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Patlayıcı yardımı ile form vermede patlayıcı kütlesinin genetic algoritma kullanılarak optimizasyonu

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Anahtar Kelimeler
Patlayıcı yardımı ile form verme,
Derin çekme,
Patlayıcı kütlesi,
Genetik algoritma

ÖZET

Bu çalışmada, genetik algoritma kullanılarak, günümüzde özellikle uçak sanayinde büyük parçaların üretiminde kullanılan patlayıcı yardımı ile form verme tekniğinde patlayıcı kütlesinin optimizasyonu yapılmıştır. Genetik algoritma yirmi yıldan fazla süredir farklı bilim dallarına uygulanan bir yapay zeka optimizasyon tekniğidir. Bu metotta, doğada meydana gelen seçme, çaprazlama ve mutasyon gibi genetik operatörlerin bilgisayar ortamına uyarlanmış kodları kullanılır. Patlayıcı yardımı ile form verme sadece dişi kalıbın (bazen sadece erkek kalıbın) üretildiği ve form verilecek parça ile birlikte daha önceden kazılmış bir çukurun tabanına konulduğu alışılmamış bir imal usulüdür. Basıncı transfer eden ara ortam (çoğu zaman su) ve patlama basıncı erkek kalıbın işlevini görür. Patlayıcı yardımı ile form verme operasyonunda, patlayıcı kütlesi işlem maliyetini belirleyen temel değişkendir. Dolayısıyla, patlayıcı kütlesini asgariye indirmek çok önemlidir. Patlayıcı yardımı ile form verme bir nevi derin çekme işlemi gibi düşünülmüştür ve derin çekme formülleri ve patlama basıncı formülleri kullanılarak, patlayıcı kütlesini minimum yapmak için parça parametrelerinin genetik algoritma kullanılarak seçilebileceği gösterilmiştir.

Optimization of explosive mass in explosive forming process by using genetic algorithm

Keywords
Explosive forming,
Deep drawing,
Explosive mass,
Genetic algorithm

ABSTRACT

In this study, by using genetic algorithm, optimization of explosive mass in explosive forming technique, which is used for production of large parts in especially aerospace industries today, is done. Genetic algorithm is an artificial intelligence optimization technique applied in very different science branches for more than twenty years. In this method, codes of genetic operators like selection, crossover and mutation happened in nature, adapted to computer environment are used. Explosive forming is a nontraditional production technique in which only female die (sometimes only male die) is produced and then put with the forming plate on the bottom of a digged hole. The transmitting medium (most of the time water) and explosion pressure are used as a male die. In explosive forming operation, explosive mass is the main variable that determines the operational cost. Therefore it is very important to make explosive mass minimum. Explosive forming can be assumed to be a type of deep drawing process and by using deep drawing formulas and explosion pressure formulas, it is shown that part parameters can be chosen by genetic algorithm to make explosive mass minimum.

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1. Introduction

Today different production techniques are developed for especially big parts used in aerospace industries. Because in conventional production techniques, design and production of a male and a female die, and pressing of metal part between these dies are needed. But this method is disadvantageous for both production cost and time.

Explosive forming is a frequently used technology in the production of big and limited numbered parts. In explosive forming operation, explosive mass is the main variable that determines the overall cost. So it is very important to use optimum explosive mass needed to form the part.

Genetic algorithm is an artificial intelligence optimization technique applied in very different science branches for more than twenty years. In this method, codes of genetic operators like selection, crossover and mutation happened in nature, adapted to computer environment are used.

In this study, explosive mass in explosive forming technique is to be optimized by using genetic algorithm.

2. Genetic algorithm

Genetic algorithm is an optimization technique depended on natural selection and genetic science. For getting the best result, all the datas are subjected to elimination by using genetic operators. The best result consists of individuals that show the best adaptation to environment or that are still alive after much iteration [1].Many different problems solutions of which are very hard or impossible can be solved with genetic algorithm very easily. These problems necessitate the investigation of best result in very big solution space. This operation that lasts very long time in conventional methods can be solved in very little time in genetic algorithm. Because in genetic algorithm, solution space is investigated in coded condition, no need to mathematical solution [2].

