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Analysis and Experimental Investigation of Rail Joint to Improve Fatigue Life Using Cold Expansion Process

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Abstract: *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 by analysis of residual stress. Residual stress is having a significant effect on fatigue life of the structural engineering components. The process introduces a region of compressive residual stresses around the hole, which attenuates fatigue crack growth rates by reducing the effective stress. 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. 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.*
This paper focuses on the evaluation of methods to overcome bolt hole fatigue failure. It describes Mandrellizing technique i.e. the cold expansion process of the rail bolt-hole joint which induces compressive residual stress around the holes, thereby eliminate the rail end bolt hole cracking problem and enhancing the service life of rail joint.

Keywords: *Cold expansion, FEA, Fatigue, Rail joint, Residual stress,*

I. INTRODUCTION

The problem of rail bolt hole cracking is not unique to any specific railroad, region or country but is recognized as a world problem. Railroad tracks are continually subjected to high loads generated by the passage of rolling stock. With the need for higher strength to weight ratio of engineering components, fatigue has become a very important phenomenon especially in automobiles, aircrafts which are subject to repeated loading and vibration. Flexing and displacement of rails at bolted joints combine to induce high cyclic tensile and shear loads in the joint bar, or fish plate, which are transferred to the attaching bolt holes. 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 creates a residual stress field, with a compressive hoop stress around the hole. The technique involves placing a longitudinally split-sleeve within the hole to be expanded and then drawing an oversized tapered mandrel through the assembly[1]. An attempt is made in this work to simulate a continuous sleeve split mandrel and pilot cold expansion process to introduce a uniform compressive residual stresses around the Rail bolt-hole. This newly proposed method is more reliable and gives increased service life improvement without any weight and risk penalty.

II. SPLIT SLEEVE

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[2].

Split Sleeve Cold Expansion is used on every commercial and military aircraft in the world because it improves the fatigue life of the structure and provides long-term operation and maintenance cost savings. 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.

Fig.1 shows a typical photo of 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.
The typical distribution of residual radial and circumferential stress surrounding a cold-worked hole is shown in Fig.2. 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[2]. 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.

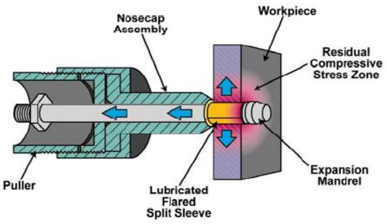


Fig.1: Cold Expansion Process

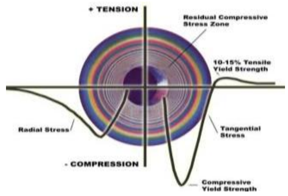


Fig.2: Stress Distributions

III. FISHPLATE USE FOR RAIL JOINT

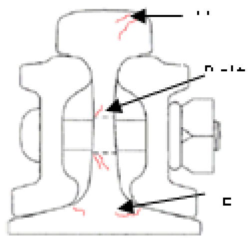
Fishplate is used to hold the two rails together both in horizontal and vertical planes with four bolts. The name fishplate is traditionally given to this fitting as its section looks like fish[4]. The steel used for fishplates should have minimum tensile strength with minimum elongation. The fishplates 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.

IV. TYPE AND POSITION OF RAIL CRACK

A number of main areas have been identified where cracks occur

Rail Heads 2. Bolt Holes

3. Foot of the Rail 4. Termite Weld



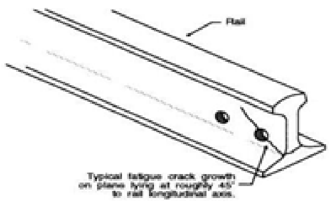


Fig. 4: Locations of the rail cracking Fig. 5: Bolt-hole crack in Rail

A defect in rail, which will ultimately lead to the fracture or breakage of rail, is called a RAIL FLAW. 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.

V. EXPERIMENTAL PROCEDURE

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, 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

The procedure followed for the expansion of the specimen hole using mandrellizing process is outlined below. The specimen is placed on Universal Testing Machine. The one side of mandrel is fixed in Universal

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Testing Machine and other side of mandrel and split sleeve was place in the hole and the mandrel was pulled through the hole at a speed of 0.2 mm/sec using a hydraulic load. The process continued until the mandrel passed completely through the hole. The split sleeve and mandrel is removed from the sleeve. It was still necessary to examine the effect of mandrellizing, on the resulting residual stress field. After Mandrellizing process is completed on the second specimen having same dimension and hole at center of specimen. Due to Mandrellizing process the expansion of the hole is about 3%.

