .

7 – Results

a - Result 1

Note through this curve, which shows the ratio of reduced diameter with stress for both aluminum and copper and iron at the, angle of α = 6˚ and has been determining the percentage reduction in the diameter of 8% to 50% found that the area between 33% to 40% are best suited in the process of drawing wire due to stress in this region to be relatively stable, and after the reduction ratio 40% increase stress greatly which gives us a perception of the region as the best process to operate. Although we often do not work in this angle.

stresses variation with different percentage reduction of diameter and different wire materials at 8 degree die angle of experiment 1 shown in Fig. 6 .

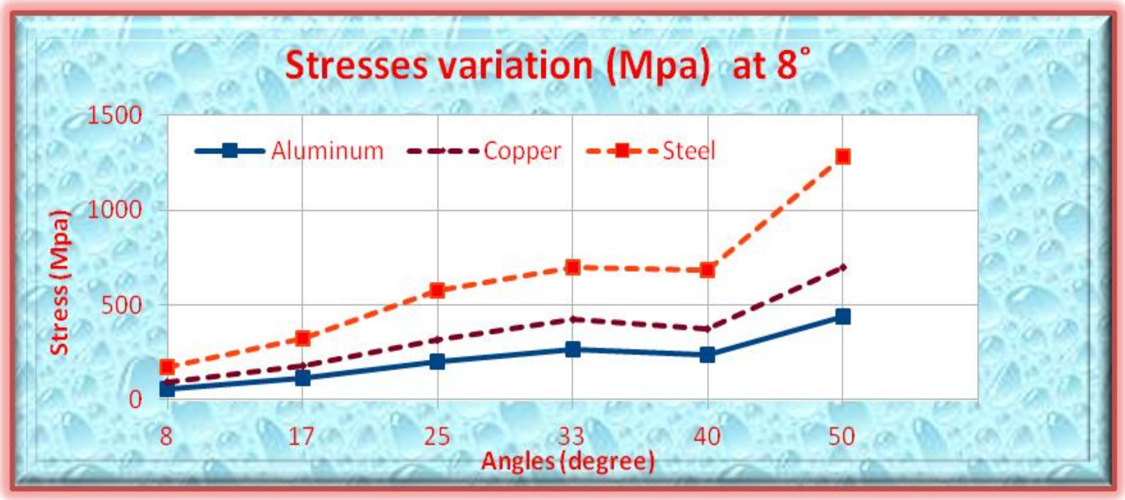


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Fig. 6 (Ex (1)) Shows stresses variation with different percentage reduction of diameter and different wire materials at 8 degree die angle.

b – Result 2

Note through this curve, which shows the ratio of reduced diameter with stress for both aluminum and copper and iron at the angle. α = 8˚ and has been in determining the percentage reduction in the diameter of 8% to 50% found that the area between 33% to 40% are best suited in the process of withdrawing the wires due to stress in this region is relatively stable, which gives us a perception as the region is better for process operating

Table 2 shows the experiment (22) stresses variation against different percentage reduction of wires dimeter with different wire materials at 10 and 11 degree die angle at different speed and friction factor.

Table 2 Experiment (2)

Experiment (22)							Outputs analysis
		Speed= different		(m/min)		Friction=differrent	
					eduction of D %		
	wire material	8	17	25	33	40	50
Stresses	Aluminum	62	125	198	257	248	474
(Mpa.)	Copper	98	200	316	409	395	754

at 10˚	Steel	178	362	573	669	723	1379
Stresses	Aluminum	62	130	196	289	325	486
(Mpa.)	Copper	98	208	313	460	517	772
at 11˚	Steel	179	377	567	735	947	1412

stresses variation with different percentage reduction of diameter and different wire materials at 10 degree die angle of experiment 2 shown in Fig. 7.