In optimization problems, appropriation of algorithm for system and adjustment of design variables are the main problems faced with frequently. Genetic algorithm is used successfully in especially complex system of big population [3].

3. Explosive forming

Explosive forming technique is a frequently used method in production of large and limited numbered parts. In this method, only female die (sometimes only male die) is produced and then put with the forming plate on the bottom of a digged hole. Hole is filled with a transmitting medium like water, sand, oil etc. An explosive is placed in this media with a standoff distance from the die. Explosive is exploded and huge pressure produced is transferred to the forming plate with transmitting medium and forces it to get the shape of the die. Namely, explosive and transmitting medium work like a male die [4, 5]. In Figure 1, a classical explosive forming mechanism is shown [6].

Explosive forming was first documented in 1888 by Charles Munroe with his article "modern explosives" in Scribner's Magazine [7]. Since then, many researches have been done for investigation of this process. Motto and Ebecken (2007) study the underwater explosion phenomena, which is the basis for explosive forming applications, and applied evolutionary solutions to the problem [8]. Mousavi et al. (2007) studied the explosive free forming phenomena and developed a numerical model for the process [9]. Wijayathunga and Webb (2006) implemented a finite element simulation of explosive forming process and compare it with experimental result [10]. Hung et al. (2005) study the elastic shock response of an air-backed plate to a nearby explosion [11]. Ramajeyathilagam and Vendhan (2004) study the deformation and rupture of thin rectangular plates subjected to an explosive shock [12]. Lam et al. (2003) study the explosive effect of an underwater shock to a laminated pipeline on the seabed [13]. Rajendran and Narasimhan (2001) study the damage prediction of clamped circular plates subjected to a contact explosion [14]. Fengman et al. (2000) investigated the production of thin-wall semi spherical parts with explosive forming process [15]. Kira et al. (1999) investigated the explosion phenomenon of an underwater explosion [16]. Iyama et al. (1999) study the non-die explosive forming of spherical vessel technology [17].

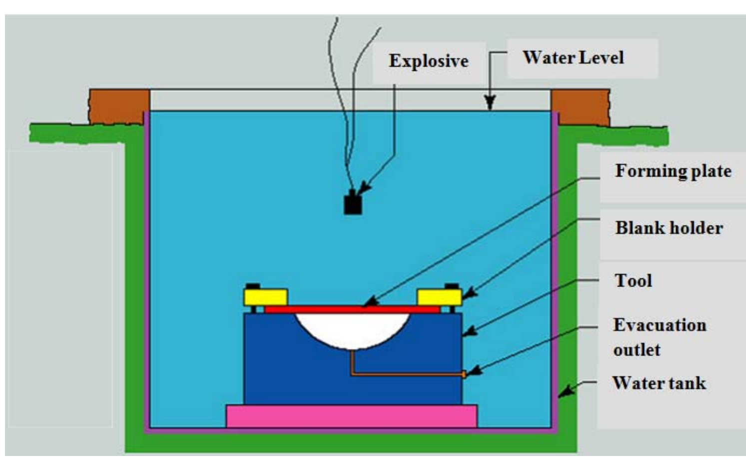

Figure 1. A classical explosive forming mechanism [6]

4. Explosive forming pressure

In explosive forming operation, the pressure of the shock wave produced after explosion of the explosive can be expressed with the following equations [4, 5, 6, 18, 19, 20, 21];

$$P_t = P_m e^{-t/\theta} \quad (1)$$

$$P_m = K_1(W^{\frac{1}{3}}/R)^{\alpha_1} \quad (2)$$

$$\theta = K_2 W^{\frac{1}{3}}.(W^{\frac{1}{3}}/R)^{\alpha_2} \quad (3)$$

In these equations:
P_m: Peak pressure of the shock wave (Pa)
θ: Decay constant (ms)
t: Time to reach to target (ms)
W: Explosive mass (kg)
R: Stand-off distance (m)
K_1, α_1, K_2 and α_2: Constants related with the type of explosive
In Table 1, K_1, α_1, K_2 and α_2 values of some explosives are shown.

