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FEM Analysis of Ogive Nose Projectile Impact on Aluminum Plates

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Abstract:- Finite element simulation of projectile impact on Aluminum plate is considered. The circular target plate is assumed to be fixed circumferentially in all directions. An elasto-viscoplastic material model presented by Johnson and Cook was used to describe the flow and fracture behavior of the target material during numerical simulation of the perforation phenomenon. The flow stress expression of the model incorporated the effect of yielding, plastic flow, isotropic strain hardening, strain-rate hardening, softening due to adiabatic heating and damage. The fracture strain expression of the model incorporated the effect of stress triaxiality, strain rate, and temperature.

Numerical analysis of the problem was carried out using finite element code ABAQUS. Different modules of the code were used to create a geometric model. Material properties were assigned to the target specimen. Contact between the target and projectile was defined. Mesh was generated after selecting appropriate elements. Analysis of the problem was carried out using explicit solution scheme of the code. Adaptive meshing was used to deal with the numerical problems associated with the excessive distortion of the elements and consequent termination of the analysis.

Influence of different parameters on energy absorption of the plate during perforation of the projectile and ballistic limit of the plate by varying the velocity of the projectile, thickness of the plate, and the angle of obliquity of the projectile is studied.

Keywords:- Johnson and Cook, Adaptive meshing, Ballistic limit, Energy absorption,Perforation.

I. INTRODUCTION

Impact is a daily phenomenon. It happens whenever two bodies collide. It could be a situation of hammering a nail, bird hitting an aeroplane, projectile impact on an armour, debris impact on space shuttle's, explosions in nuclear plants, collision of vehicles as in the case of accidents, explosions in under water. The risk of damage to the life and property is high in impact events. There is need for designing safer structures which may absorb the impact energy and have good resistance to penetration and perforation.

In earlier days the impact problems were primarily confined to the military. As the civilian technology has grown in sophistication, more studies are being carried out to understand the behavior of materials subjected to short duration of loading. The field of impact dynamics is of interest to engineers concerned with the design of light weight armour, safety of nuclear reactor containment vessels subjected to missile or aircraft impact, protection of spacecraft from meteoroid impact and safe transportation of hazardous materials.

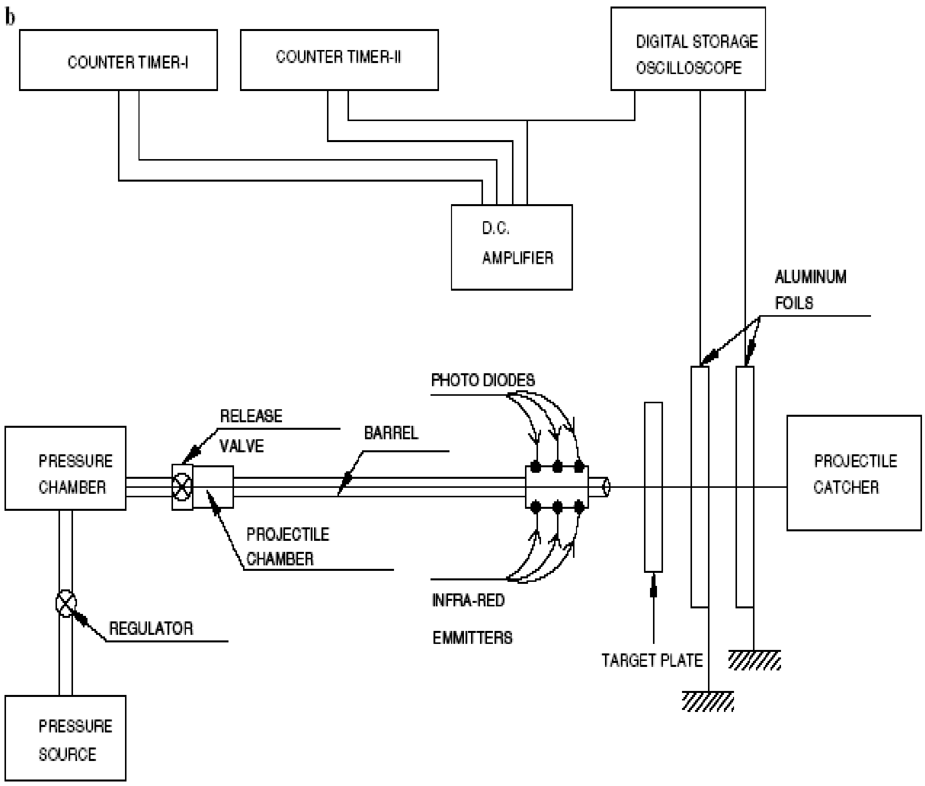
These structures are designed by using different materials available in nature. While designing any structures we should have to consider safety, weight and cost of structures. In most of the cases these structures are designed by using steel and aluminum alloys. By considering above three factors aluminum alloys are mostly preferable than steel. The reason for this is aluminum alloys have low density, high specific strength, high specific energy absorption capacity, good corrosion resistance and good thermal conductivity. The latter indicates that aluminum is less sensitive to adiabatic shear banding and thermoplastic instability than most steels.

