

## Leak Proof Sheet Metal Crimp Simulation and Stress Analysis using FEM

Bharat S. Kodli<sup>1</sup>, Vijayanand B.K<sup>2</sup>,

Department of Mechanical Engineering, P.D.A. Engineering College, Gulbarga India

**Abstract**—Minimization of response times and costs and maximization of the efficiency and quality in producing a product are imperative for survival in the competitive manufacturing industry. Sheet metal forming is a widely used and costly manufacturing process, to which these considerations apply. This work will be done to study the finite element (elastic-plastic) analysis of sheet metal crimp forming process using the finite element software. Ansys simulation is carried out to gain accurate and critical understanding of crimp forming process. Simulation of elastoplastic behavior of aluminum sheet is carried out with non-linear condition to investigate sheet metal crimping process. Maximum stress regions are identified. This can be improved by suitable curvature radius which is possible once FEM process is understood. In the present work contact elements are generated between crimp and crimp nut and the sliding dies for forming process. The contact pressure, vonmises stress and load requirements are captured for different angle of crimp sheets. The results shows drop in crimp load requirements with crimp metal inclination. Also a uniformity of contact is observed between crimp nut and crimp metal which is desirable feature for leak proof joints. Also iterations are carried out to find 3 layer crimp formation which is the best formation method for leak proof joints by adjusting the crimp metal and crimp nut lengths.

**Keywords**—Sheet metal forming, Crimping, FEM, Aluminum, Analysis.

### I. INTRODUCTION

**DEFINATION OF CRIMPING:** Crimping is an assembly method to attach a metal fitting to a sheet metal structure. This method mechanically locks the fitting and the sheet metal together by means of a crimp die.

Welding and brazing were some of the methods used in the past for this purpose [10]. However, the joints produced by these methods were never mechanically consistent and they all required the costly pre and post cleaning operations. Thus, the industry kept searching new methods and finally a crimping process was developed for this purpose. This process is a forming process. It rolls the edge of the machined fitting over the shell flange and locks them together. It requires a machined fitting with a flange, shell with a flange and a crimp die [2]. Components of crimping process shown in figure 1.

### II. FINITE ELEMENT METHOD

The FEM is originated in the year of structural mechanics and has been extended to other areas of solid mechanics and later to other field. In fact FEM has been recognized as a powerful tool for engineering problems therefore the generic finite element module is used for this study. Ancys mixed approach is used to build the geometry, Boolean operations are used to build the curved geometries. A4 noded element (plain182) is used to mesh the structure. Target 169 and contact 174 elements are automatically built the pairs for contact estimation. The top die is given a displacement to close the gap to simulate the formation of crimp processes solve the problem in require domain with different iteration.

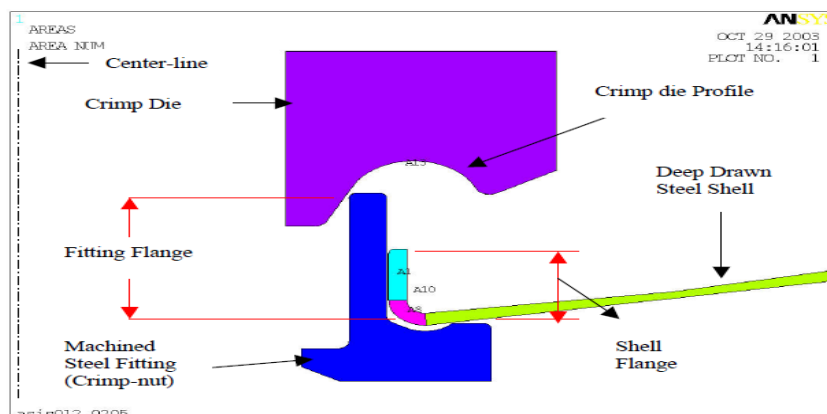


Fig. 1 The components of crimp joint

#### 2.1 Stress strain properties of aluminum

The sheet metal material is aluminum. The stress strain properties are shown below.

