Journal of Manufacturing Engineering, December, 2012, Vol. 7, Issue. 4, pp 196-201

SPLIT SLEEVE COLD EXPANSION OF BOLT-HOLE FOR IMPROVEMENT IN MODIFICATION OF RAIL JOINT

***Sagar J Aswar[1]**

[1]Department of Mechanical Engineering, School of Engineering & Research Technology, Siddhivinayak Technical Campus, Khamgaon, Maharashtra-444203, India

ABSTRACT

This paper focuses on the Mandrellizing i.e. the cold expansion process of the rail bolt-hole joint which induces compressive residual stress around the holes, thereby enhancing the service life of it. Rail joint is the critical section where induced fatigue stresses are maximum due to the presence of bolt holes where the cross-sectional area is minimum. These holes may cause a major source of fatigue cracking when high shear loads are transferred through the joint. This makes the joint weak and ultimately the critical site for failure. Therefore it is imperative to pay attention towards improvement of fatigue life of rail joint. Residual stress is having a significant effect on fatigue life of the structural engineering components. Mandrellizing expands the hole diameter by means of the radial interference pressure to allow radial plastic flow of material and some elastic recovery after the removal of mandrel.

Keywords: *Fatigue, Residual Stresses and Split-Sleeve Process.*

1. Introduction

With the need for higher strength to weight ratio of engineering components, fatigue has become a very important phenomenon especially in automobiles, aircrafts, gas turbines which are subject to repeated loading and vibration. Considerable interest in the influence of residual stresses on fatigue behavior of components exists in the industry

Cold expansion of Rail bolt-holes is one of the methods to increase the fatigue life of assemblies (Rail Joint), Rail bolt- holes may cause a major source of fatigue cracking when high shear loads are transferred through these joints. Cold expansion introduces compressive residual stresses around the hole, which delay or suppress the crack initiation or reduce the crack propagation rate. An attempt is made in this work to simulate a continuous sleeve split mandrel and pilot cold expansion (CsSmPCx) process to introduce a uniform compressive residual stresses around the Rail bolt-hole [1]. This newly proposed method is more reliable and gives increased service life enhancement compared with the presently used Mandrellizing methods, without any weight and risk penalty.

The Split Sleeve Cold Expansion technique was developed by the Boeing Company and marketed by Fatigue Technology Inc. It has been widely accepted as a standard practice in the United States fig 1.[2].

The process is accomplished by using an oversized solid tapered mandrel and a lubricated split sleeve. The nose cap assembly restrains the sleeve in the hole while the mandrel is pulled through the hole. The purpose of the sleeve is to prevent the hole from damage while the tapered mandrel expands radially and cause the material surrounding the hole to yield. The sleeve is discarded after the expansion process. The insertion of the mandrel and removal of the sleeve in the cold expansion process does not require access to the backside of a component, thus easing the repair of existing structures. The process can also be applied to stack-up of multiple materials [3].

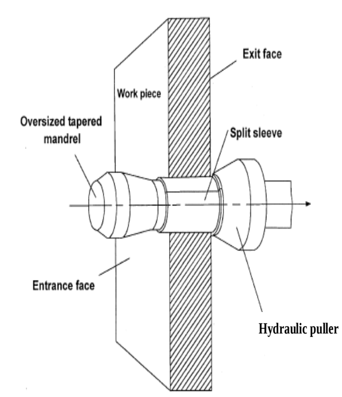


Fig. 1schematic Diagram of the Cold Expansion Process

**Corresponding Author - E- mail: aswarsagar123@gmail.com*

Fig. 2: Photo Elastic Residual Strain Pattern

Fig.2 shows a typical photo-elastic pattern for a cold expanded hole and its corresponding residual stress field. The residual stress field is formed as a result of the plastic yielding of the surrounding material and subsequent elastic spring back of the material lying beyond the plastically deformed hole.

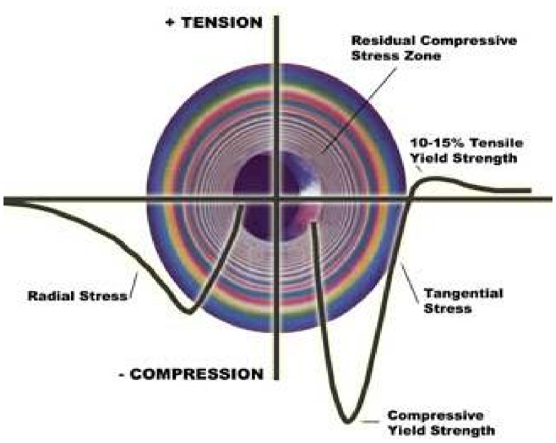


Fig. 3 Typical Residual Radial and Circumferential Stress Distributions

Fig.3 shows the typical distribution of residual radial and circumferential stress surrounding a cold-worked hole. The annular zone of compressive stresses typically extends radially from the edge of the hole and has a peak magnitude approximately equivalent to the material compressive yield strength. A tensile stress zone with a peak stress of between 10 – 15% of the material tensile yield strength lies just beyond the compressive zone. Hence, the hole is effectively shielded from the tensile stresses by the residual compressive zone [4].