Table 1. K_1, α_1, K_2 and α_2 values of some explosives [4, 5, 18, 19]

Parameter	Explosive type		
	HBX-1	TNT	PETN
K_1	22,347	22,505	24,589
α_1	1,144	1,18	1,194
K_2	0,056	0,058	0,052
α_2	-0,247	-0,185	-0,257

When shock pressure reaches the forming plate, it forces the plate to get the shape of the tool. There is a maximum force and pressure for the plate to get the shape of the tool. Since explosive forming process is like a deep drawing process, when deep drawing force and then deep drawing pressure are calculated, it can be assumed that the deep drawing pressure is the P_t pressure in Equation 1. Then explosive mass needed can be calculated.

Siebel developed an analytical model based on the elementary theory of plasticity. According to this theory maximum deep drawing force is [22]:

$$F_{d,max} = \pi d_m S_0 [\underbrace{1.1 e^{\mu\pi/2}\sigma_{f,m,1}}_{A} \underbrace{\ln(d_{f,max}/d_m)}_{B} + \underbrace{\frac{2\mu F_N}{\pi d_{f,max} S_0}}_{C} + \underbrace{\sigma_{f,m,1} S_0/(2r_D)}_{D}] \quad (4)$$

A B CD

Here term A corresponds to the required work for homogeneous deformation, term B is due to the work necessary to overcome the friction between the flange and die and blank holder, term C is related to the friction at die radius and term D is related to bending around the edge radius of the die [22]. In this equation:

d_m: Mean diameter and equals to $d_1 + S_o$ (mm)
S_o: Plate thickness (mm)
d_1: Punch diameter (mm)
μ: Coefficient of friction between die and plate
$\sigma_{f,m,1}$: Mean flow stress around flange area (MPa), in most cases $\sigma_{f,m,1} = 1.35\ S_u$
S_u: Ultimate tensile strength (MPa)
$d_{F,max}$:Flange outer diameter when deep drawing force becomes maximum (mm)
$d_{F,max}$ value is nearly equal to $0.77d_o$.
d_o : Blank diameter (mm). For a plate with flange, blank diameter is:

$$d_0 = \sqrt{4d_1 h + {d_2}^2} \quad (5)$$

d_2: Outer diameter of the plate (mm)
h: Height of the plate (mm)
r_D : Die edge radius
$\sigma_{f,m,11}$: Mean flow stress around die edge area (MPa) and can be expressed as:

$$\sigma_{f,m,11} = C(\ln\sqrt{1+\frac{S_0}{r_p}})^n \quad (6)$$

Here:

C: Strength coefficient of plate (MPa)
n: Strain hardening exponent of plate
r_P: Punch edge radius
F_N: Blank holder force and can be expressed as:

$$F_N = P.A \quad (7)$$

$$A = ({d_0}^2 - {d_e}^2)\frac{\pi}{4} \quad (8)$$

$$d_e = d_1 + 2w + 2r_D \quad (9)$$

In these equations:

d_e : Effective wideness of blank holder (mm)
w: Drawing gap (mm) and can be expressed as:

$$w = S_0 + 0.07\sqrt{10S_0} \quad (10)$$

$$P = [(\beta-1)^2 + \frac{d_1}{200.S_0}]\frac{Su}{400} \quad (11)$$

β: Drawing ratio

$$\beta = S_0/d_0 \quad (12)$$

Lastly, maximum deep drawing pressure can be expressed as:

$$P_ç = F_{d,max}/S_0\pi d_m \quad (13)$$

5. Results and discussions

For the optimization of explosive mass in explosive forming process, the optimum outer diameter and tool edge radius to form the part with minimum deep drawing pressure will be found. Then with these optimized parameters, optimum deep drawing force and pressure will be found. This pressure is thought to be the pressure of explosive shock wave in front of the metal part after explosion. Finally by using explosive pressure formulas explosive mass will be found with given standoff distance.