STRESS	STRAIN
240	0.0034
280	0.1
300	0.2
320	0.4
321	0.5
325	0.6
330	0.8

Table1. Aluminum stress-strain properties

2.2 Geometry

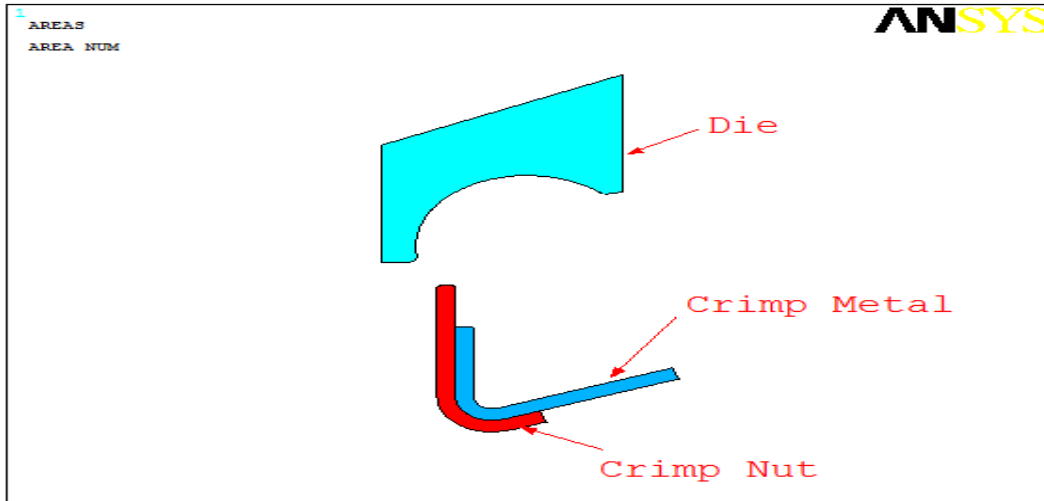


Fig. 2 Geometrical view of the problem

III. RESULTS AND DISCUSSION

The crimp formation is carried out in number of iterations. The formation of crimp metal along with crimp nut stresses are represented as shown in the following figures. The total crimp process is represented in the figures

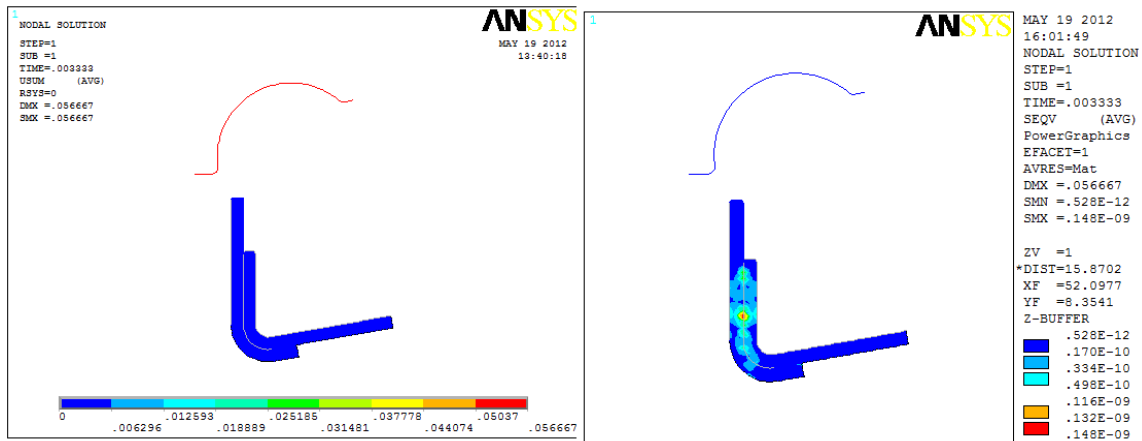


Fig. 3 Iteration 1 ( Movement of movable die)

Almost zero stresses can be observed in the problem as there is no contact between the members. The total displacement of 18mm is given in 70 steps. So the figure shows first incremental displacement of 0.056mm applied on the top die. But no stresses can be observed as the member is free to move. Bottom crimp die and sheet metal are not subjected to any stresses as there is no load transfer due to non contacting regions.