II. OBJECTIVE

To study the numerical analysis of the energy absorbed during penetration and perforation of aluminum plates impacted by the ogival nosed projectile by varying following parameters:

i. Effect of target thickness,
ii. Effect of projectile velocity,
iii. Effect of change in obliquity angle.

III. EXPERIMENTAL LAYOUT



IV. EXPERIMENTAL DATA RECEIVED FROM TECHNICAL LITERATURE

Table

Observed values of impact velocity V_i, residual velocity V_r, velocity drop V_d, impact energy E_i, residual energy E_r and absorbed energy E_a for ogive nosed projectiles impacted on plates of various thicknesses

Target thickness (mm)	S. No.	Initial velocity V_i (m/s)	Residual velocity V_r (m/s)	Velocity drop (m/s)	Impact energy (Joule)	Residual energy (Joule)	Absorbed energy (Joule)
0.5	1	107.805	99.423	8.382	305.075	259.4795	45.595
	2	97.885	88.72	9.165	251.514	206.62	44.893
	3	92.46	81.783	10.677	224.407	175.5721	48.835
	4	83.892	68.437	15.455	184.744	122.9451	61.798
	5	77.41	58.217	19.193	157.298	88.967	68.331
	6	69.638	48.114	21.524	127.298	60.767	66.53
	7	62.472	38.807	23.665	102.447	39.532	62.915
	8	54.102	27.629	26.473	76.8344	20.038	56.796
	9	47.468	17.153	30.315	59.1468	7.723	51.423
	10	40.665	8.038	32.627	43.4081	1.695	41.712
	11	33.749	0	33.749	29.8986	0	29.898
0.71	1	114.937	103.721	11.216	346.776	282.398	64.377
	2	111.061	99.384	11.677	323.782	259.276	64.505
	3	103.007	90.423	12.584	278.524	214.628	63.895
	4	97.885	83.384	14.501	251.514	182.513	69.0
	5	88.325	69.983	18.342	204.784	128.562	76.221
	6	72.258	48.578	23.68	137.057	61.945	75.111
	7	64.993	38.859	26.134	110.882	39.638	71.244
	8	51.249	19.588	31.661	68.9446	10.071	58.872
	9	44.255	8.485	35.77	51.4108	1.889	49.520
	10	38.406	0	38.406	38.7193	0	38.719
1.0	1	112.725	99.112	13.613	333.557	257.858	75.698
	2	97.236	78.267	18.969	248.19	160.8	87.389
	3	82.973	61.622	21.351	180.719	99.678	81.04
	4	81.913	58.194	23.719	176.131	88.896	87.233
	5	73.307	44.384	28.923	141.065	51.71	89.354
	6	65.801	29.687	36.114	113.657	23.134	90.521
	7	57.283	17.867	39.416	86.1352	8.379	77.755
	8	51.279	8.726	42.553	69.0253	1.998	67.026
	9	45.308	0	45.308	53.8864	0	53.886
1.5	1	112	97.037	14.963	329.28	247.174	82.105
	2	108.932	87.916	21.016	311.487	202.892	108.595
	3	106.247	84	22.247	296.321	185.22	111.101
	4	100.2	75.714	24.486	263.551	150.481	113.07
	5	96.326	69.975	26.351	243.566	128.533	115.032
	6	88.746	58.174	30.572	206.741	88.835	117.905
	7	74.644	39.522	35.122	146.258	41.0	105.255
	8	62.88	23.467	39.413	103.79	14.455	89.333

