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Design and Analysis of Metal Flow in Hot Aluminium Extrusion of T and C Channel Shaped Profilies with Various offset Pockets

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Abstract: The simulation of hot extrusion processes is a difficult and challenging problem in process modelling. This is due to very large deformations, high strain rates and large temperature changes during the process. Computer models that with sufficient accuracy can describe the material behavior during extrusion can be very useful in process and product development.

Main purpose is to investigate the influence of offset pocket design on metal flow behavior in hot aluminium extrusion of T- C-channel shaped profiles. A series of finite element simulations are doing by offsetting the centre of pocket cross-section and examining exit velocity distributions, temperature, displacement of the profiles cross-section for each case. CATIA V5 R20 software is used to create the models and analysis is performed in DEFORM3D software. Finally optimum model have to prepare with maintain constant velocity.

Keywords: Aluminium, Behavior, Deformation, Extrusion and Hot

I. INTRODUCTION

Extrusion is an often-used forming process among the different metal forming operations and its industrial history dates back to the 18th century. In 1797, Joseph Bramah an English inventor patented the first extrusion process for making lead pipe. It involved preheating the metal and then forcing it through a die via a hand driven plunger. In the past 30 years, its economic importance has increased, primarily as a result of technological advances that have drawn on extensive practical experience and on numerous fundamental investigations into the extrusion process, tooling, and metal flow. The development of the extrusion press from the first dimple lead press to the modem automatic extrusion plant represents a chapter in the history of metalworking. Several important dates mark the path to the versatile process used today for both nonferrous metals and steel. A brief summary is given below.

In recent years, researchers started to be attracted by three-dimensional problems in metal forming. At present three-dimensional modelling is still regarded as a highlighted and difficult problem. Different methods of analysis have been extended to three dimensional, among which the finite element analysis is most commonly used. Most of the papers published on three dimensional finite element method simulations are based on different software package like ALGOR, DEFORM-3D etc.

II. METHODOLOGY

Extrusion is a plastic deformation process in which a block of metal (billet) is forced to flow by compression through the die opening of a smaller cross-sectional area than that of the original billet as shown in Fig. 1. Extrusion is an indirect-compression process. Indirect-compressive forces are developed by the reaction of the work piece (billet) with the container and die; these forces reach high values. The reaction of the billet with the container and die results in high compressive stresses that is effective in reducing the cracking of the billet material during primary breakdown from the billet. Extrusion is the best method for breaking down the cast structure of the billet because the billet is subjected to compressive forces only. Extrusion can be cold or hot, depending on the alloy and the method used. In hot extrusion, the billet is preheated to facilitate plastic deformation.

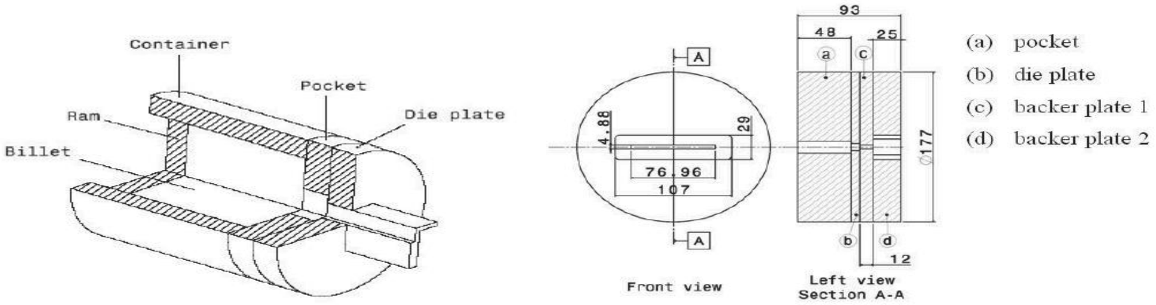

Fig.1 Extrusion Parts.