5.1. Defining Objective Function

Objective function is the maximum deep drawing force:

$$F_{d,max} = \pi d_m S_0[1.1e^{\mu\pi/2}\sigma_{f,m,1}\ln(d_{f,max}/d_m) + \frac{2\mu F_N}{\pi d_{f,max} S_0} + \sigma_{f,m,1}S_0/(2r_D)\,] \quad (14)$$

5.2. Variables, Parameters and Constraints

For optimization, a model part is used (Figure 2). Design variables are part outer diameter (d_2) and tool edge radius (r_D).

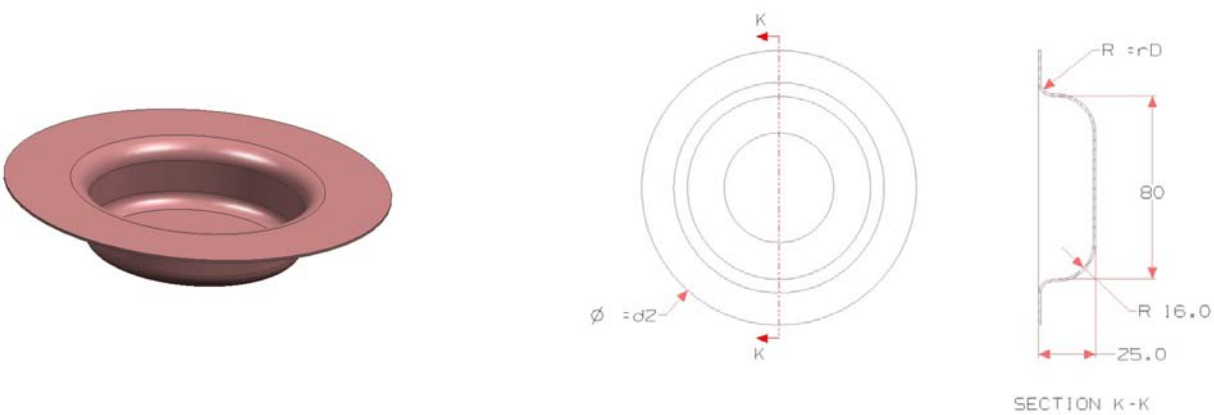

Figure 2. Part to be formed

Parameters that will be used in the problem is shown in Table 2. [22, 23].

Table 2. Parameters that will be used in the problem

Specification	Symbol	Unit	Value
Inner radius of the part	d_1	mm	80
Punch diameter	r_P	mm	16
Part thickness	S_o	mm	1
Mean diameter ($d_m = d_1 + S_o$)	d_m	mm	81
Coefficient of friction	μ	-	0.12
Ultimate tensile strength (DIN 1.0347)	S_u	MPa	325
Mean flow stress around flange area ($\sigma_{f,m,1} = 1.35\ S_u$)	$\sigma_{f,m,1}$	MPa	438.75
Part height	h	mm	25
Strength coefficient of plate	C	MPa	348.3
Strain hardening exponent of plate	n	-	0.07
Mean flow stress around die edge area ($\sigma_{f,m,11} = C(\ln\sqrt{1+\frac{S_0}{r_p}})^n$)	$\sigma_{f,m,11}$	MPa	286.246
Draw gap ($w = S_0 + 0.07\sqrt{10S_0}$)	w	mm	1.221

Definition interval of design variables are:

$$120 \le d_2 \le 160 \quad (15)$$

$$4 \le r_D \le 6 \quad (16)$$

Design constraints are [23]:

Minimum tool edge radius:

$g_1 = r_D \geq 0.035[50 + (d_0 - d_1)]\sqrt{S_0}$ (17)

The applied deep drawing force must be smaller than the crack force. Crack force is the force that can make cracks in the part when applied. Crack force is:

$$F_{cr} = S_u S_0 \pi d_m \quad (18)$$

When parameters are inserted:

$$g_2 = F_{d,max} \leq 82700 \quad (19)$$

5.3. Coding of Variables and Genetic Algorithm Parameters:

The bit of variables can be found by:

$$2^l \geq (x_{i,top} - x_{i,bottom})/\varepsilon \quad (20)$$

Here;

L = Bit number of variables
ε = Increase interval of variable
Forming of variables is shown in Table 3.