	9	54.297	0	54.297	77.3893	0	77.389
2.0	1	126.518	91.384	35.134	420.179	219.214	200.963
	2	116.713	77.423	39.29	357.576	157.350	200.224
	3	111.325	69.364	41.961	325.323	126.298	199.024
	4	105.263	58.037	47.226	290.858	88.417	202.44
	5	95.75	46.218	49.532	240.662	56.072	184.588
	6	83.697	29.975	53.722	183.886	23.585	160.3
	7	67.152	0	67.152	118.372	0	118.371
2.5	1	123.031	88.111	34.92	397.336	203.793	193.543
	2	117.845	79.031	38.814	364.545	163.954	200.59
	3	111.408	69.603	41.805	325.808	127.17	198.638
	4	103.106	57.025	46.081	279.06	85.361	193.698
	5	96.749	40.57	56.179	245.71	43.205	202.504
	6	79.351	0	79.351	165.285	0	165.285
3.0	1	118.091	72.656	45.435	366.069	138.571	227.498
	2	112.422	60.399	52.023	331.766	95.761	236.005
	3	105.618	36.718	68.9	292.823	35.39	257.432
	4	100.216	27.633	72.583	263.635	20.044	243.591
	5	96.9	20.77	76.13	246.477	11.324	235.153
	6	90.436	0	90.436	214.69	0	214.690

V. WORK CARRIED OUT

1. PROBLEM DESCRIPTION:

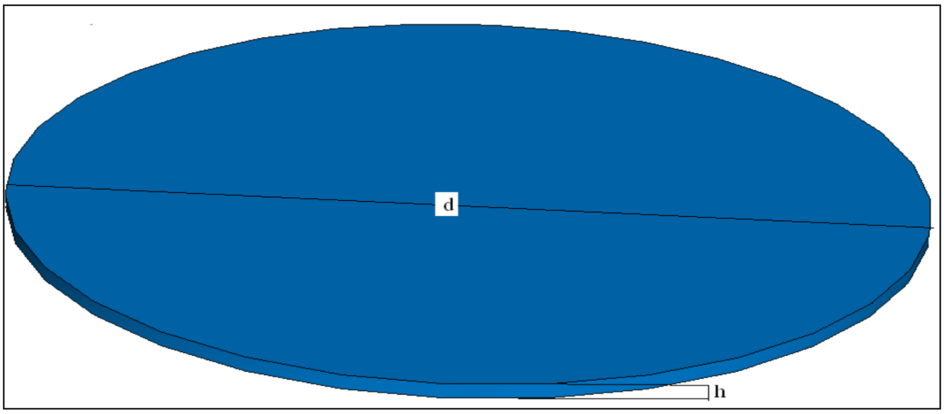
The present study is a numerical investigation on the behavior of thin aluminum plates of 2 mm, 4 mm thickness subjected to impact by ogival nosed projectile. Projectile was impacted on the targets with varying the projectile velocities. Impact and residual velocities have been predicted and energy absorbed by the target plates has been predicted. Residual velocity and velocity drop of the projectiles have been related to the impact velocity and plate thickness.

Projectile used in numerical analysis had Mass, length, and diameter 55grams, 49.6mm, 15mm respectively. The above projectile parameters were kept constant while the thickness of the target plate made of 1100-H12 aluminum was varied. Target plates were circular having a span diameter of 205 mm.

Finite element simulation of the impact situation was carried out by using explicit finite element code ABAQUS. Adaptive meshing was used to deal with numerical problems associated with excessive distortion of the elements and consequent termination of the analysis. Mesh density was found to be a significant parameter affecting the accuracy of the computational results.

2. MODEL DESCRIPTION:

The proposed model is shown in the Figure. A circular aluminum plate of diameter‘d’ and thicknesses ‘h’ is considered. The ogival rigid projectile of diameter ‘D’ and total length ‘L’ is considered in this model.



