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Computer Simulation and Experiment Research on Security of Skew Bridge Structure

Wenrui Wang
School of Mechanical Engineering, University of Science and Technology Beijing,
100083, Beijing, China

Abstract: Skew bridge structure is an important part of blast furnace equipment, whose reliability. In this study, through the investigation, detection and calculation, analysis and performance testing of the skew bridge the safety was assessed which can deal with the measures put forward for the skew bridge security issues provided a basis. The finite element model was established to simulate the modal frequency, static and dynamic mechanic response that is the same trend about the skew thickness changing. At last, the stress test result is nearly to the simulation result which can validate the simulation modal correction. The study methods and result in the study can be extended to use in large iron or steel structures which is important to the bridge safety issues in theory and engineering.

Key words: Skew bridge, modal frequency, safety assement, stress test, finite element

INTRODUCTION

Skew bridge type feeding machine is important auxiliary equipment in blast furnace production which mainly consists of skew bridge, skip car, storage bin and traction mechanism and so on. The blast furnace skew bridge consists of 4 girders (Fig. 1), each girder adopt the welded H-beam section structure; horizontal truss and vertical truss interconnect and make up the two spans between the girders, there is a railway on each span and the skip car run on it. In this study, through the investigation, detection and calculation, analysis and performance testing of the skew bridge dynamic characteristics, its safety was assessed which can deal with the measures put forward for the skew bridge security issues provided a basis (Donoho,1995). The study methods and result in the study can be extended to use in large iron or steel structures security research which is important to the bridge safety issues in theory and engineering.

Fig. 1: Appearance of blast furnace skew bridge

SKEW BRIDGE STRUCTURE SAFETY MECHANICAL SIMULATION

The skew bridge is a complex truss beam structure, composed of all kinds of H steel beam, steel plate welding. In the finite element simulation, the main consideration to solve modeling using shell element (Liu, 2009). Static and dynamic characteristics simulation model of the skew bridge were established which can get the static and dynamic response in the condition of experiment load and full load before the structure corrosion and thinning taken into consideration, the same work has been done about the response after corrosion and thinning. On the basis of the test spots and butt joint position, computation model chose as Fig. 2 shows. The experiment load calculation result and field test result are compared and the correctness of the model is proved (Ma, 2003).

Skew bridge statics simulation: In the statics simulation model computation, two spans model is adopted to analog the structure of skew bridge and we get the basic transformation of the skew bridge at self-weight, because of the support from middle inclined pillar, the transformation curve along the vertical of the main girder shows a rule of "trough-crest-trough-crest-trough" and the transformations of middle and bottom web plate are basically same.

Skew bridge Von Mises stress due to its own weight are shown in Fig. 3 which show the skew bridge deformation caused by its own weight Von Mises stress of skew bridge girder caused by the weight is very low, most of the regional stress is less than 6 Mpa. High stress area is mainly concentrated in inclined pillar in the bottom, middle and connection part at the bottom of the small pillar and the main girder support, where Von Mises stress value is not more than 12 Mpa. Through analyzing the static simulation of skew bridge can be obtained, under the full load condition, the material is 16 Mn of structural stress level is not high that is not more than 12 Mpa which means the structure has great static strength safety allowance.

Skew bridge has appeared local thinning, in the process of using, according to the data after thinning of the bridge structure, whose finite element modal is established (Yun, 2006). The result shows deformation and stress distribution of amplitude have almost no changed. The maximum transformation spot is the inclined support of the skew bridge, it is far less than the allowable stress of the material, however, it should be the focus of monitoring in routine repairs.