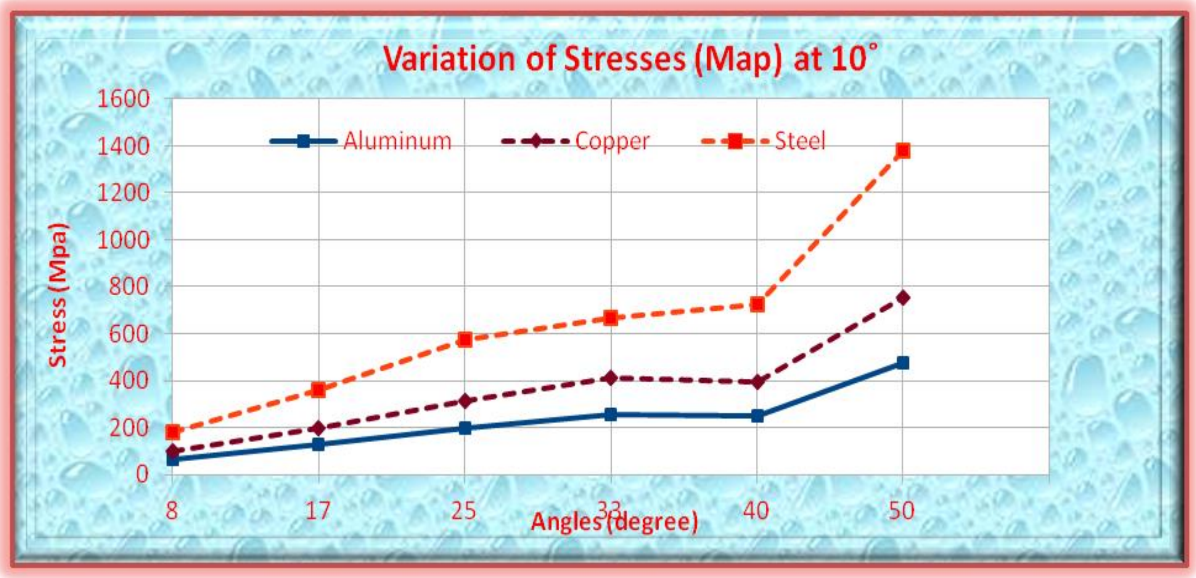

Fig. 7. (Ex (2)) Shows stresses variation with different percentage reduction of diameter and different wire materials at 10 degree die angle.

c – Result 3

Note through this curve, which shows the ratio of reduced diameter with stress for both aluminum and copper and iron at the angle. α = 10˚, which was that of determining the rate of reduction in the diameter of 8% to 50% found that the area between 33% to 40% are best

suited in the process of drawing the wires due to stress in this region is relatively stable, which gives us a perception as the region is better process operating.

stresses variation with different percentage reduction of diameter and different wire materials at 11 degree die angle of experiment 2 shown in Fig. 8.

d – Result 4

Note through this curve, which shows the ratio of reduced diameter with stress for both aluminum and copper and iron when, angled .α = 11 ˚, which was that of determining the rate of reduction in the diameter of 8% to 50% found that the area between 33% to 40% is best suited in the process of drawing wires due to stress in this region is relatively stable, which gives us a perception of the region as the best process to operate.

