International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(02), December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

COMPUTER AIDED ENGINEERING AND DEVELOPMENT OF A CONTINUOUS EXTRUSION MACHINE

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ABSTRACT

This paper presents a detailed application of CAE process for the design and development of continuous extrusion (continuous rotary extrusion) machine. Modeling of different components is done on the SOLID EDGE (V19) the model has been validated and redesigned by the simulation on DEFORM-3D.

Key Words: ***CAE, CONFORM, Continuous Rotary Extrusion Machine***

I INTRODUCTION

Extrusion process is a chip less manufacturing process of forcing a work material to flow through a die opening of desired shape. Conventional or direct extrusion finds application in the manufacture of solid rods, bars, hollow tubes, and hollow and solid sections according to the design and shape of the die. But in the modern era there is a requirement of a process in which continuous long profiles can be formed without any interruption i.e. a continuous extrusion process. There are several continuous extrusion processes available for manufacturing different kind of profiles, parts and coiled lengths. Amongst these processes, the Conform extrusion (continuous rotary extrusion) is used widely for the continuous extrusion of aluminium, copper, lead, and their solid in the solid, liquid or powder states. The principle of conform extrusion process is as follows. A wire is inserted in a grooved wheel; the stock is drawn by friction against the wheel. The groove is closed by a close fitting shoe having an abutment **[1]** at the end. The material is prevented from continuing its passage around the wheel by means of the abutment. As a result, high temperatures and pressures is developed in the material, which becomes plastic and subsequently emerge out of the machine through an extrusion die. A lot of work is already being done by the various researchers in the area of conform process and tooling development and the optimal design. The CONFORM continuous extrusion machine and process for the continuous extrusion of metals, particularly aluminium and copper, were developed by the United Kingdom Atomic Energy Authority (UKAEA) in the early 1970 **[2].** In theprocess of design and development of machine,results of parametric study done by Moddock [**3]** have been helpful where an analytical was presented for the continuous extrusion process by investigating the relationship between the control parameters set by the machine operator and process output parameters. The velocity distribution and strain in the deformation zone were simplified for estimating shear stress. Given the operator input parameters the model predicts the equilibrium temperatures, flash rates, and pressure distributions.The measure developments in the field of conform technology is doing by the Holton conform and BWE Ltd. Conform machines build by Holton conform are very basic machines and they are using L shaped shoe and three plates for gap adjustment **[4-6]**. But there is one drawback of this machine is their large size and more power consumption. Comparative to Holton machines the BWE ltd. Develop advance technique for 3rd generation equipments with induction heating **[7]** and insert tooling etc. they develop an advanced system of wheel cooling **[8].**

II DESIGN AND MODELING OF CONTINUOUS EXTRUSION MACHINE

As the machine offers a continuous and versatile method for obtaining a high degree of deformation and rapid heating in a single step hence some basic requirements for the machine must be taken into consideration before going for the design and modeling the parts.

1. Design for lower power requirement.
2. Design for continuous work load
3. Design for higher tooling life.
4. Design for higher factor of safety for equipment as well as for operator.
5. Design for fully automatic process
6. Design for lower cost
7. Design for minimum wastage of material

Following are the main steps fallowed for the design of machine and its different components.

1. Calculation of power required for the extrusion process
2. Extrusion wheel groove and wheel diameter calculations
3. extrusion wheel shaft strength calculation
4. die ,die holder, abutment and material exit end plate
5. shoe
6. coining wheel
7. bearings
8. gear box design(inverted gear train)
9. hydraulic locks and intensifier

III EVALUATION AND REDESIGN OF THE MACHINE

The evaluation process causes the changes in the design of machine parts .The redesign is done on the CAD software (solid edge) which is again simulated for the process conditions. The fallowing components are redesigned during the rigorous CAE process as given below.

3.1 Evaluation of Shoe

During the simulation of process blocking of the material in the entry section is occurred; while the feed stock is carried by the extrusion wheel. A centrifugal force acting on the feed rod try to separate out the material from the groove which results in the strike of material to the entry front of the shoe as shown in Fig.1.

3.2 Solution of Problem

To short out this problem a guided entry section is made in the shoe whose upper part is tangential to coining wheel and the lower part is to the free space diameter of the feed stock. The guided entry section in the redesigned shoe is shown in the fallowing Fig. 2.