Table 1 Physical properties of the workpiece and tooling

Properties	AA6063
Heat capacity (N/mm2 ºC)	2.433
Thermal conductivity (N/s ºC)	180.2
Heat transfer coefficient between workpiece and die/container/ram (N/s mm ºC)	5
Heat transfer coefficient between die/container/ram and air (N/s mm ºC)	0.02
Emission	0.7

The plastic behavior of the aluminum is defined via the flow stress. It describes the relation between the effective stress ,and the equivalent viscoplastic strain rate is

$$\dot{\bar{\varepsilon}} = A\left(\sinh\left(\alpha\bar{\sigma}\right)\right)^{n} \exp(-H/RT)$$

Table 2 Plastic properties of aluminium

Aluminium alloy	A	N	H	A	R
-	-	-	J/MOL	S^{-1}	J/MOL K
6063	0.04	5.4	1.4E5	6E9	8.314

Total geometry profile models are created in modelling software CATIA V5 R20.

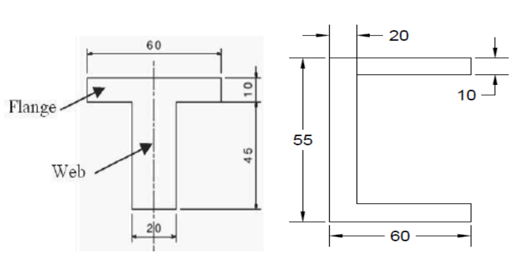

Fig.2 Dimensions of T-shaped and C-shaped profiles

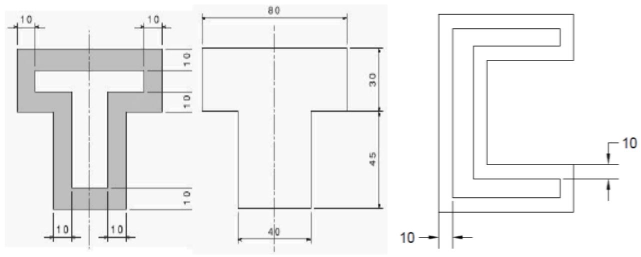

Fig.3 Dimensions of T-shaped pocket and C-shaped pocket