2. Study of Rail Joint

Fishplate is used to hold the two rails together both in horizontal and vertical planes with four bolts. The name fishplate is traditionally given to this fitting as its section looks like fish. The steel used for fishplates should have minimum tensile strength with minimum elongation. The fishplates are designed to have roughly the same strength as the rail section. Strength of fishplates is less than rail section. Small gaps are deliberately left between the rails, which are known as “expansion joints” to allow for expansion of the rails in hot weather, the holes through which the fishplate bolts pass are oval to allow for expansion.

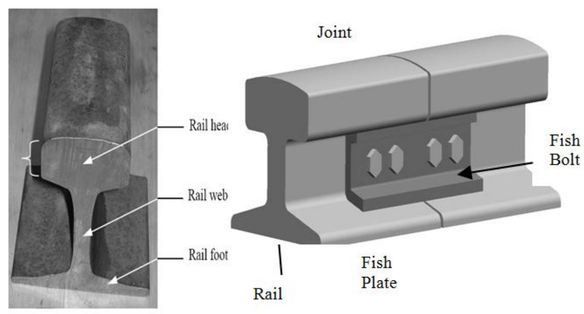


Fig. 4 Schematic Diagram of the Rail Joint

When rail passes from the rail joint longitudinal as well as shear force imposed on it, due to this a number of main areas have been identified where cracking occurs. The French Elastician Boussinesq was the first and Hertz in Germany gave detailed theory to determine the area of contact and the pressure distribution at the surface contact between the rail and wheel. Cracking can be found in the head of all types of tracks, but is predominantly found on highly canted curves where stresses develop due to the extra pressure and wear of the wheel on the rail shown in fig. 5 [5, 6].

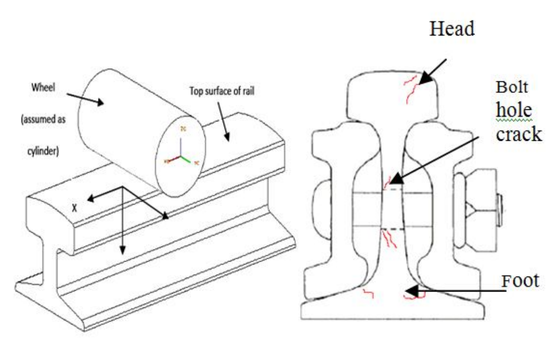


Fig. 5 Schematic Diagram of the Rail Cracking and where it Occurs

2.1 Rail Failures

A defect in rail, which will ultimately lead to the fracture or breakage of rail, is called a RAIL FLAW (Fig.6, 7). Rail integrity refers to control of the risk of the rail failures, which are generally caused by defects in rail metal. Such defects form and glow in railroad rails from the repeated action of wheel load exerted on the rail by passing trains. The growth rate of rail defects is relatively slow at first, but increases as the defects become larger. If the growth is allowed to continue unlocked, the defect will eventually reach a “critical” size at which the next wheel load will cause the defect to extend rapidly, fracturing the rail into two or more pieces [6, 7].

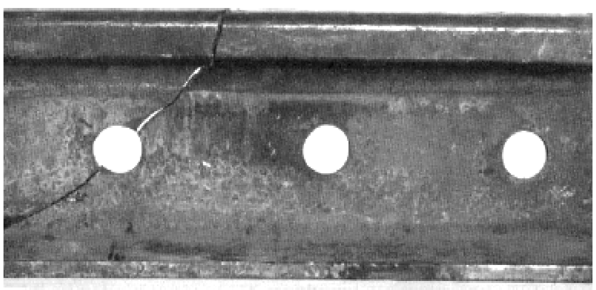


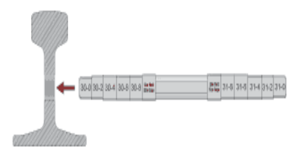
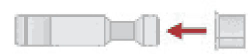
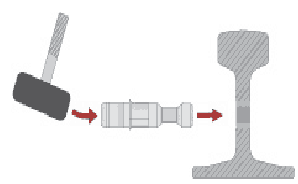
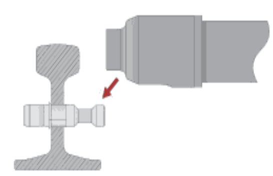
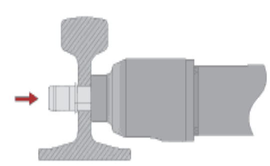
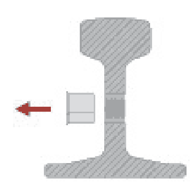
Fig. 6 Bolt-Hole Crack in Rail