3.1 Problems with different angles for sheet metal :

Analysis with 15° inclination of sheet

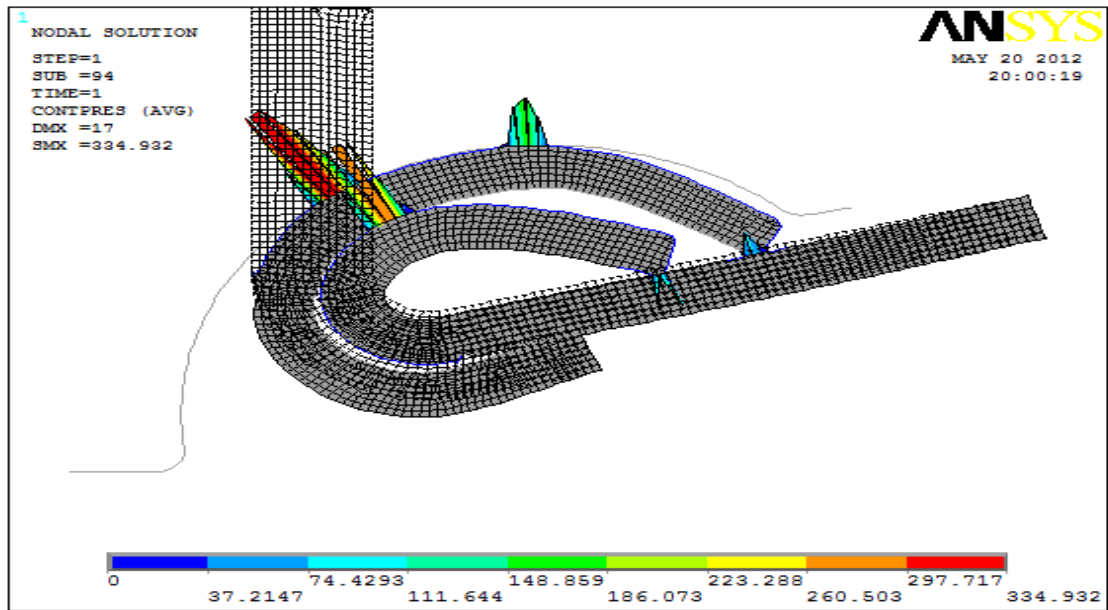


Fig.4 Contact pressure distribution(Uneven distribution)

