THE EFFECTS OF PUNCHING DIE GEOMETRY ON STRESS DISTRIBUTION USING FINITE ELEMENT TECHNIQUE

A thesis submitted for the PH. D. degree in.
Mechanical Engineering
Production Engineering

BY

ENG. **MOHAMED ADEL AHMED RIZK**
B. Sc., M. Sc. Mechanical Engineering

Presented to
Faculty of Engineering
Ain Shams University

supervised by:

PROF. DR. ENG. **MONIR M. F. KOURA**
Faculty of Engineering, Ain Shams University
Cairo, Egypt

DR. ENG. **AHMED-NAGEB AHMED**
Faculty of Engineering, Ain Shams University
Cairo, Egypt

CAIRO - 1993

THE EFFECTS OF PUNCHING DIE GEOMETRY ON STRESS DISTRIBUTION USING FINITE ELEMENT TECHNIQUE

Ph. D. thesis submitted by

ENG. MOHAMED ADEL AHMED RIZK

EXAMINERS

PROF. DR. ENG. **ABDALLA S. WIFI**
Faculty of Engineering, Cairo University
Cairo, Egypt

PROF. DR. ENG. **SAMY J. EBEID**
Faculty of Engineering, Ain Shams University
Cairo, Egypt

PROF. DR. ENG. **MONIR M. F. KOURA**
Faculty of Engineering, Ain Shams University
Cairo, Egypt

CAIRO - 1993

بسم الله الرحمن الرحيم

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Philosophy in Mechanical Engineering .

The work included in this thesis was carried out by the author in the Department of Design & Production Engineering , Ain Shams University, from 1987 to 1993.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

Date: 02/12/1993
Signature:
Name: Mohamed Adel Rizk

Ain Shams University

Faculty of Engineering

C.V.

Student Name: Mohamed Adel Ahmed Rizk

Born on: 24- 1- 1953- Cairo

First University degree:

B. Sc. (June 1977) in Mechanical Engineering - Production section.

Other Certificate:

M. Sc. degree in Mechanical Engineering - (Production Engineering) 1986

Previous Experience:

Field Engineer in Petroget Company 1977 - 1980

Demonstrator in Design and Production Department

1980 - 1986

Assistant lecturer in Design and Production Department

1986 - 1993

Present job:

Assistant lecturer in Design and Production Department

Name: Mohamed Adel Ahmed Rizk

Assign:

Date:

TO THE MEMORY OF MY PARENTS

ACKNOWLEDGEMENT

The author wishes to express his deep thanks and appreciation to his supervisors, Prof. ***Monir M. F. Koura,*** *and* ***Dr. A.-N. Ahmed*** *for their sincere supervision and guidance as well as their endless support throughout the course of this work.*

The author also indebted to all who have offered any direct or indirect help.

SUMMARY

The stress distribution in punching dies has not been investigated either experimentally or theoretically. As a result, the die design has -so far- been based upon experience. The present work is devoted to study the stress distributions in punching dies by the application of the finite element technique. For this sake, a finite element software capable to handle linear elastostatic problems was established. In addition, some supplementary programs were prepared for pre-processing, and post-processing finite element solution. The program was tested by comparing the results computed for some fundamental problems with the corresponding results obtained from closed form solutions. A model was then established to simulate a punching die block having a circular opening, taking into consideration the frictional forces, and the thrust forces, as well as the main cutting forces. The model was verified experimentally. Experiments were performed to determine the strain distribution on the surface of a punching die, by using electrical strain gauges. Comparing the experimental results with the results obtained through the finite element analysis established the validity and usefulness of the proposed model. Consequently, the model was employed to study the stress distributions in punching dies, and the effects of the die geometry on these distributions. The main results showed that, the stresses are at its maximum near to the cutting edge, and tend to reduce sharply beyond the loading zone. The width of the loading zone, as well as the stock thickness and its shearing strength are the major factors affecting the values and the distribution of the stresses, while the geometry of the die affects the value and direction of the radial displacement of the cutting edge. Increasing the diameter of the opening beneath the die results in increasing the tangential stress, but it seems that it does not influence both the axial and the radial stress significantly.