Fig. 7 Fracture in Rail due to Bolt-Hole Crack

3. Split Sleeve Cold Expansion of Rail Bolt- Hole

The System is developed for the rail industry and is based on Split Sleeve Cold Expansion System. The flexibility of the system enables it to be easily applied to all main line or branch line track as part of routine maintenance. Rail with small fatigue hole-cracks can be reworked and safely returned to service. Additionally, the system can be used during the manufacture of rails also the cold expansion process increases the life of a bolt hole by producing a zone of residual compressive stresses around the hole. This is achieved by drawing an oversized, tapered mandrel through an internally pre-lubricated split sleeve in the hole. When the mandrel passes through the hole, the combined major diameter of the mandrel and thickness of the sleeve enlarge the hole, (*Table-I*) yielding the material directly around the hole and creating the protective zone of residual stress. This zone protects the hole from the stresses applied to the rail end and significantly decreases the probability of fatigue cracks.

Table 1: Steps in Split Sleeve Cold Expansion Process

S. No	Steps	Process
1	Measure the diameter of the hole using the Mandrel Selection Gage	
2	Slide the internally pre-lubricated split sleeve over the selected mandrel	
3	Insert and seat the mandrel/sleeve assembly into the hole ensuring that the tang end of the mandrel is on the outside of the rail	
4	Place the nose cap of the puller unit down onto the tang end of the mandrel. Make sure the nose cap is flush against the rail	
5	Activate the puller unit to pull the mandrel through the sleeve and cold expand the hole	
6	Remove the used sleeve from the hole and discard	

4. Experimental Finding and Analysis

Graphs of stress distribution in various directions plotted to see exactly what type of stresses are developed around the hole before and after the cold expansion of hole.

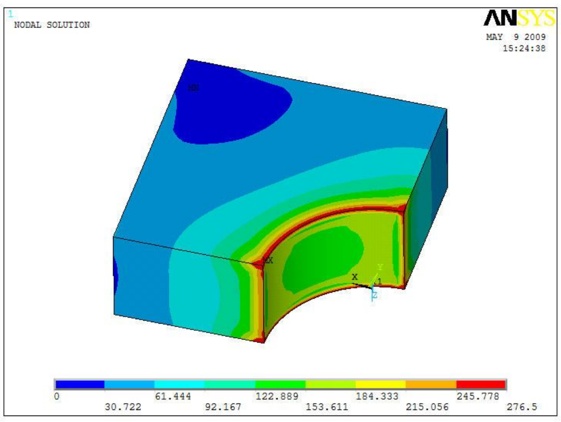


Fig.8: Von Mises Stress Plot [MPa] without Cold Expansion of Hole

Stresses are around the hole before cold expansion as shown in Fig. 8. When applied 1000 N force in Radial direction, other sides of block are fixed. The stress around the hole are found 276.5 MPa.

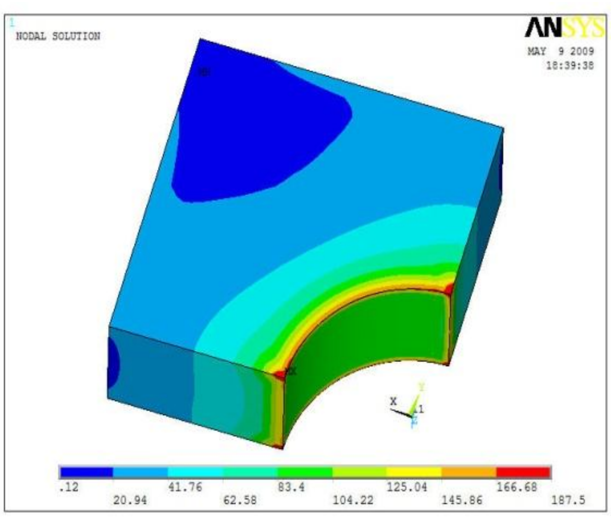


Fig.9: Von Mises Stress plot [Mpa] after Cold Expansion of Hole

Stresses are around the hole after cold expansion as shown in Fig. 9. When applied 1000 N force in Radial direction, other sides of block are fixed. The stresses around the hole are found 187.5 MPa.