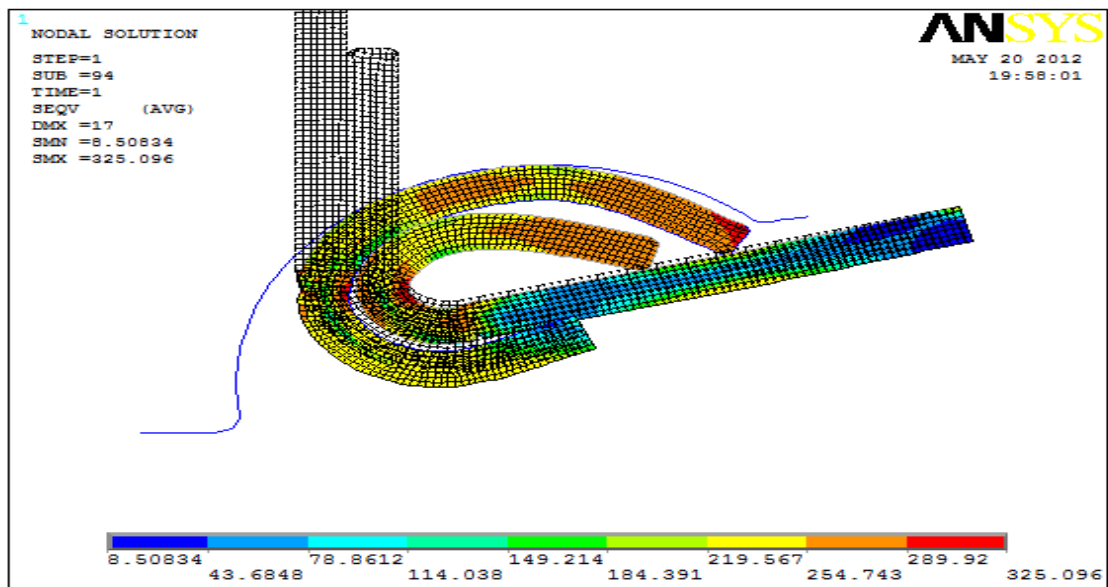


Fig.5 Vonmises Stress distribution

Analysis with 25<sup>0</sup> inclination of sheet

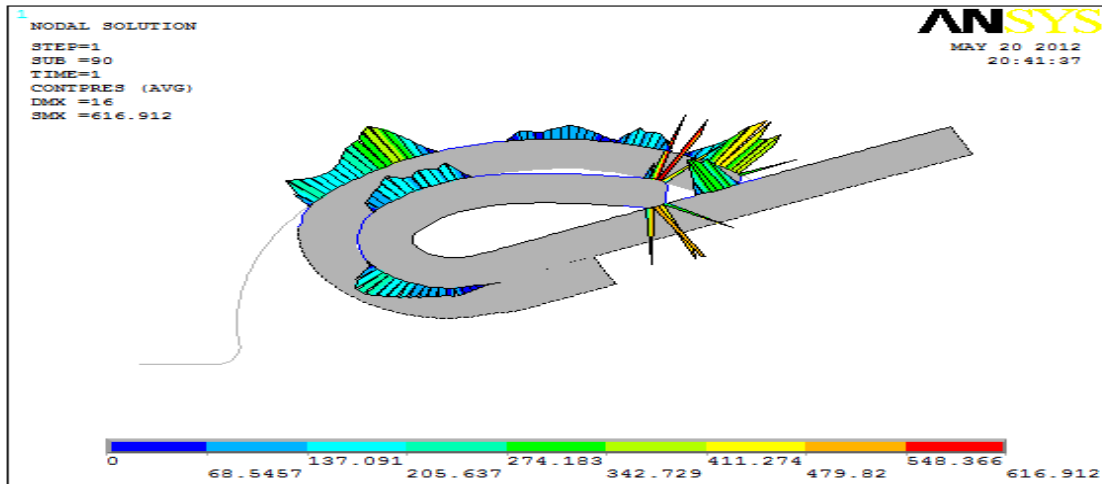


Fig.6 Contact pressure distribution (better than previous case)

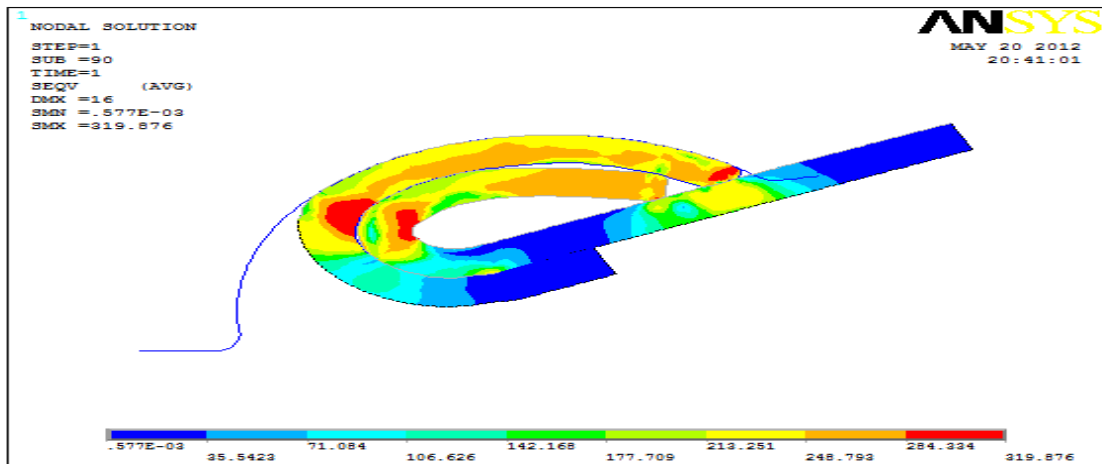


Fig.7 vonmises Stress distribution(Improved contact)