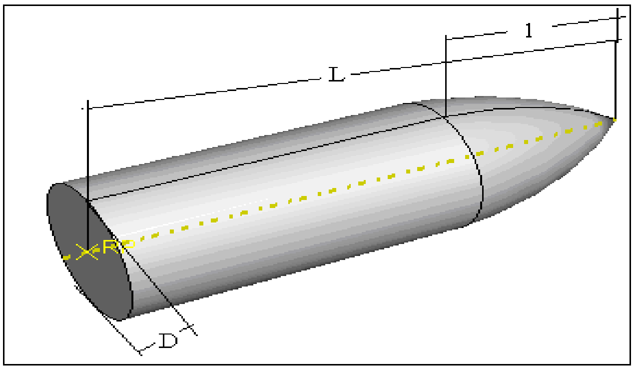


Figure 1: 3-D modeling of projectile and plate

VI. COMPUTATIONAL RESULTS AND DISCUSSION

1. INPUT DATA:

A number of different models were developed in the present study to analyze the perforation process to focus attention on different ranges of impact velocity. Following are the geometrical data taken to study the perforation of projectile into targets.

Geometric Data:

Target: d=205 mm, h=2 mm and 4 mm.
Projectile: D=15 mm, L=49.6 mm, l= 19.6 mm.

Material Data: Table 2

Material parameters for the targets: Aluminum (1100-H12)

Modulus of Elasticity E (N/mm2)	65.762 E 3
Poison's ratio	0.3
Density (kg/m3)	2700
Yield stress A (N/mm2)	148.361
B (N/mm2)	345.513
N	0.183
C	0.001
Reference strain rate (1/s)	1.0
M	0.859
Tmelt (oK)	893
T0 (oK)	293
Specific heat, Cp (J/kg K)	920
Inelastic heat fraction, η	0.9
D1	0.071
D2	1.248
D3	-1.142
D4	0.147
D5	0.0

Projectile mass (m): 55grams.

2. VALIDATION OF THE PROPOSED MODEL:

The proposed model was verified with the help of an example solved in is taken as given in the literature [14]. The projectile of diameter 19 mm and length 50.8 mm is impacted on the aluminum plate of thickness 2 mm. The projectile is modeled as rigid body and plate as deformable body.

The results of residual velocity, residual energy, and energy absorption during perforation with respect to the impact velocity obtained from the proposed model were compared with result available in Ref [14].

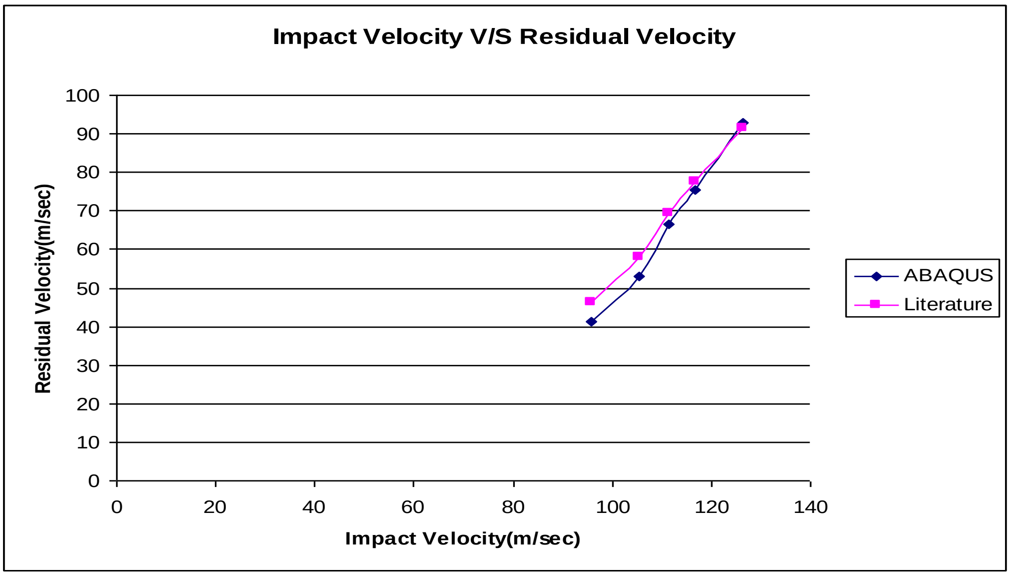


Figure 2: Impact Velocity V/S Residual Velocity

1.3 RESULTS:

Numerical results of the ogival nosed projectile normally impacted on the 2mm and 4 mm thick target plates are presented in the table 3. The effect of impact velocity on the residual velocity, velocity drop, impact energy, residual energy of the projectile as well as energy absorbed by the target plate is presented in the table 3

Table 3: Predicted values of Impact Velocity, Residual Velocity, Velocity Drop, Impact Energy, Residual Energy, And Absorbed Energy for 2 mm thick.