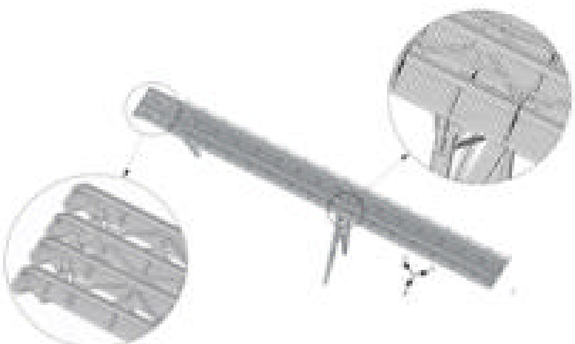

Fig. 2: Computation model choosing

Skew bridge structure modal analysis: The results of the modal of skew bridge structure indicates that the mode of vibration of skew bridge shows as “up and down”, “left and right” and “inside and outside” three modes. The former 10 modal vibration frequency is very low, they are all below 15 Hz. The first modal is the left and right swing of the girder,shown in Fig. 4. The second and third modal is little up and down swing of the girder, the transformation of inclined pillar at the middle of skew bridge is the most obvious. The forth modal is the transformation of middle inclined pillar. Fifth modal is the left and right swing of the girder, the node of vibration modal is around the inclined pillar. Seventh modal is left and right swing of the girder, there is no obvious node and the girder has side torsion to a certain extent. Eighth modal is a left and right swing and a inside and outside torsion at the girder between the inclined pillar and upper small pillar. Ninth modal is a inside and outside torsion transmitted to girder between inclined pillar support and bottom support. The tenth modal is a up and down swing and is stronger than second and third modal, shown in Fig. 5.