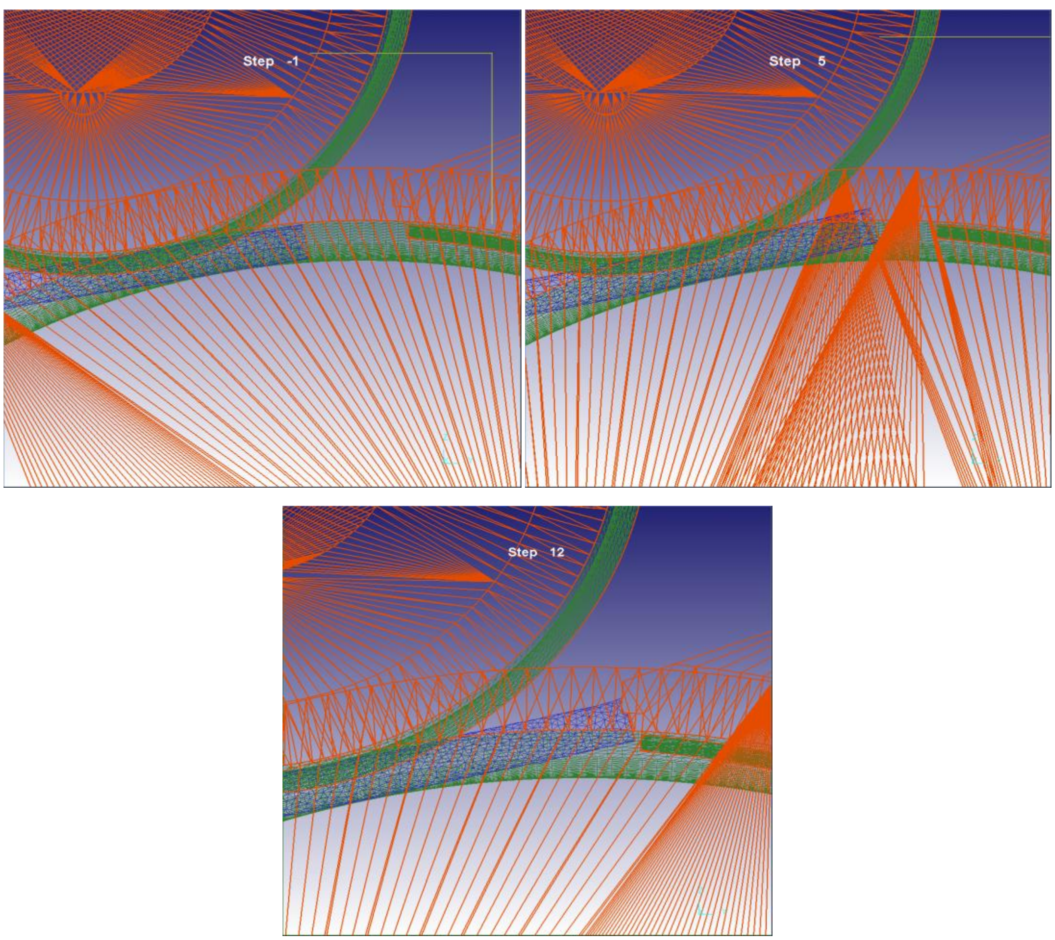

Fig. 1: Striking the material to the shoe at entry section

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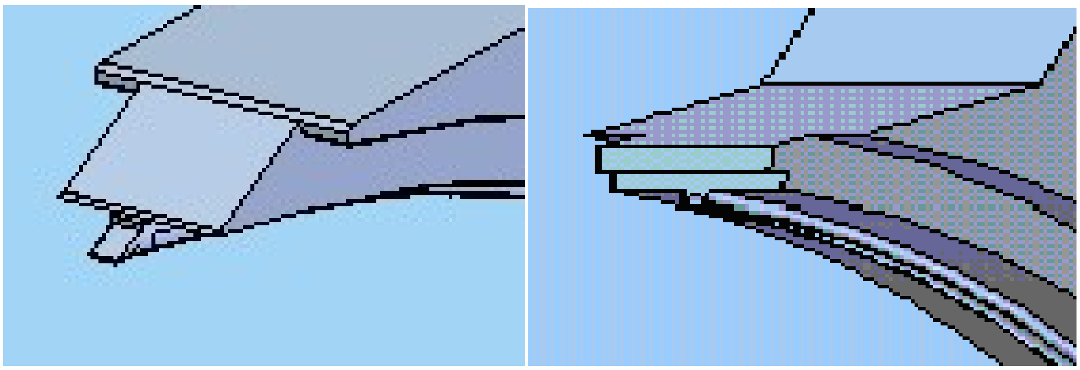
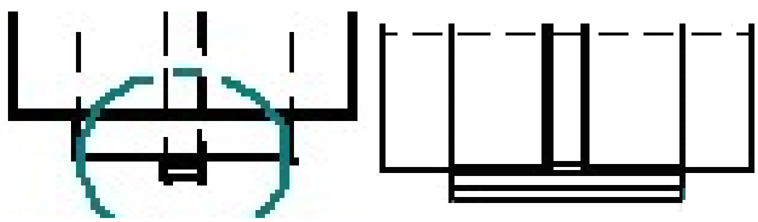
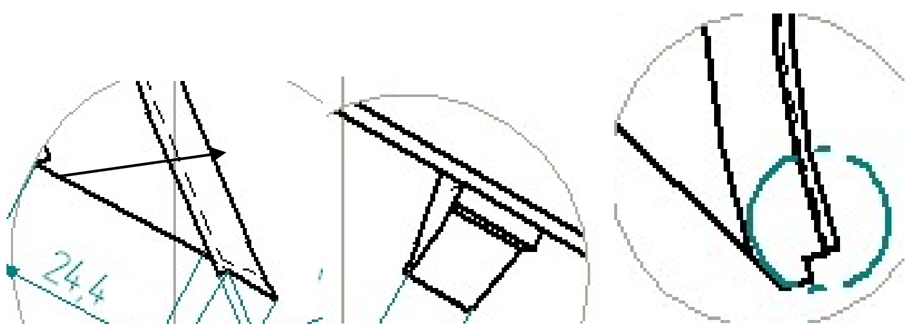


(a) **(b)**



Top view



Side view of redesigned shoe entry **old shoe**

Fig. 2: Entry section of (a) Redesigned shoe (b) Previously designed shoe

The above redesigned shoe entry section part leads to very common problems as the casting of shoe entry section and the wear of entry part. These problems can be easily overcome by fallowing the shaping and polishing operation and hardening the guided part .respectively. Its benefit is not only to provide smooth entry but also the gap control at the entrance. The following Fig. 3 shows the use of redesigned entry section. The DEFORM process images shoes how the material is entered in the shoe groove without striking to the shoe.