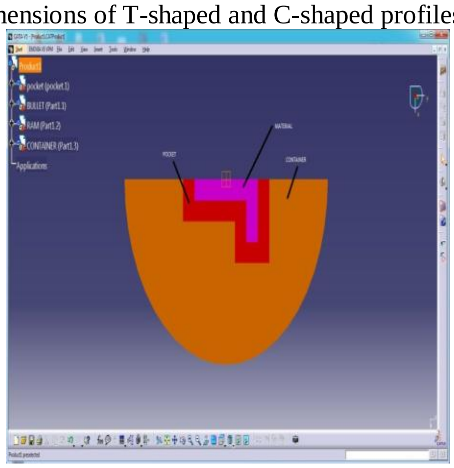

Fig.4 Different parts in extrusion process

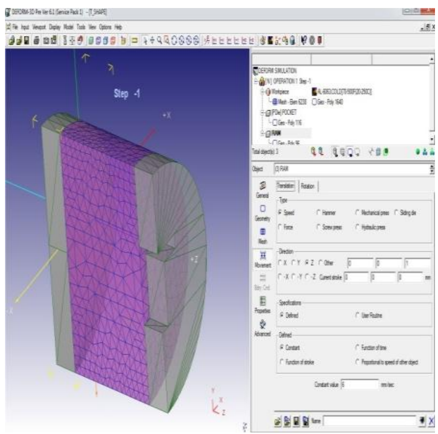

Fig.5 velocity applied to ram

III. RESULTS AND DISCUSSIONS

T-SHAPED PROFILE EXTRUSION RESULTS

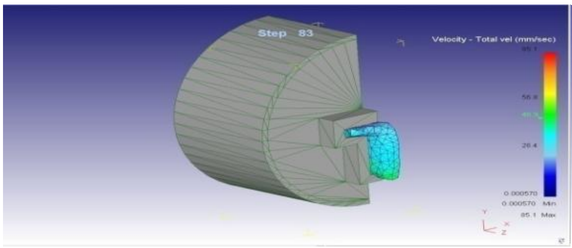

Fig 6 Velocity plot of center T-shape profile

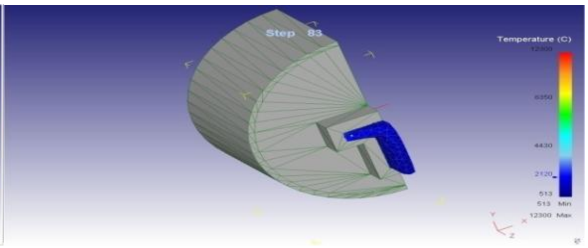

Fig.7 temperature plot of center T-shape profile

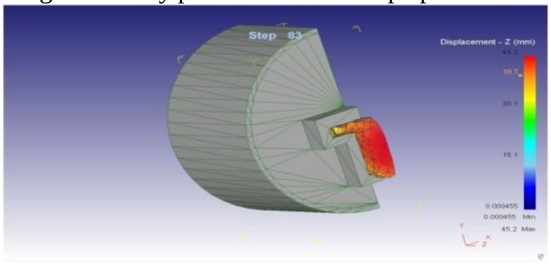

Fig.8 Displacement plot of center T-shape profile

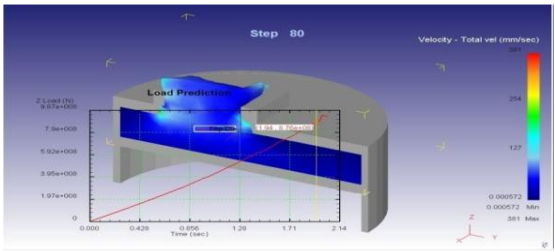

Fig. 9 Load on ram plot of center T-shape profile

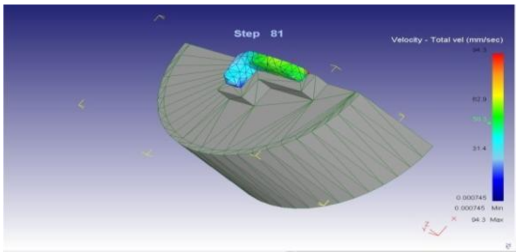

Fig.10 Velocity plot of 3 mm down T-shape profile

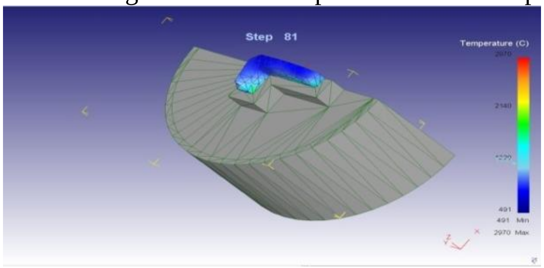

Fig .11 Temp plot of 3 mm down T-shape profile.

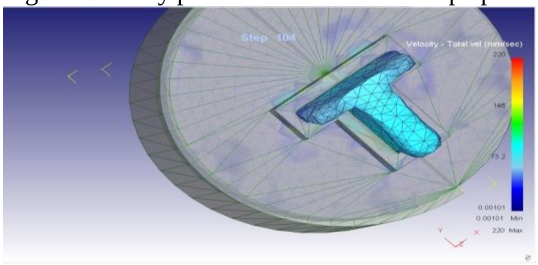

Fig .12 Displacement plot of 3mm down T-shape profile.

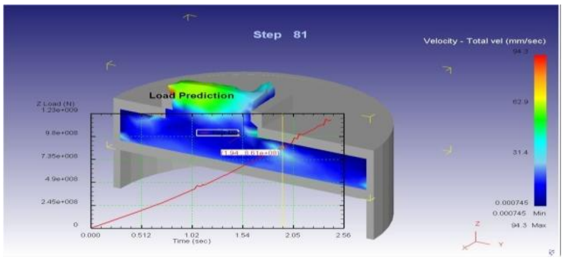

Fig.13 Load plot of 3mm down T-shape profile.