S.NO	Impact Velocity(m/sec)	Residual Velocity(m/sec)	Velocity Drop(m/sec)	Impact Energy(J)	Residual Energy(J)	Absorbed Energy(J)
1	65	0	65	116.188	0	116.188
2	70	0	70	134.75	0	134.75
3	75	0	75	154.688	0	154.688
4	85	0	85	198.688	0	198.688
5	90	0	90	222.75	0	222.75
6	95	33.91	61.09	216.56	31.622	216.566
7	98	42.21	55.79	215.12	48.990	215.12
8	110	68	42	205.59	127.16	205.59

1.3.1 Variation of the Projectile Velocity With Respect To Time:

When the projectile comes in contact with the plate there was a drop in the velocity as the time increasing, the velocity becomes zero when the projectile completely penetrated in to the plate. This process was observed below the ballistic limit, but above the ballistic limit there was no change in the velocity of the projectile after particular time.

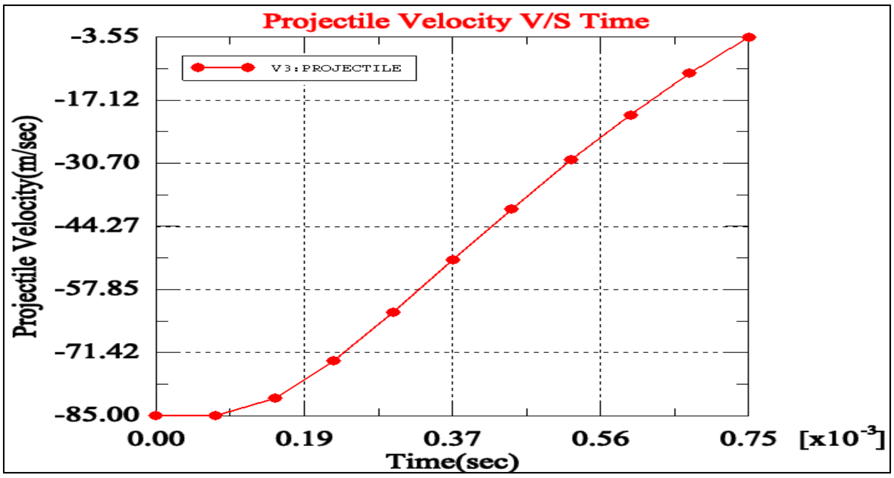


Figure 3: Projectile Velocity With respect To Time (below ballistic limit)

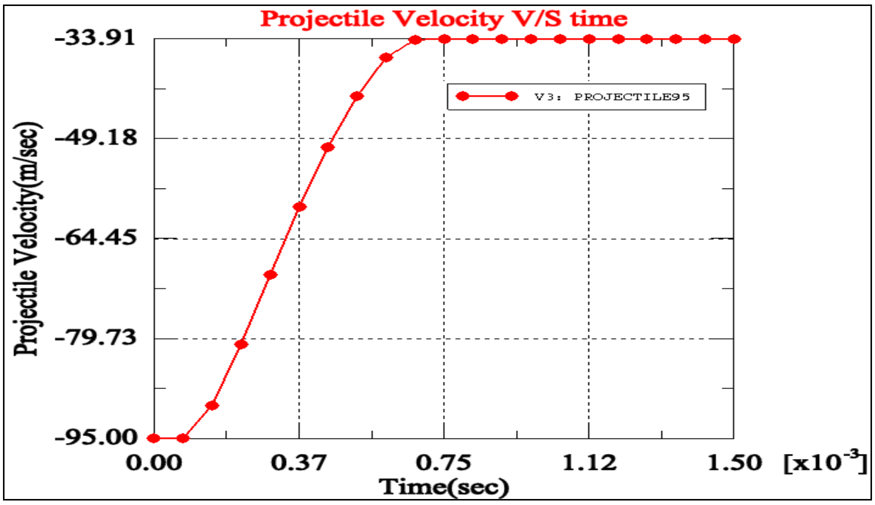


Figure 4: Projectile Velocity With respect To Time (at ballistic limit)\

VII. CONCLUSIONS

The present study was carried out for analyzing the effect of some of the important factors that affect perforation of a target plate by an ogival rigid projectile. The parameters investigated include thickness of the plate, angle of obliquity, and initial velocity of the impactor. The projectile was normally and obliquely impacted on the target plates at varying velocities in simulation.