Analysis with 30<sup>0</sup> inclination of sheet

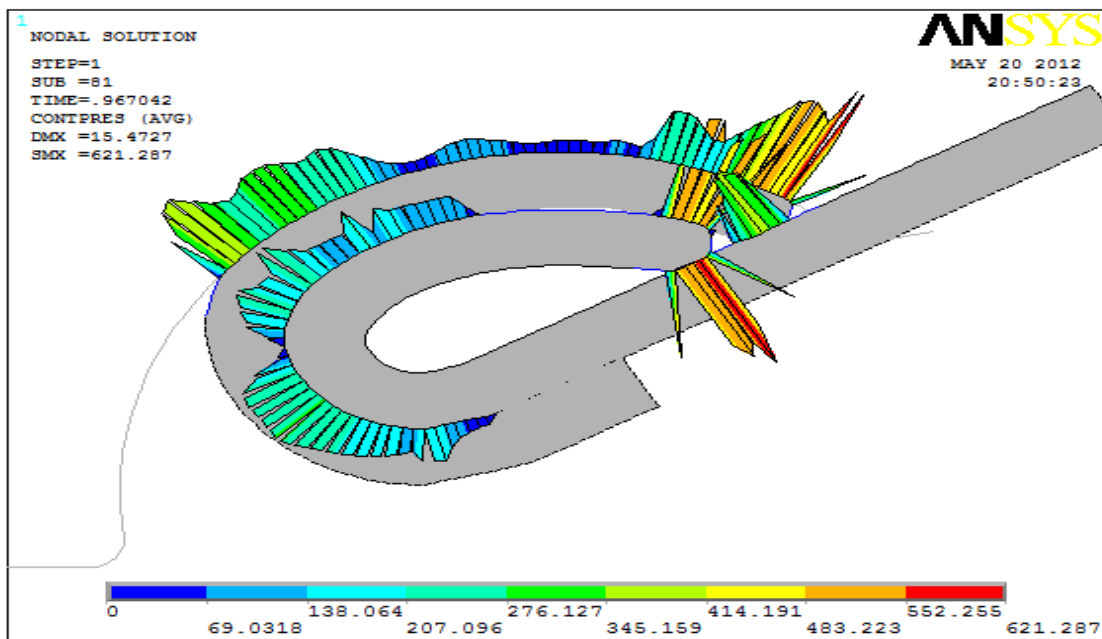


Fig.8 contact pressure distribution(Better then previous case)