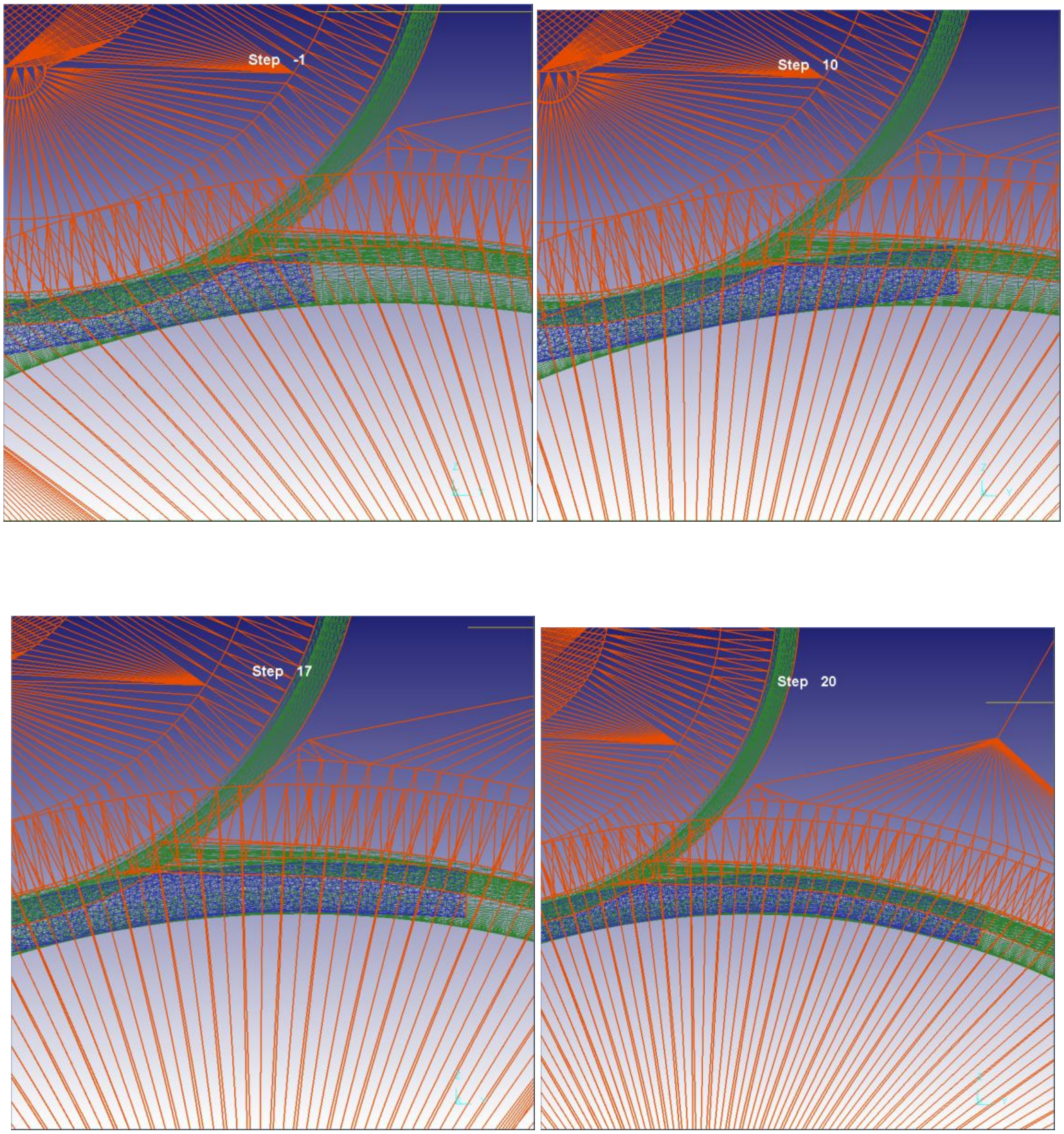


Fig.3: Entry of feedstock through redesigned shoe

3.2 Evaluation Die Holder

The abutment and extrusion die are fixed in the die holder. While the billet strike to the abutment its natural tendency is to bulge out away from the extrusion wheel hence a care is needed in gap at the end condition. During the simulation of process it found that the material is bulged due to the excessive gap between the wheel grooves and die holder as shown in Fig. (4).