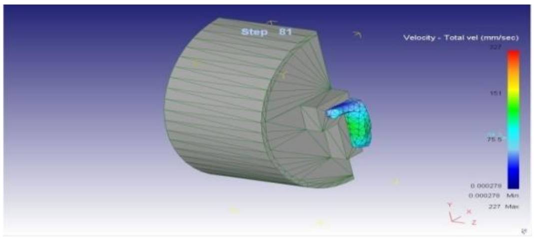

Fig.14Velocity plot of 5 mm down T-shape profile

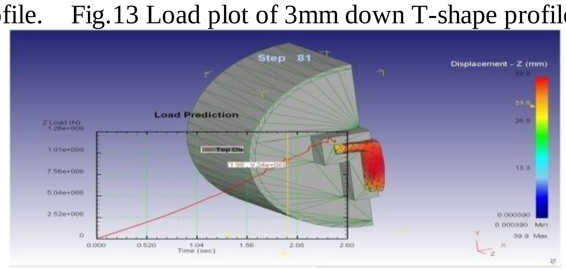

Fig.15 Load plot of 5 mm down T-shape profile

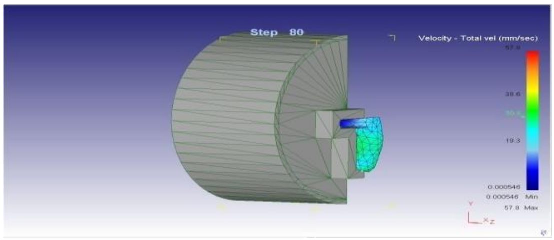

Fig.16 Velocity plot of 3 mm up T-shape profile

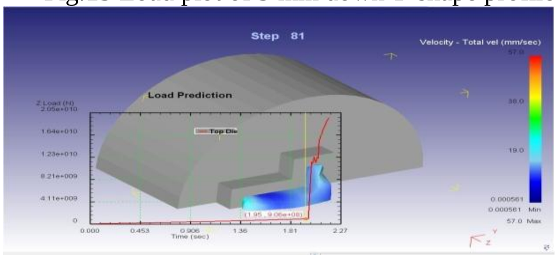

Fig.17 Load plot of 3 mm up T-shape profile

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C-SHAPED PROFILE EXTRUSION RESULTS