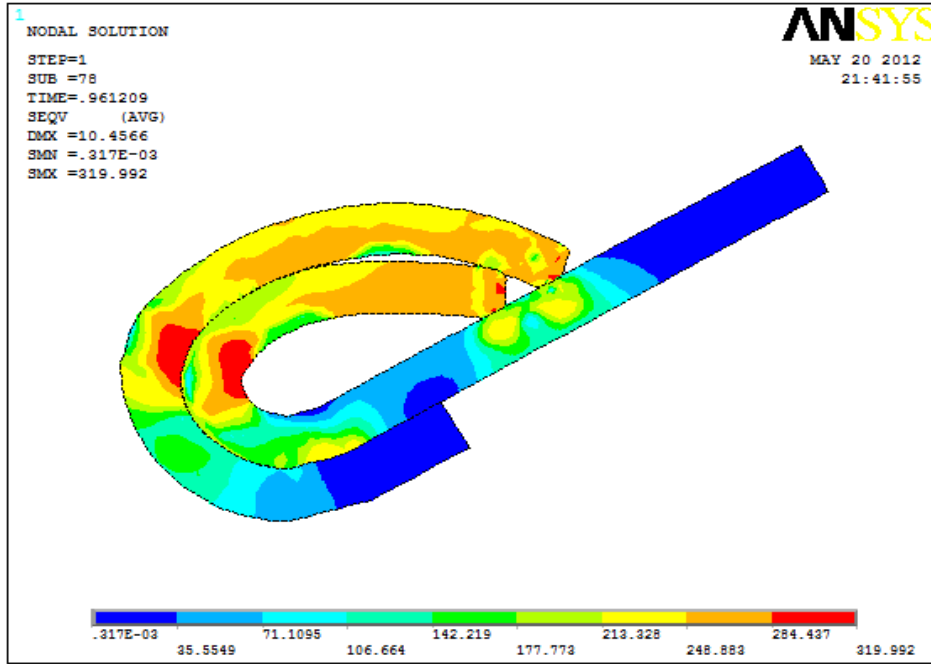


Fig.9 Vonmises stress in the crimp formation

Angle of crimp (degrees)	Load Requirement(N)	Area Requirements( crimp Nut)	Contact Pressure(Mpa)	Vonmises Stress (Mpa)
10	32610.	17.66	284	326
15	30450.	17.16	334	325
20	27628	16.66	659	324
25	25432	16.41	616.9	319
30	22291	16.16	621	321

Table 2. Crimp load requirements and contact pressure

The table2 shows crimp load requirements with the inclination of the crimp metal. A constant reduction of crimp load can be observed. Also metal requirement also reduce with crimp angle. So both are desirable for economic working of crimp process.

**3.2. Three layer crimp formation :**

By increasing the crimp metals length, 3 layer formation can be obtained which is more important for leak proof joints. Literature also shows importance of 3 layer crimp formation requirements for total leak proof arrangement. The analysis is carried out by altering the crimp metal and crimp nut lengths to obtained 3 layer crimp formation.

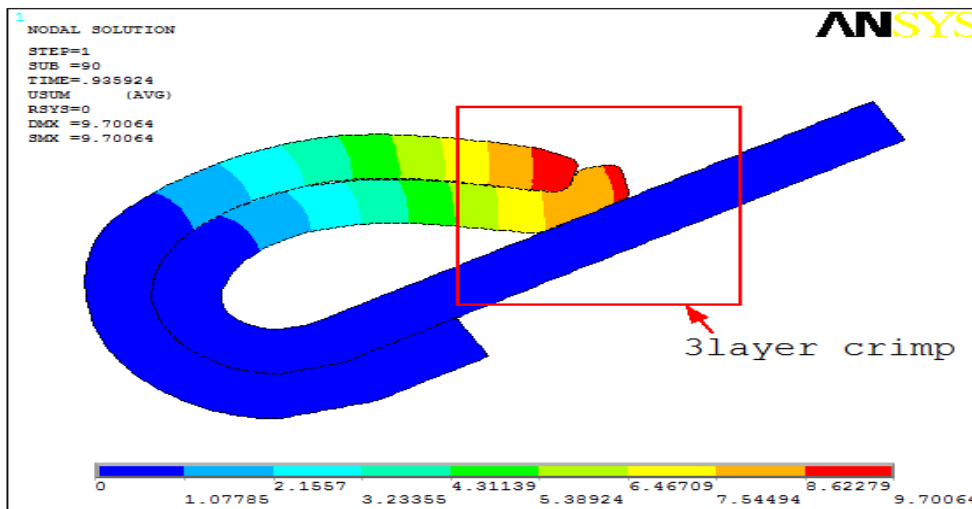


Fig. 10 Deformation plot of 3layer crimp formation

The figure 10 shows 3 layer crimp formation with the finite element simulation. Almost uniform contact can be observed between the crimp nut and crimp metal which is desirable feature for leak proof joints.

### 3.3 Discussion :

The crimp formation which is advantageous compared to welded and riveted joints is simulated through finite element simulation. The analysis is carried out with different inclination for crimp metal. Initial  $10^0$  inclination shows more open or non contact regions between crimp nut and crimp sheet. This indicates possible stress based corrosion in the joints and nonuniform distribution of loads which is not a desirable feature for leak proof joints. Later analysis is carried out to improve the problem by increasing the inclination. The results shows better contact and load distribution by inclination of the sheet metal. The results better contact between the members along with reduction in crimp load. Also crimp metal reduction can be observed. Both reduction of load and area requirements are desirable features for better crimp products. The reduction in load requirements helps in reduced power requirements. The reduction in metal area requirements helps in lesser manufacturing costs. Also by adjusting the lengths of sheet metal and crimp nut 3layer leak proof joints can be formed.