CONTENTS

NOMENCLATURE

VARIABLES

A	Area
[B]	Strain-displacement matrix
b	Width of loading band
C	Constant
c	Clearance
[D]	Stress-strain matrix
D_o	Outer Diameter
D_i	Inner Diameter.
E	Young's modulus
e	Depth of penetration
F	Force
f	Force function
f_e	Expansion factor
H	Die height (die thickness)
[J]	Jacobean matrix
[K]	Stiffness matrix
k	Shear strength of the stock
l	Length of die opening
L_c	Length of cutting perimeter.
L_1,L_2,L_3	Area co-ordinates
M	Die margin
[N]	Shape function matrix
p	Pressure
q	Intensity of the boundary reactions
Q	Boundary reactions
r	Radial co-ordinates
R_i	Inner radius
R_0	Outer radius
S	Surface
t	Stock thickness
u,v,w	Displacement components.
V	Volume
x,y,z	Cartesian co-ordinate
α	Relief angle
γ	Shear strain
$\{\delta\}$	Displacement array
ε	Normal strain
η,ζ,ξ	Natural co-ordinates
μ	Coefficient of friction
$\mu\varepsilon$	Micro strain
ν	Possion's ratio

Π	Potential energy
θ	Angle of rotation
σ	Normal stress
τ	Shear stress

ABBREVIATION

2D	Two dimensions.
3D	Three dimensions.
ASTME	American society of tools and manufacturing engineers.
D.F.E.M	Displacement finite element method.
Eq.	Equation.
F.E.	Finite element
Fig.	Figure.
QRC	Quadratic rectangular element.
QTE	Quadratic triangular element.
RAM	Random access memory.
Ref.	Reference.
Sec.	Section.
T.R.M	Tool room microscope.

SUBSCRIPTS

b	Bolster plate
c	Cutting edge
e	element
g	global
j	j th component
k	k th component
m	mth component
max	Maximum
p	Punching
perm	Permissible
r,θ	Components in radial and tangential direction respectively.
x,y,z	Components in x,y, and z directions respectively
1,2,3	Principal directions

SYMBOLS

{ }	Vector
[ ]	Matrix
$[\ ]^T$	transpose
$\|\ \|$	Determinator
$[\ ]^{-1}$	Inverse

INTRODUCTION

The cost of tooling in punching process contributes a substantial part to the overall cost of manufacturing a component. It is therefore imperative to keep down this cost by optimum selection of the tool parameters. One way to achieving this is to study the displacement, strain and stress fields in the tools during operation.

A survey of the literature showed that the design procedure for the punch component has been well established. It has been shown that the maximum allowable length of the punch and the unit compressive stress on it could be determined analytically (1-8). However, the design of the die block component has so far, been dealt with experience (5,6,9-13). No theoretical or precise empirical relationship is available that can aid tool designer in the optimum selection of the die dimensions. Reasons for this may be attributed to the complexity of the die geometry and the associated loading system.

In such situation where analytical solutions are not possible to be obtained , engineers resort to numerical methods that provide approximate, but highly acceptable solutions. Out of the available numerical methods, the finite element method (F.E.M) has rapidly become a very popular numerical technique for computer solution of complex engineering problems. The method has initially developed on a physical basis for solving the problem in structural mechanics (14). Later, the application of the method to stress analysis problems was developed through the use of the principle of virtual work and energy method (15,16). In 1965, the method was generalised when Zienkiewicz and Cheung (17) reported that it is applicable to all field problems that can be casted into variational form.

Depending upon the nature of the problem to be solved, F.E.M. can be divided into three categories namely; equilibrium problems, eignvalue problems, and propagation problems. The problem encountered in the present work is in the realm of equilibrium problems. Problems in this field are usually tackled by one of three approaches: the displacement method, the equilibrium method and the mixed (hybrid) method. For a large class of problems. the displacement method is the simplest to apply. Consequently, it remains the most widely used technique (18-26).

In the present work. the displacement finite element method (D.F.E.M) is employed to predict the displacement, strain, and stress distributions in punching dies. The effects of the die geometry on these distributions are also investigated. The study is mainly concerned the effect of die dimension, neglecting the effect of die shape.

Depending upon the obtained results, some conclusions will be provided to enable the tool designer to asses the minimum die dimensions required for maximum strength and minimum distortion.

CHAPTER I