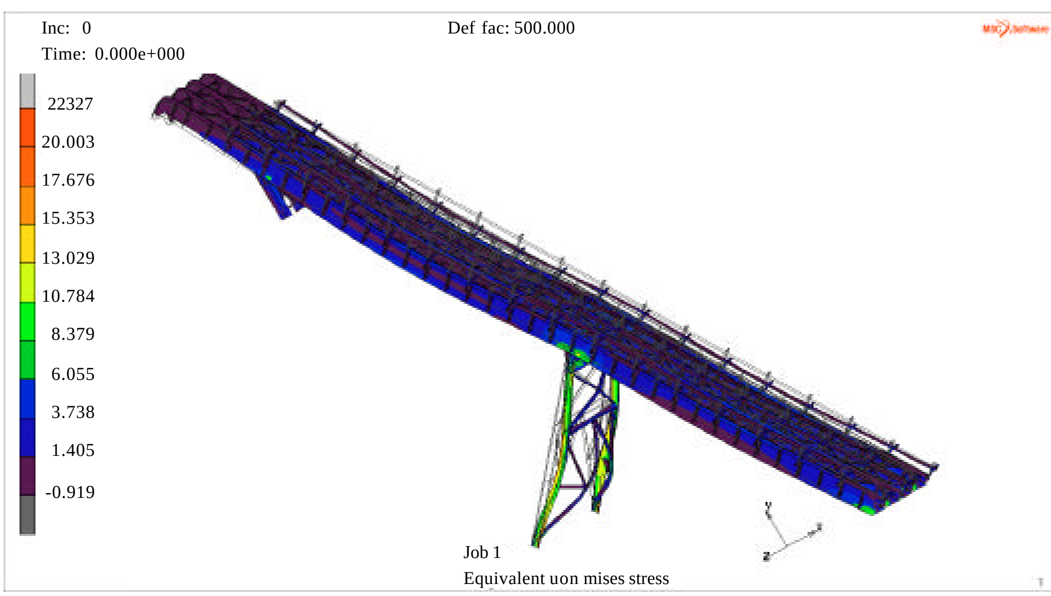

Fig. 3: Self-weight caused static strength analysis after the thickness

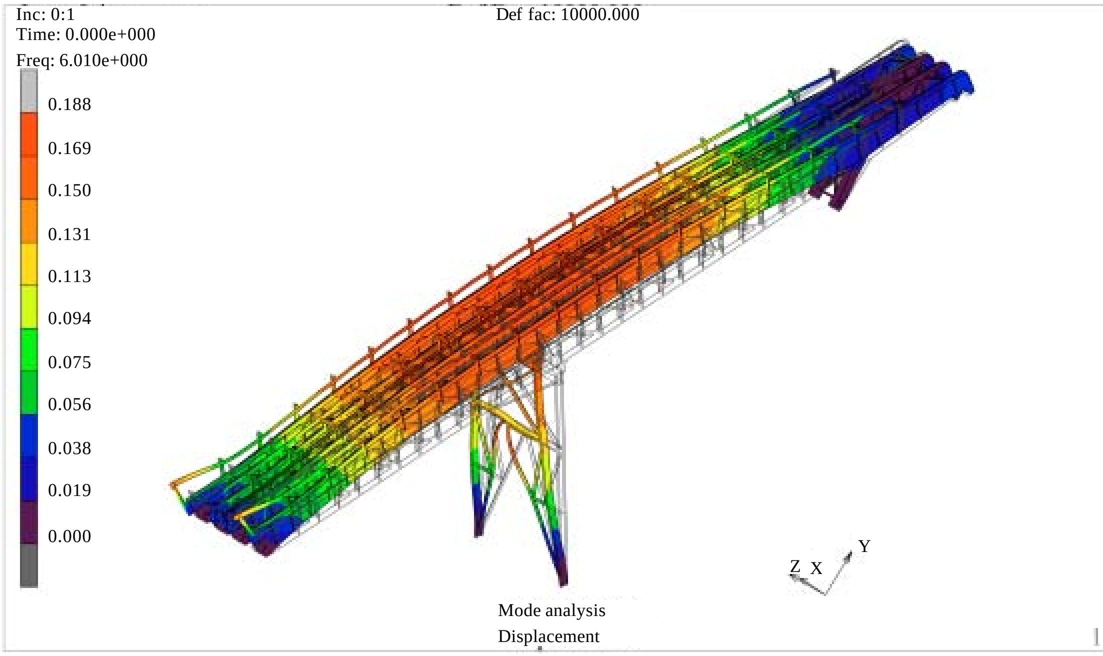

Fig. 4: First modal picture

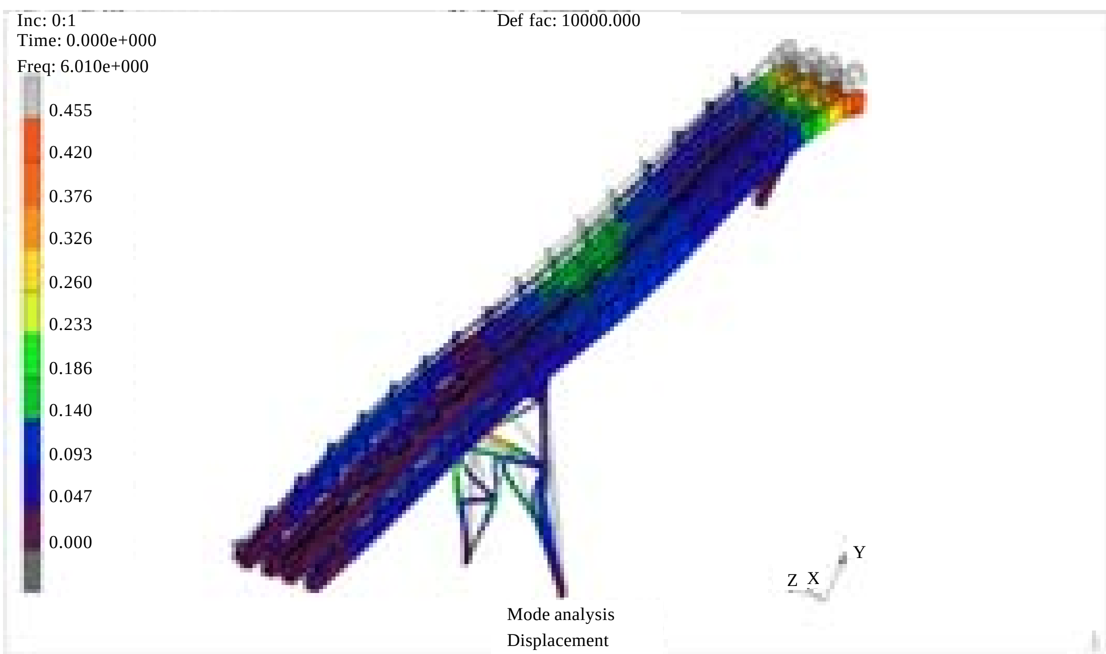

Fig. 5: Tenth modal picture

The 4 mm (within 2 m of the middle inclined support) local thinning of the girder web plate cause a little skewing to the natural frequency of skew bridge, the maximum skewing is not beyond 0.5 Hz, the vibration frequencies of first 10 modals are still below 15 Hz. The whole vibration condition is the same as that before thinning.