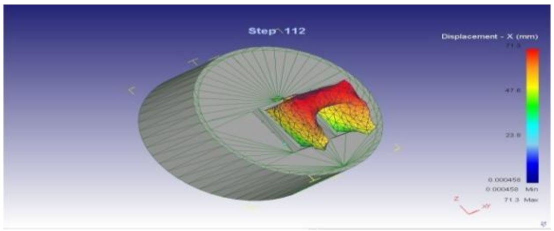


Fig.18 Displacement plot of center C-shape profile

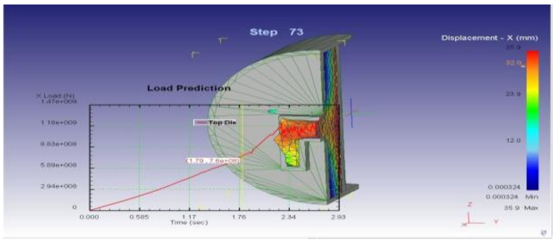


Fig. 19 Load on ram plot of center C-shape profile

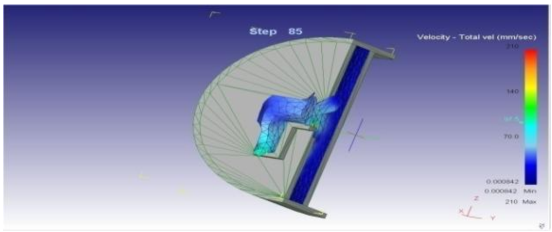


Fig 20 Velocity plot of 3 mm down C-shape profile

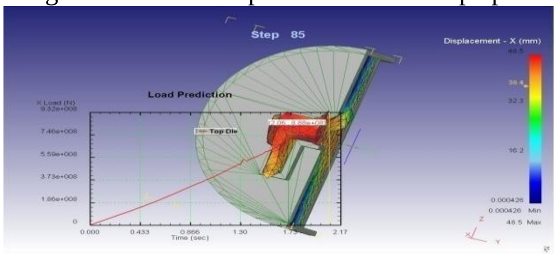


Fig. 21 Load plot of 3 mm down C-shape profile

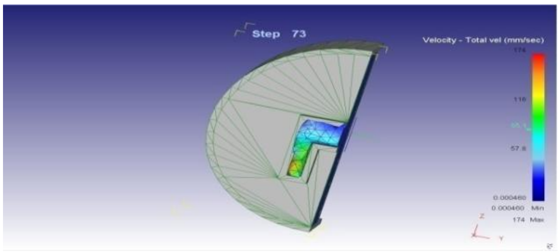


Fig.22Velocity plot of 5 mm down C-shape profile

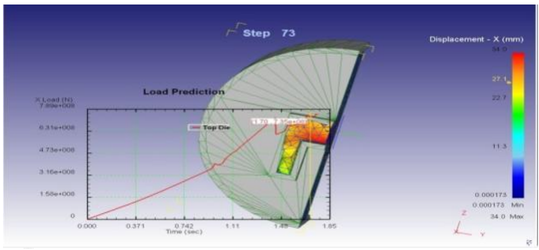


Fig.23 load plot of 5 mm down C-shape profile

IMPROVED POCKET DESIGN

The new design of the pocket was proposed based on the analysis to achieve uniform velocity across the T-section of extrudate with the aim to regulate the flow. Since the web of the T-shaped profile is twice larger than the flange width. With the standard pocket and a single bearing length, the velocity of the web area was greater than the velocity of the flange. By moving the centre of pocket upward it results slower velocity in the web and a little higher velocity on the flange. Therefore, the new pocket would be designed and it shown as below.

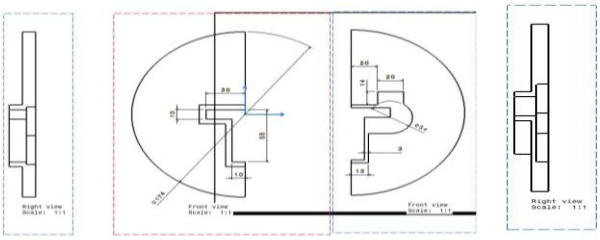


Fig 24 New pocket design of T-shaped profile

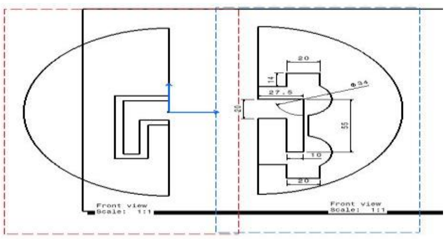


Fig 25 New pocket design of C-shaped profile

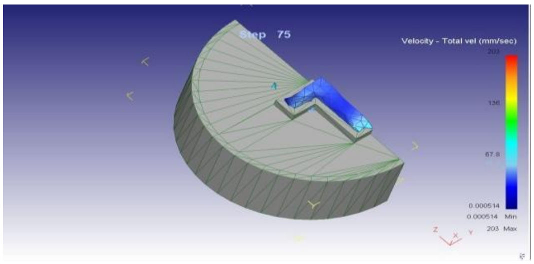


Fig.26 Velocity plot of T-shaped extrusion (new design)