From analysis the stresses around the hole are less after the cold expansion. And stress are varies from 276.5 MPa to 187.5 MPa i.e. the stress are reduces by 100 MPa. As the stress are reduces, the tangent modulus of the material increases i.e. material stiffness is increasing after increasing strain hardening rate.

4.1. Circumferential residual stress distribution

When mandrel inserted in the hole, it is expands, but for analysis in ANSYS use 3% displacement in radial direction (0.66mm) [8]. The Von-Mises stress and circumferential residual stress distribution (x-directional stress radial) are shown in Fig10, 11. And when mandrel is removed stress are created in hole shown in Fig. 12, 13.

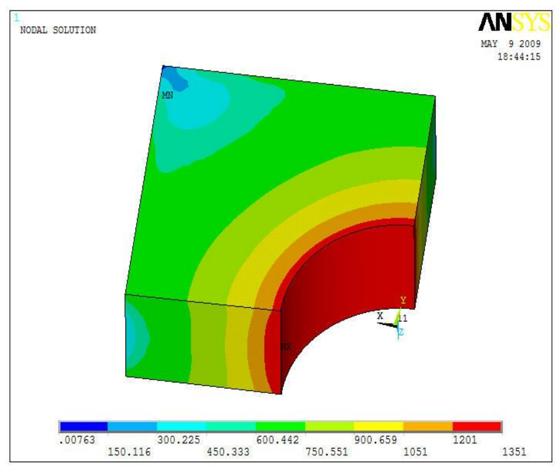


Fig.10: Von-Mises Stress (MPa)

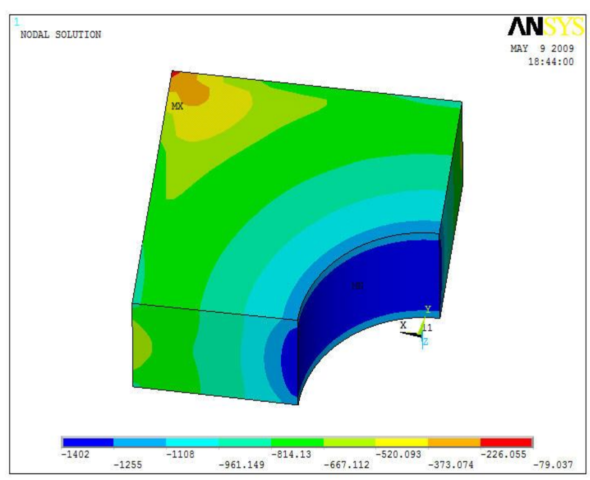


Fig. 11 X-Directional Residual Stress (radial) Stress (MPa)

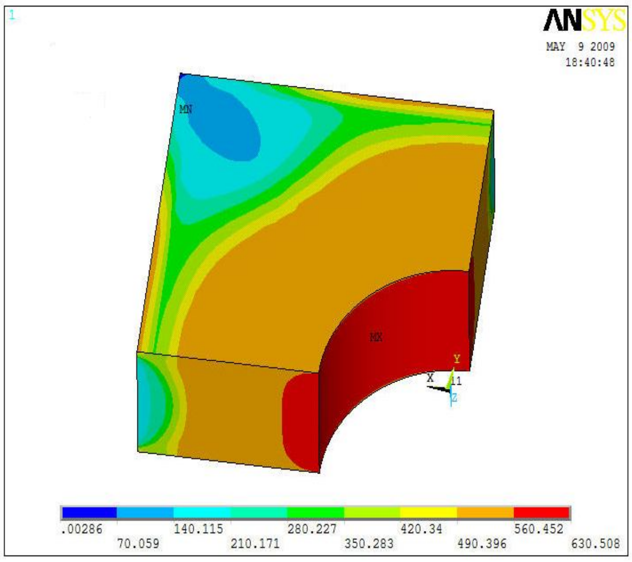


Fig. 12 Von-Mises Stress (MPa)