Table 3. Forming of variables

Variables	Bottom limit	Top limit	Increase interval	Bit number
Part outer diameter (d_2)	120	160	1	6
Tool edge radius (r_D)	4	6	0.1	6

So our solution is made by 12 bits. That means that we have 2^{12} alternate solutions in solution space. Genetic algorithm parameters used is shown in Table 4.

Table 4. Genetic algorithm parameters

Genetic algorithm parameters	
Bit number of solution	12
Population density	16
Number of generation	100
Crossover ratio	0,5
Mutation ratio	0,001

When program is run with these parameters part outer diameter is found to be 120 mm and tool edge radius is found to be 6mm. The change in part outer diameter and tool edge radius with number of generation is shown in Figure 3 & 4.

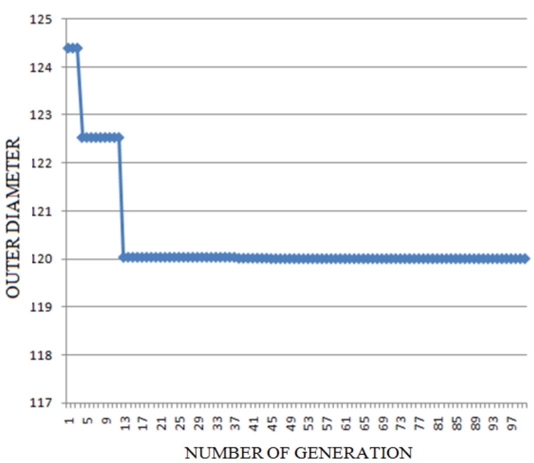

Figure 3. Part outer diameter-number of generation graph

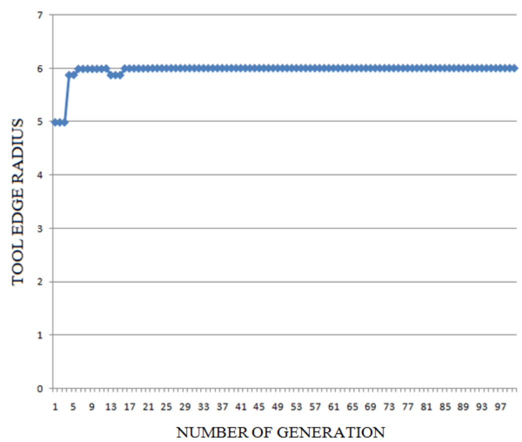

Figure 4. Tool edge radius-number of generation graph

When deep drawing force and deep drawing pressure is calculated with these parameters, they are found to be 60370 N and 237.239 Mpa.

This pressure is thought to be the pressure of shock wave when reached to the metal part after explosion. If TNT is used and explosive is placed 0.15 m away from the metal part, the explosive mass can be found as:

$$237.239 = [52.16(W^{\frac{1}{3}}/0.15)^{1.13}]e^{-0.0001/(92.5W^{\frac{1}{3}}(W^{\frac{1}{3}}/0.15)^{-0.22})} \quad (21)$$

W= 0.188268 kg = 188.268 gr. That means that part in Figure 7.1 with outer diameter 120 mm and tool edge radius 6 mm can be formed with explosive forming technique by using 188.268 gr TNT placed 0.15 m away from the work piece.

6. Conclusion

In this study explosive mass in explosive forming technique is optimized by using genetic algorithm. For this, first of all, the optimum outer diameter and tool edge radius to form the part with minimum deep drawing pressure was found. Then with these optimized parameters, optimum deep drawing force and pressure was found. Finally by using explosive pressure formulas explosive mass was found with given standoff distance. With this study it is shown that genetic algorithm can be applied to the explosive forming process successfully.

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