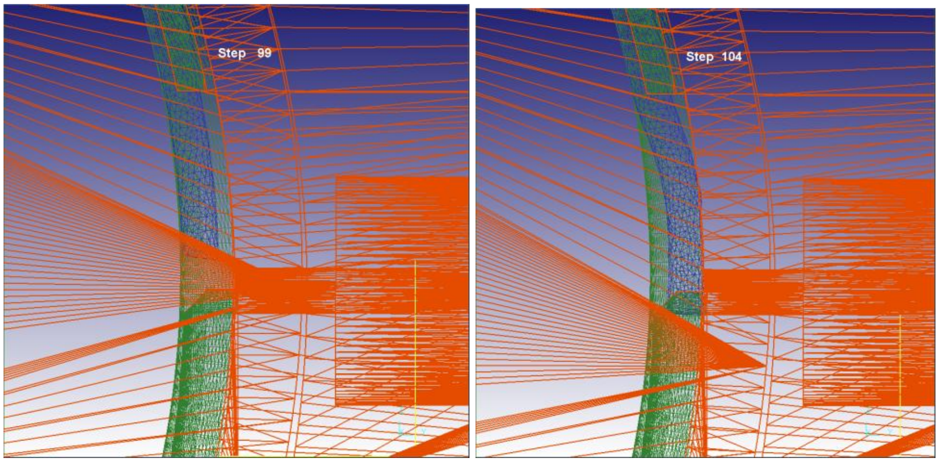
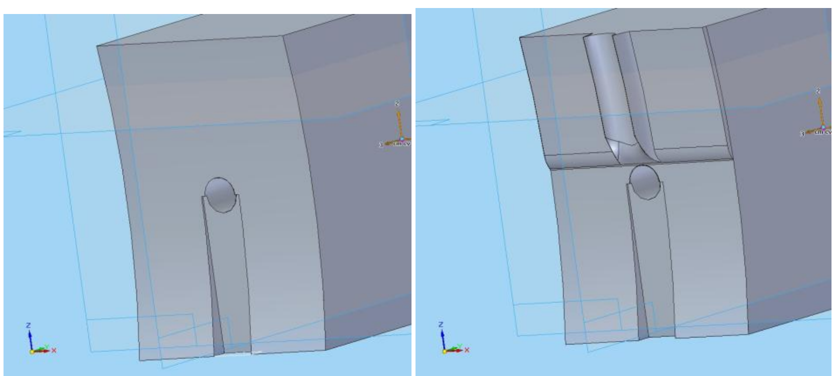


Fig.4: Buckling in material due to gap between extrusion wheels and die holder

3.3 Solution of problem

To fill that gap a protruded part of the replica of wheel groove is made on the die holder fitted into the gap. The modifications in the die holder design are shown in the Fig.5. That shows the metal flowing without any bulging while striking to the abutment. And moreover its rounded entry part provides easy flow of material without wrinkling at the corner as shown in Fig.6.



(a) Previously designed die holder (b) Redesigned die holder

Fig. 5: Extrusion wheel mating part differences between old and redesigned die holder

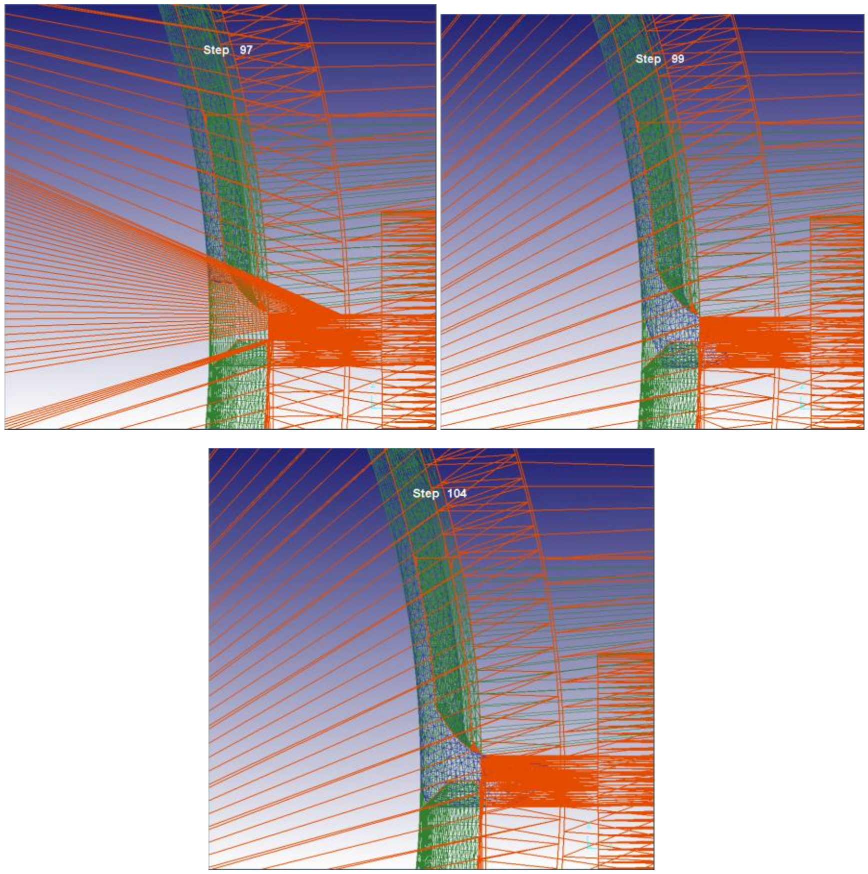


Fig. 6: Effect of redesigned die holder on flow of materials

3.4 Evaluation of Abutment

When the feed stock material strike on the abutment the material flow is hindrance due to that sudden increase in torque requirement is takes place. This sudden increase in torque may overload the motor and the process can be stopped. This situation is never desirable and to avoid these situations flow study of material over the abutment is needed. Here the same work is done by using de-form simulation results.