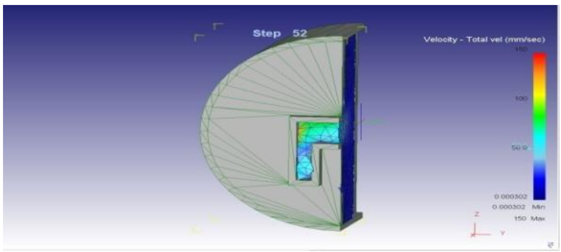


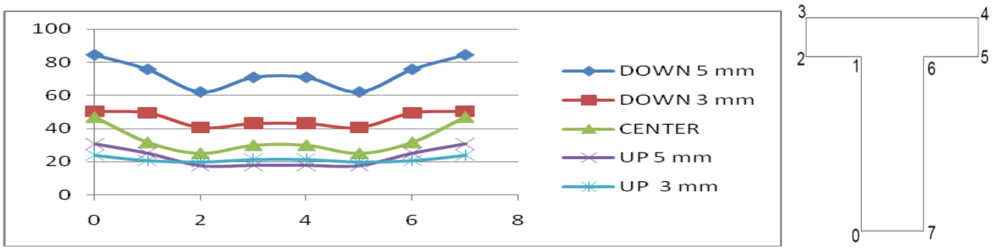
Fig 27 Velocity plot of C-shaped extrusion (new design)

All individual parts are created in CATIA and individual parts are saved as STL file to import to DEFORM 3D software. Especially deform 3d software is very useful for hot extrusion process. Here all parts are imported into software using geometry import option. Billet materials are kept as elasto plastic material. And aluminium material is assigned to billet material, 480 degree temp is applied to billet and 20 m/s velocity is assigned to ram.

Here five different analyses are performed in software. One is profile is placed at center place, profile is keeping at 3 mm downward direction, profile is keeping at 5 mm downward direction, profile is keeping at 3 mm upward direction and profile is keeping at 3 mm upward direction.

Different points are identified in T- shape profile as shown in below. And velocity readings are noted at different points and plotted in graph as shown below.

T-SHAPED PROFILE RESULTS



Graph 1 Velocity distribution of T-shaped profile in different cases

Table 3 Velocity results for T-shaped profile

parameters	0	1	2	3	4	5	6	7
DOWN 5 mm	84.3	75.6	62	70.8	70.8	62	75.6	84.3
DOWN 3 mm	50.3	49.4	40.7	43.1	43.1	40.7	49.4	50.3
CENTER	46.9	31.6	25	29.9	29.9	25	31.6	46.9
UP 5 mm	30.8	25.2	17.8	18	18	17.8	25.2	30.8
UP 3 mm	23.8	20.6	19.8	21.3	21.3	19.8	20.6	23.8

From the above results , at downward 3 mm T-shaped profile has maximum velocity at 7th point and minimum velocity at 2nd and 5th point and difference is 9.3 m/s between minimum and maximum velocities.

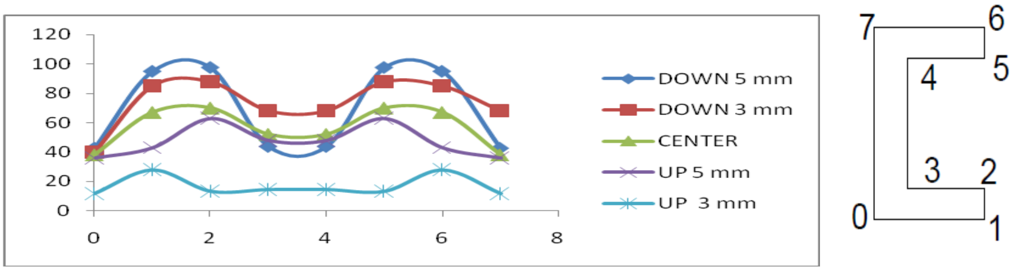
At downward 5 mm T-shaped profile has maximum velocity at 7th point and minimum velocity at 2nd and 5th point and difference is 22.3 m/s between minimum and maximum velocities.

At centred T-shaped profile has maximum velocity at 7th point and minimum velocity at 2nd and 5th point and difference is 22 m/s between minimum and maximum velocities.