1. Impact and residual velocities of the projectiles was computed.
2. Deformation pattern and Energy absorption of the target plates during the perforation of the ogive rigid projectile was studied.
3. The total energy of the projectile was completely absorbed by the plate during the perforation at lower velocities, above the ballistic limit there was some residual energy, the remaining energy was absorbed by the plate only.
4. Effect of the projectile impact velocity on the plastic deformation of the target plates was studied. It was found that for lower velocities the deformation of the target plates is increased, and after that the deformation of the plate is decreased.
5. As the angle of obliquity increases the ballistic limit, and energy absorption of the plate was decreased.
6. The ballistic limit increases as the thickness of the plate increases.
7. The impact velocity decreases with time after impact and gradually comes to zero below the ballistic limit and for above the ballistic limit there is some residual velocity, it is constant after perforation of the plate.

REFERENCES

[1]. Zukas JA, Nicholas T, Swift HF, Greszczuk LB, Curran DR, editors. Impact Dynamics. New York: Wiley, 1982.

[2]. Backman ME, Goldsmith W. The mechanics of penetration of projectiles into targets. Int J Eng Sci 1978; 16: 1–99.

[3]. Landkof B. & Goldsmith W. Petalling of thin, metallic plates during penetration by cylindro-conical projectiles. Int. J. Solids struct. 1985; 21: 245-266.

[4]. Corbet GG, Reid SR, Jhonson W. Impact loading of plates and shells by free- flying projectiles: A Review. Int J Impact Engg 1996; 18: 141-230

[5]. N.K.Gupta R.Ansari, S.K.Gupta Normal impact of ogive nosed projectiles on thin plates. Int. J. Impact Engg. 2001: 25: 641-660.

[6]. Dr. Ansari R, PhD Dissertation, Department of Applied Mechanics, Indian Institute of Technology .1998

[7]. T. Borvik, O.S. Hopperstad, M.Langseth, K.A. Malo, Perforation of 12 mm thick steel plates by 20 mm diameter projectiles with flat, hemispherical and conical noses part I: Experimental study. Int. J. Impact Engg.2002: 27:19-35

[8]. T. Borvik, O.S. Hopperstad, M.Langseth, T. Berstad, Perforation of 12 mm thick steel plates by 20 mm diameter projectiles with flat, hemispherical and conical noses part II: Numerical simulations. Int. J. Impact Engg.2002: 27:37-64

[9]. T. Borvik, O.S. Hopperstad, M.Langseth, Arlid H. Clausen, Perforation of AA5083-H116 aluminum plates with conical-nose steel projectiles---Experimental study. Int. J. Impact Engg.2004: 30:367-384

[10]. T. Borvik, O.S. Hopperstad, M.Langseth, Arlid H. Clausen, M. Eriksson, T. Berstad Experimental and numerical study on the perforation of AA6005-T6 panels. Int. J. Impact Engg.2005: 32: 35-64

[11]. S. Dey, T. Borvik, O.S. Hopperstad, J.R. Leinum, M.Langseth. The effect of target strength on the perforation of steel plates using three different projectiles nose shapes. Int. J. Impact Engg.2004:30:1005-1038

[12]. X. Teng, T. Wierzbicki. Numerical study on crack propagation in high velocity perforation. Computers and Structures 2005:83:989-1004

[13]. T. Borvik, O.S. Hopperstad, M.Langseth, K.A. Malo, Effect of target thickness in blunt projectile penetration of Weldox steel plates. Int.J.Impact Engg.2003:28:413-464

[14]. Dr. M. Ashraf Iqbal, PhD dissertation, Department of Applied Mechanics, Indian Institute of Technology .2005.

[15]. Clausen AH, Borvik T, Hopperstad OS, Benallal A. Flow and fracture characteristics of aluminum alloy AA5083-H116 as function of strain rate, temperature and triaxiality. Mat Sci Engg. 2004:A364:260-272.

[16]. ABAQUS Manual, Version 6.6.1, 2006.

[17]. Mendelson, A. Plasticity theory and applications, 1970.

[18]. Cristescu, N. Dynamic Plasticity, 1967