While the conventional straight profile abutment is used the following results are visualized in Figs.7(a-c). Here from step 97 to 98 the increment is gradual compared to the increment in torque between steps 98to 115 (i.e. a large and sudden increment in torque is visualizes here). In Fig (8) the velocity distribution of material can be seen.

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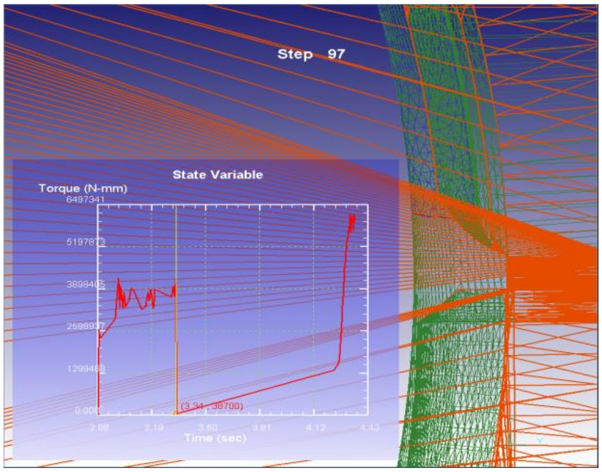

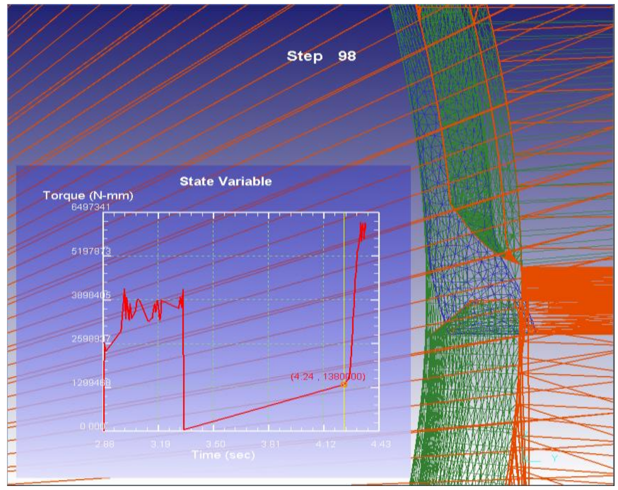

Fig. 7(a) Torque before material strikes abutment **Fig. 7 (b) Torque needed just the material to strikes the abutment**