At upward 3mm T-shaped profile has maximum velocity at 7th point and minimum velocity at 2nd and 5th point and difference is 4 m/s between minimum and maximum velocities.

At upward 5 mm T-shaped profile has maximum velocity at 7th point and minimum velocity at 3nd and 4th point and difference is 12.8 m/s between minimum and maximum velocities.

C-SHAPED PROFILE RESULTS



Graph 2 Velocity distribution of C-shaped profile in different cases

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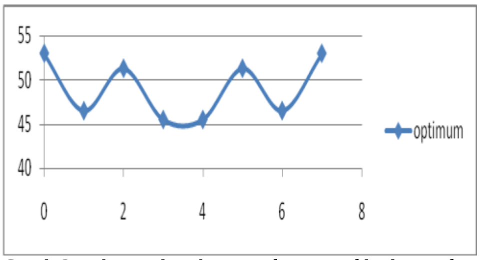
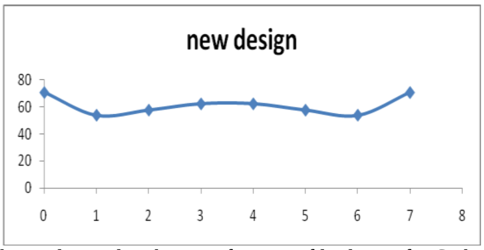
Table 4 Velocity results for C –shaped profile

parameters	0	1	2	3	4	5	6	7
DOWN 5 mm	42.7	94.9	97.5	43.9	43.9	97.5	94.9	42.7
DOWN 3 mm	40	85.1	88	68.2	68.2	88	85.1	68.2
CENTER	38	67	70	52	52	70	67	38
UP 5 mm	36	43	63	48	48	63	43	36
UP 3 mm	11.6	13.2	28	14.4	14.4	28	13.2	11.6

From the above results, at downward 3 mm C-shaped profile has maximum velocity at 5th point and minimum velocity at zero point and difference is 44 m/s between minimum and maximum velocities.
At downward 5 mm C-shaped profile has maximum velocity at 5th point and minimum velocity at zero point and difference is 54.8 m/s between minimum and maximum velocities.
At centred C-shaped profile has maximum velocity at 5th point and minimum velocity at zero point and difference is 32 m/s between minimum and maximum velocities.
At upward 3mm C-shaped profile has maximum velocity at 5th point and minimum velocity at zero point and difference is 16.4 m/s between minimum and maximum velocities.
At upward 5 mm C-shaped profile has maximum velocity at 5th point and minimum velocity at zero point and difference is 27 m/s between minimum and maximum velocities.



Graph 3 Velocity distribution of new profile design for T-shape



Graph 4 Velocity distribution of new profile design for C-shape

Table 5 New profile results for T-shape

parameters	0	1	2	3	4	5	6	7
Optimum	53	46.5	51.3	45.5	45.5	51.3	46.5	53

Table 6 New profile results for C-shape

parameters	0	1	2	3	4	5	6	7
optimum	70.8	53.8	57.6	62.3	62.3	57.6	53.8	70.8

T-shaped profile has maximum velocity at 7th point and minimum velocity at 4th point and difference is 7.5 m/s between minimum and maximum velocities.

T-shaped profile has maximum velocity at 7th point and minimum velocity at 6th point and difference is 17 m/s between minimum and maximum velocities.

IV. CONCLUSIONS

Finite element model was developed for hot aluminium extrusion to study the influence of offset pocket by performing a series of simulations for various positioned pocket. It was found that the offset pocket has influence on the metal flow during extrusion process. Small distance between the edge of the pocket and the edge of the die leads to slow flow velocity but if the distance is large the metal can flow through easily, hence higher velocity. With the information from the analyses, the new pocket was proposed. The velocity difference across the cross-section of the extrude was smaller compared to the original pocket. The extrudate is straight and not bent. Offsetting pocket can therefore be used to control metal flow to the die.

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