## IV. CONCLUSION & FURTHER SCOPE

### 4.1 Conclusion:

The initial movable rigid die, crimp nut and crimp sheets are created using Ansys mixed approach. The geometry is meshed with 4 noded plane182 elements. The nonlinear material properties are applied using stress strain data. The contact elements are created between the movable die , crimp nut and the crimp metal . The displacement value of 18 mm is given for the top movable die. The results are presented for the analysis The results shows simulation or bending of crimp and crimp nut with the movement of die. No stress raise can be observed until contact is established between the members. Once the movable die touches the crimp nut, stress raise can be observed. Stress values and critical stress regions can be estimated from the simulation. The simulation helps in proper design of die to reduce the stress effect on the crimp metal for smooth bending to the required shape. The results shows stress raise at the curvature regions which are the potential sources for residual stress formation and higher strain rate which is also not advisable for proper functioning of the material. Using the simulation methodology prior estimation can be done for any void or gap or debur formation on the crimp metal. It is similar to the CNC simulation before the actual product machining. So in the present work a suitable methodology is applied to find finite element simulation for the sheet metal formation. The effect of crimp metal angle plays important role in forming good contact between crimp nut and crimp to prevent any leakage in the members. Also increases the strength of the joint by forming uniform joint. The loads and the material required for crimping process also reduces by the inclination of crimp sheet. Also by adjusting the lengths of crimp nut and crimp metal 3 layer crimps can be formed which are the most desirable features for leak proof joints. So Finite element simulation helps in finding suitable material requirements, crimp loads for leak proof joints. Also it helps to find separation regions and crimp plastic strains to estimate possible weak regions which can be improved after identification.

### 4.2 Further scope:

- Ansys-Ls Dyna solvers can be used to improve further the efficiency of the system by sudden time variations .
- Residual stress estimations can be carried out
- Crimp metal thickness requirements can be carried out for the leakage and strength requirements.
- Possible thermal effects can be studied
- Optimisation of dies shape and load requirements. can be carried out using the computer simulation.

## REFERENCES

- [1]. J. H. Whitley, "The mechanics of pressure connections", presented at The EDN Regional Engineers Meeting, New York, 1964.
- [2]. R. S. Mroczkowski and R. J. Geckle, "Concerning "cold welding" in crimped connections", in Proc. 41st IEEE Holm Conf. on Elec. Contacts, Montreal, Canada, 1995, pp. 154-164.
- [3]. S. Kugener, "Simulation of the crimping process by implicit and explicit finite element methods", in AMP J. Tech., vol. 4 June, 1995.
- [4]. T. Morita, K. Ohuchi, and M. Kaji, "Dynamic finite element analysis simulation of the terminal crimping process", in Proc. 42nd IEEE Holm Conf. on Elec. Contacts, Chicago, 1996, pp. 151-155.
- [5]. G. Villeneuve, D. Kulkarni, P. Bastnagel, and D. Berry, "Dynamic finite element analysis simulation of the terminal crimping process", in Proc.42nd IEEE Holm Conf. on Elec. Contacts, Chicago, 1996, pp. 156-172.
- [6]. R. S. Mroczkowski, R. J. Geckle, and Y. Ling, "A closer look at the principles of crimped connections", in Proc. 29th Annu. Conn. And Interconn. Symp., Boston, 1996, pp. 439-448.
- [7]. S. Ogihara, K. Takata, and Y. Hattori, "Mechanical analysis of the crimping connection", in Proc. 52nd IEEE Holm Conf. on Elec. Contacts, Quebec, Canada, 2006, pp. 89-94.
- [8]. Caner Demirdogen, Hakan Oka, Chad Thomas, Tarik Ogut, "Sheet Metal Forming/Crimping Simulation in ANSYS"
- [9]. Manas Shirgaokar ,Hyunjoong Cho,Gracious Ngaile , Taylan Altan, Jang-Horng Yu, John Balconi , Richard Rentfrowb, W.J. Worrell."Optimization of mechanical crimping to assemble tubular components" Journal of Materials Processing Technology 146 (2004)