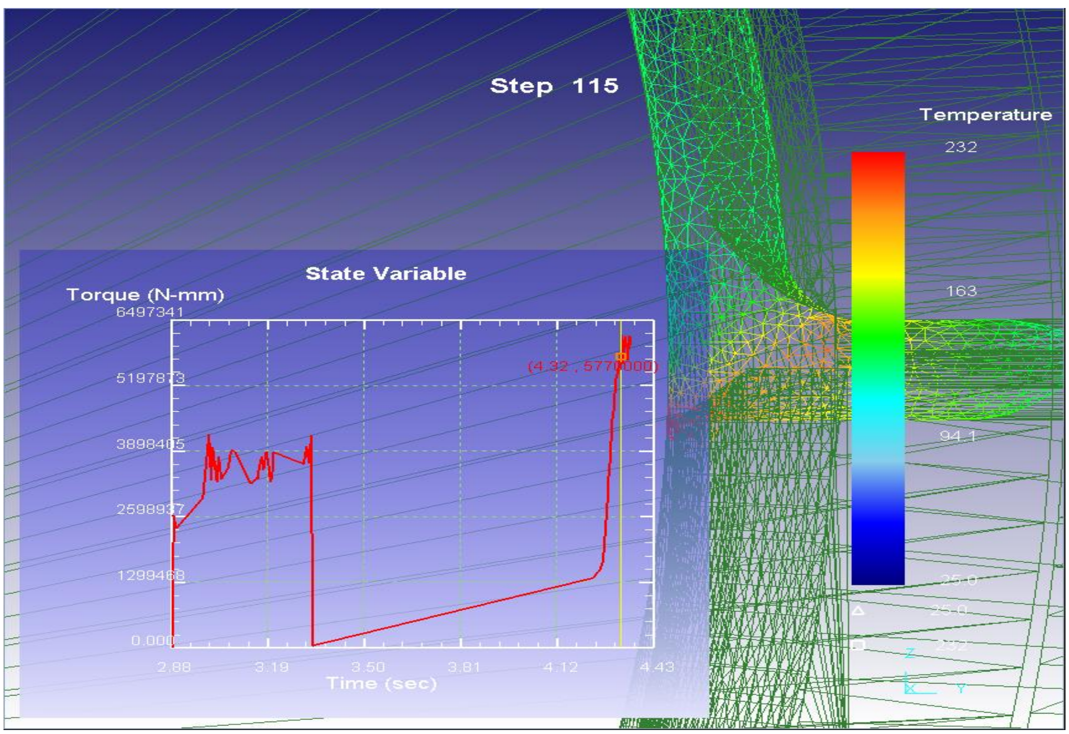

Fig. 7(c) Torque when material passed through abutment

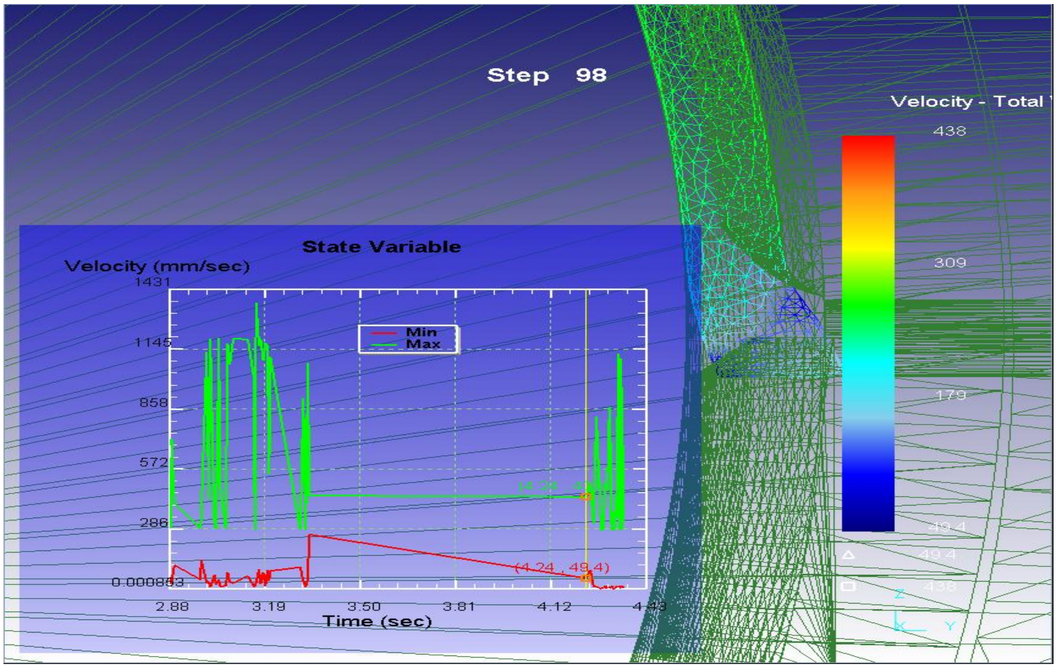

Fig. 8: Velocity distribution when material strikes abutment

In the above Figures the fallowing conclusions can be drawn.

- Sudden large increment in torque from 1380000 N-mm to5197873 N-mm in .08 seconds is not desirable. This happens due to lack of slipping.
- Flash can be minimized, and wrinkling at the corner is not desirable.
- The velocity at the striking point is almost 0 which represents high sticking condition. (Minimum velocity 0.0000853mm/sec.)

To avoid these conditions the fallowing two changes are made in the design of abutment.

1. Providing 3rd order profile in place of straight profile in the face of abutment. Because it reduced the power requirement **[9],** increased the slipping conditions and easy manufacturability.
2. Enlarge it to minimize the scrap.

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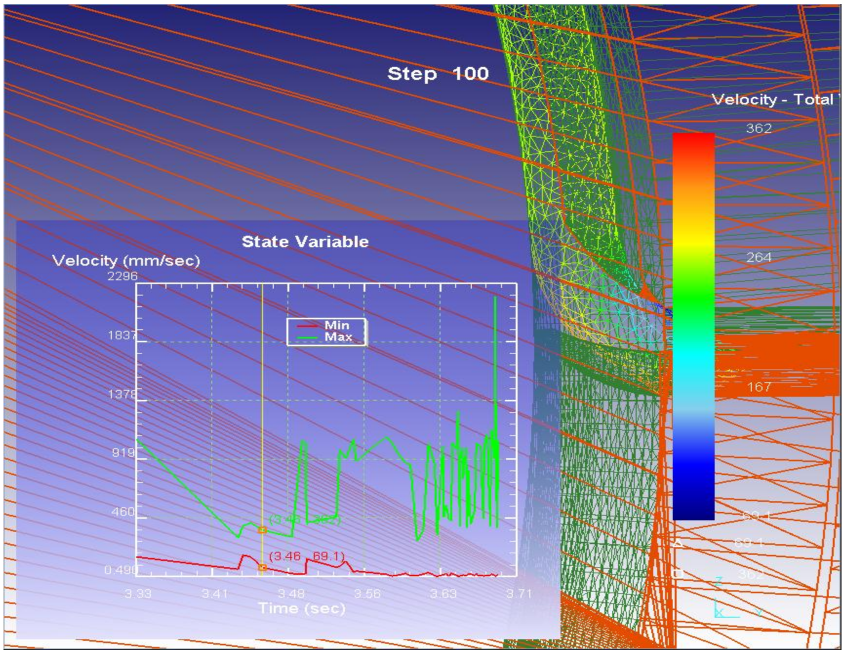

Fig. 9: Velocity distribution when material strikes abutment

The above velocity distribution shows the effect of using 3rd order profile .here we can see that the velocity in the region of abutment profile is in the range of 260-280mm/sec.and the velocity is distributing in the higher to lower value away from abutment face to die holder guiding. Figure (9) shows the changes those are made in abutment.