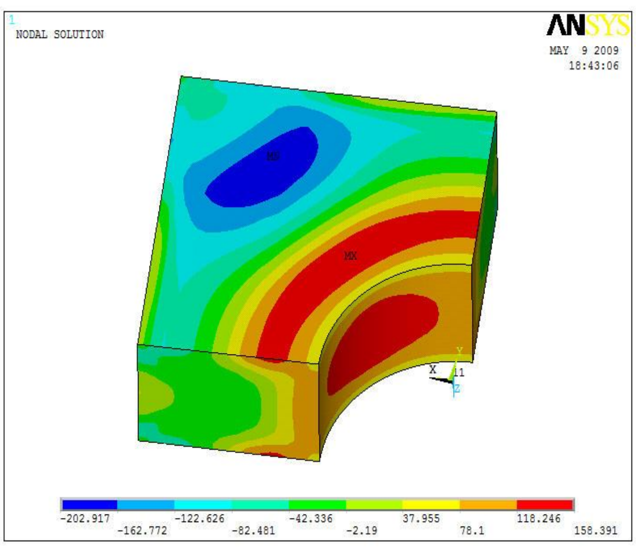


Fig. 13 X-directional Residual Stress (radial) Stress (MPa)

The effect of the stresses on the Rail web bolt-hole is analyzed. The compressive residual stresses are the responsible for the fatigue life enhancement of the Rail web bolt-hole. The residual compressive stresses along the web decreases with increases in the tensile stress and less is the variation of the stresses is because of the ability of the material to withstand at more loads due to increased tangent modulus. Higher the strain hardening rate, higher the ability of the material to withstand higher load.

Cold expansion has long been used as a means of improving the resistance at a hole to failure by fatigue. Effectively, it is achieved when the hole surface is expanded locally beyond the materials yield point. The contraction of the material means there are negative residual stresses remaining at the hole edge as depicted in the FEA as shown in Fig.11. The percentage of expansion increases, the fatigue strength increases & optimum expansion was found. Thus the method of cold hole expansion slows down the rate of crack initiation and propagation or will totally arrest the growth of small cracks under normal operating load conditions.

Thus it produces a large residual compressive zone around the hole. This zone acts as a barrier to crack growth thereby enhancing the service life of the structural components.

5. Conclusion

The effect of the stresses on the Rail web bolt-hole is analyzed. The compressive residual stresses are the responsible for the fatigue life enhancement of the Rail web bolt-hole. Higher the strain hardening rate, higher the ability of the material to withstand higher load.

Cold expansion has long been used as a means of improving the resistance at a hole to failure by fatigue effectively, it is achieved when the hole surface is expanded locally beyond the materials yield point. The contraction of the material means there are negative residual stresses remaining at the hole edge. Cold expansion (Strain hardening or Work hardening) process is the method, which gives out much better and efficient results in less time. This helps to avoid initiation and propagation of crack.

This tries to enhance the fatigue life of rail bolt-hole joint using cold expansion mechanism which helps to make the material harder and stronger. In this way the fatigue life of the rail track has been enhanced and thus facilitates it for long terms operation and maintenance without much cost penalty.

References

1. *Wadegaonkar P, Ravikumar S, Kurhade and Pradhan B (2004), "Finite Element Analysis of Effects of Strain Hardening Rate on Cold Expansion of Fastener Holes.*

2. *Seng H Y and Ying Z G (2008), "Using Hole Cold Working as A Fatigue Improvement Modification" Structural Mechanics Group EDC, Singapore Technologies Aerospace.*

3. *Pavier M J, Ponssard C G C and Smith D J (1998), "Finite Element Analysis of Effects of Strain Hardening Rate on Cold Expansion of Fastener Holes," Journal of Strain Analysis for Engineering Design, Vol. 33, 275-289.*

4. *Reid L F, "Addressing Structural Fatigue Issues on Aging Aircraft", Fatigue Technology Inc.*

5. *Anon (1999), "American Railway Engineering and Maintenance-of-Way Association", AREMA Manual for Rail Engineering, Vol. 1.*

6. *Talamini B, Jeong D Y and Gordon J (2007), "USA Estimation of the Fatigue Life of Railroad Joint Bars", Proceedings of JRCICE2007 ASME/IEEE Joint Rail Conference & Internal Combustion Engine Spring Technical Conference, Pueblo, Colorado.*

7. *Jeong D Y (2004), "Applying the Strain Energy Density Criterion to Fatigue and Fracture Problems in the Transportation Industry", Journal of the Chinese Institute of Engineers, Vol. 27, 865-869.*

8. file:///D:/defects/New%20Folder%20(2)/Crystal%20Defects/Crystal%20Defects%20%20Linear%20Defects%20(Dislocations).htm

9. *Johnson K J and Clark D A (2002), "Three-Dimensional Finite Element Analysis of the Cold Expansion of Fastener Holes in Two Aluminum Alloys", Journal of Engineering Materials and Technology, Vol. 124, 140–145.*