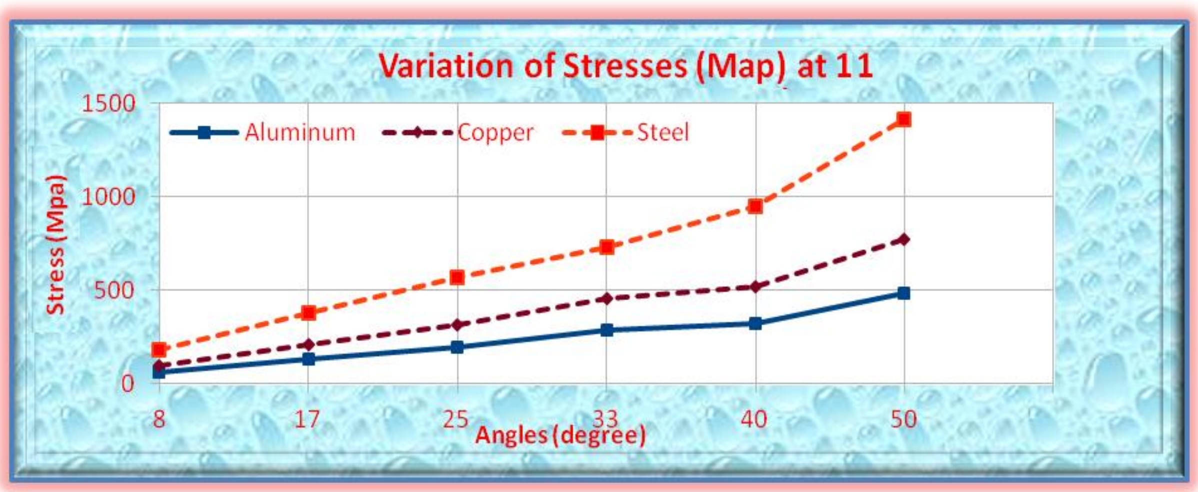

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Fig. 8. (Ex (2)) Shows stresses variation with different percentage reduction of diameter and different wire materials at 11 degree die angle.

8 - Conclusions

These conclusions have been discovered from theoretical calculations by special program of analysis . It is hard to found them from the practical reality because of the difficulty of obtaining the values of the stresses during the drawing process. This study was used one of the specialized programs in the analysis of stresses and heat generated from the drawing process. the program used is (Ansys Workbench 15), and has advantages, for example, reduce the time and effort and cost to get the most accurate results when applied to practical reality

It is noted in this theoretical study of the formation processes of the process of wires drawing . that the idyllic angles of the operation processes are located in the plastic zone in the stress-strain curve and either angles where the stresses are few or upward it will be in elastic region of the curve mentioned , so we exclude these angles because the metal drawn is not formed in the required form due to the elasticity of the metal in this area.

3- Through this study, we found that the maximum stresses resulting from the operation process increases with the speed of drawing wires values.

4- Through this study, we concluded that the more area of deformation wire inside the mold. Whenever distributed stresses and heat on this area as a result of a large reduction ratios in wire diameter and smaller mold angle

5- Through this study, we found that as greater the friction coefficient the higher the maximum values of the stresses resulting from the operation process

And coefficient of friction depends on the lubrication process and the type of mold

6- Through this study we found that the optimal percentage of reducing wire drawing diameter in different angles of the mold and these percentages ranging from 33% to 40%, and these results are shown in (stress with percentages of reducing the diameters of the wires) diagrams. We did not find any previous studies in the field to compare them with these results.

9 - Recommendations

In this study, we were concluding perfect angles to the values of maximum stress, to reduction diameters ratios, as approximate values, We therefore recommend in the upcoming studies to focus on these angles and to get more accurate results.

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10-Abendix

NOMENCLATURE

D_0	Inlet Diameter
D_1	Outlet Diameter
f	Friction coefficient
L	Bearing length
l_0 &l_1	Initial & Final Length
β&α	Die angel
σ_x	Axial Stress
σ_m	ydrostatic Stresses
σ_z	Longitudinal Stresses
FEM	Finite Element Method
FEA	Finite Element Analysis
F	Draw Force
r	The cross-sectional area reduction
V_f	Outlet drawing speed
V_i	Outlet drawing speed
Wa	Friction Energy
ρ	Density
A_f	Final wire cross-section
ε_{avg}	Average Strain
S_0&S_1	Spherical Surface
H_c	Bearing Cylindrical Zone
T/C	**Tungsten carbide dies**
α_{opt}	Optimum die angle
τ	Shearing Stresses
$R_{0.2}$	Tensile Strength
R_m	Yield Strength
T	Temperature