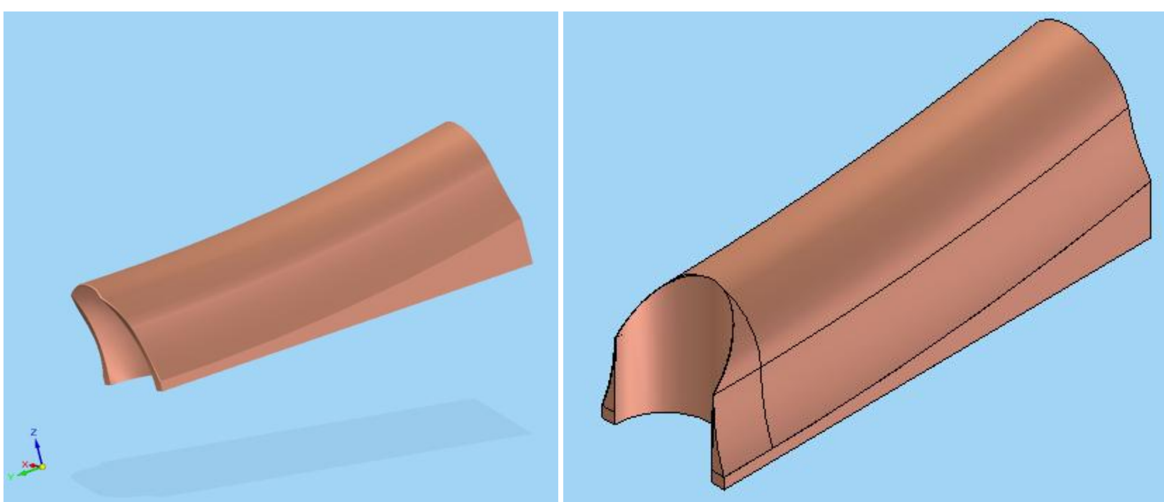

Fig. 9(a) Solid model of re-designed and straight abutments

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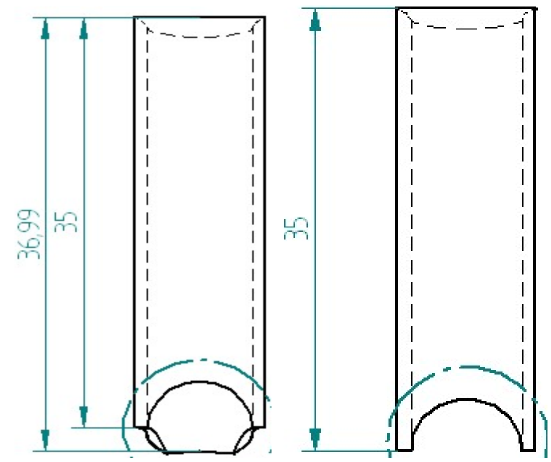

Figure 9: (b) Bottom view of redesigned and straight abutment

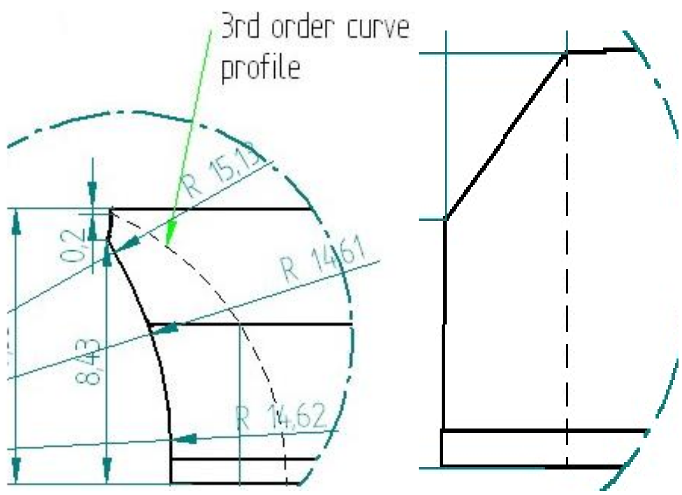

Figure 9 (c) Diagram shows the profile of abutments

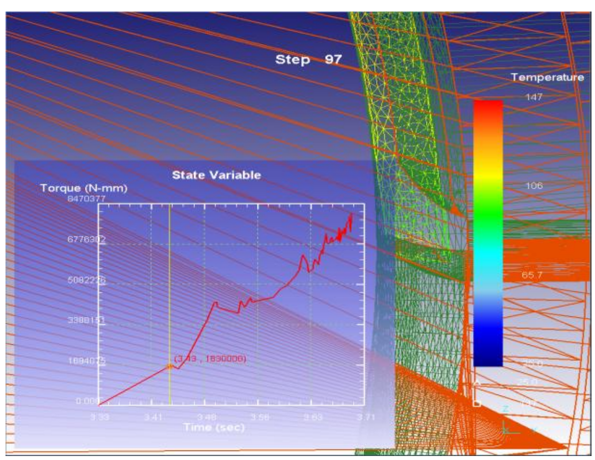

Figure 10: (a)