Fig. 6: Experimental Process

VI. RESULTS

The experimental test and analysis has been carried out on a rail bolt hole & result are plotted for the variation of stresses with & without cold expansion of rail bolt hole.

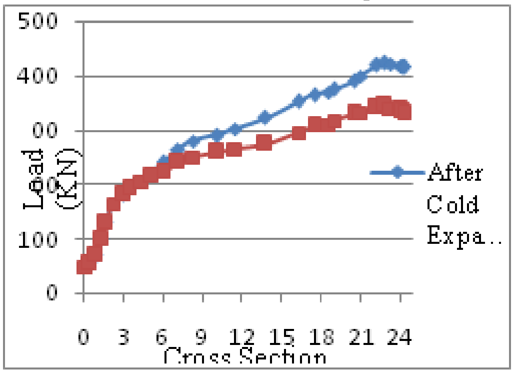


Fig.7 Experimental result Load Vs Cross Section Travel

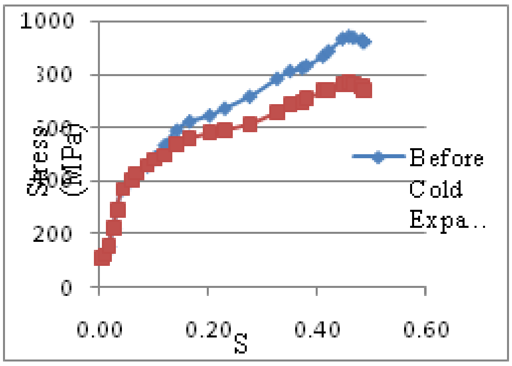
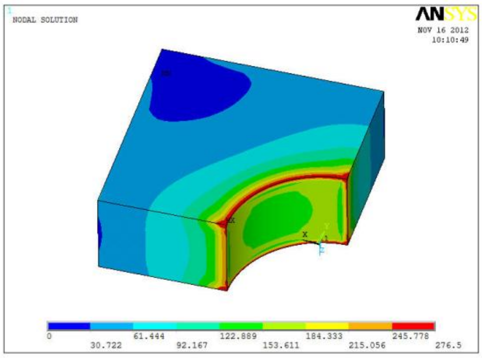


Fig.8 Experimental result Stress Vs Strain

The load carrying capacity is maximum in after cold expansion process than the before cold expansion process during experiment is shown in the fig. 7. The toughness of specimen after cold expansion is less than the before cold expansion. Strain energy stored in the specimen after cold expansion is less and strain energy is more for the specimen before cold expansion as shown in fig 8.



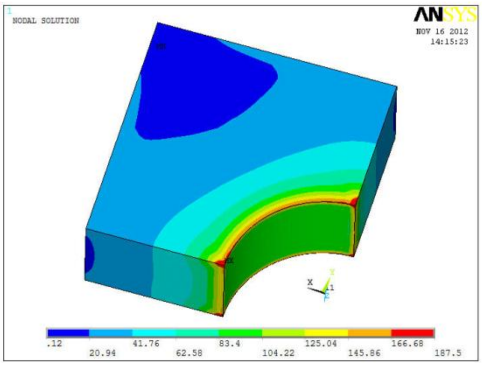


Fig.9: Von Mises Stress without Cold Expansion of Hole Fig.10: Von Mises Stress (MPa) after Cold **Expansion of Hole**

From analysis, 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.

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

VII. CONCLUSION

The effect of the stresses on the Rail web bolt-hole is analyzed. The problem of rail bolt hole cracking has been overcome by introduction of compressive residual stresses around the hole.

Cold expansion is the cost effective method 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 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 improve the fatigue life of rail bolt-hole joint using cold expansion mechanism which helps to make the material harder and stronger. This result in better fatigue life of the rail track, safer and more economical rail operations, reduced routine or special joint maintenance cost and extended joint inspection intervals.

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