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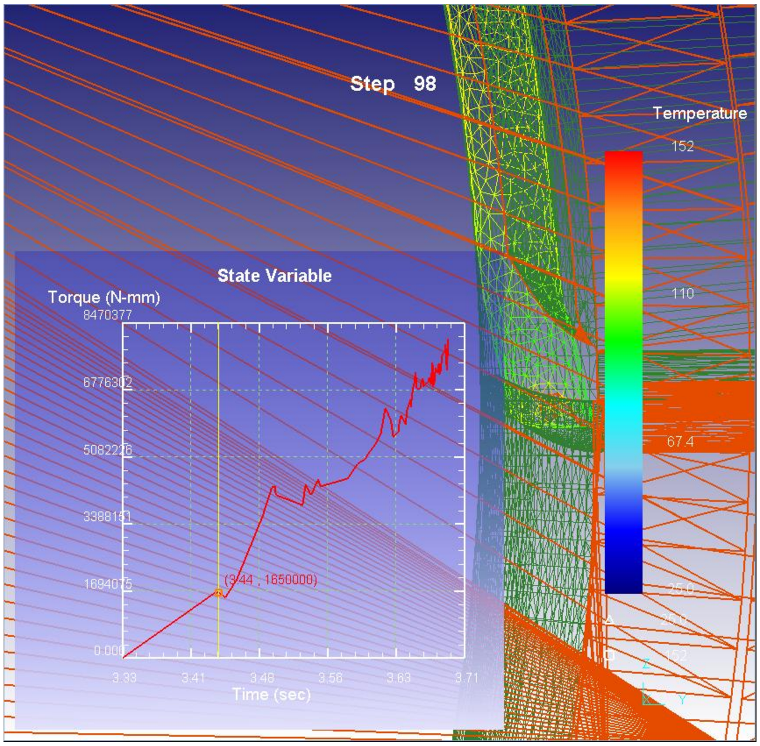

Figure 10: (b)

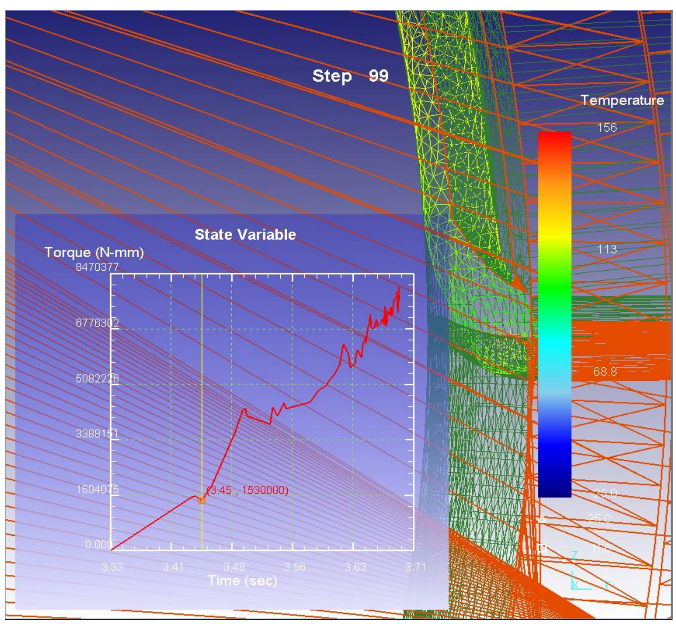

Figure 10: (c)

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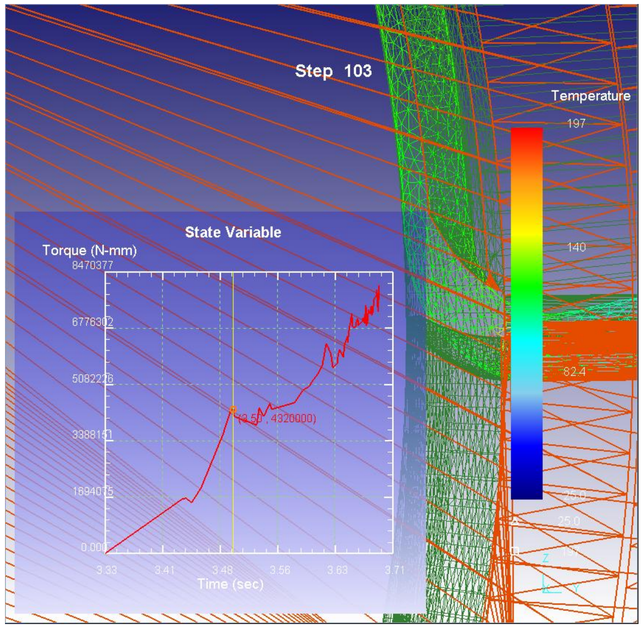

Figure 10 (d): Torque variation by using 3D profiled abutment

In the above Figures 10 (a)-10(d), it can be seen that from step 97 to 99 the torque requirement is decreased because of slipping occurring on the abutment face. From step no.99 to 103, it can be seen that the torque is increased which is because of the material deformation caused by the change in flow path. This increment is more gradual than in the straight abutment and the increment is also limited from1530 to 4320 KNmm without any visible scrap during the whole process.

IV CONCLUSION

Different parts of Continuous extrusion machine are designed by the rigorous process of CAE. The evaluation and redesign process of machine components through DEFORM has made possible improvement in the final design of the machine. The detailed study performed on the shoe and abutment with their design improvement leads better quality product and with lower power consumption.

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