Skew bridge dynamic simulation: Dynamics mechanical analysis of the skew bridge is during the skip car running time (Paul and Holloway, 1992). Under the action of skew bridge gravity and full load of double skip cars stress calculation, the dangerous section of skew bridge can be found. Considering skew bridge thinning before and after as shown in Fig. 6, the maximum deformation of inclined bridge is 5.95 mm. When the skip car moves to the bottom and middle part of skew bridge, the fluctuation of its girder flange began to bear the role of the car loading. Though the maximum stress of skew bridge area still near the bottom of the fixed place of main girder, before plate thinning, the maximum stress can be reached 88 Mpa; After thinning, the maximum can be 89 Mpa.

In the working state, the skew bridge girder under the stress of the flange level is relatively high, but the maximum stress is near 50 Mpa fluctuations. The high stress area is associated with the skip car line which always appear near the joint of the skew bridge and supporting parts (Zhao *et al*., 2004).

SKEW BRIDGE STRUCTURE SAFETY DETECTION

Nondestructive flaw detection: In order to accurately assess the current situation of skew bridge, skew bridge structure is tested by nondestructive flaw detection (Wu, 2003). It mainly includes steel member ultrasonic thickness measurement, steel plate intensity field test, ultrasonic flaw detection weld joint surface defect test and magnetic particle interior weld joint defect test.

Steel plate thickness is tested by ultrasonic thickness indicator, thickness of the skew bridge plate right above the is flushing tank decreases by 36% local web plate "pockmark" is seriously corroded.7 most typical weld joints are tested by ultrasonic flaw detector, 3 of them have defect, according to GB11345-1989 (B-II class qualified) standard, they are disqualified.7 weld joints make the magnetic particle flaw detection and no defect is found, according to JB/T4730.4-2005 (I class qualified), they are qualified.

Tensible strength test of the material: To have a further analysis to the property of skew bridge structure material and have a accurate assessment to the reliability of skew bridge, a sample was taken from the skew bridge (Fig. 7) to make into a international standard tension test-piece, then observe the texture and mixture under metallographic microscope to assess the property of the skew bridge material (Zhang *et al*., 2001).

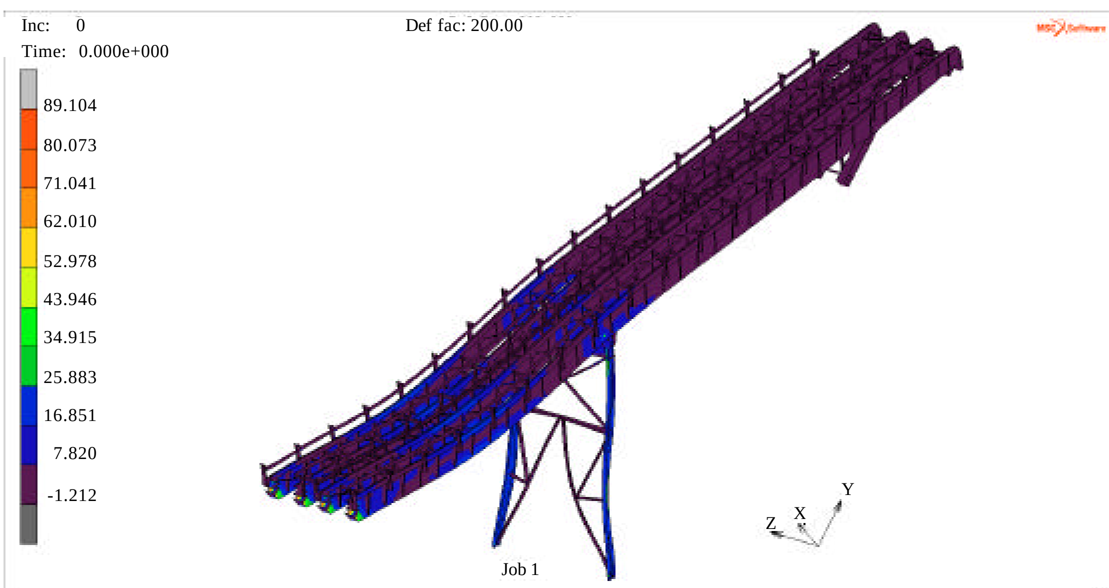

Fig. 6: maximum dynamic stress after the thickness of skew bridge

Fig. 7: Picture of the skew bridge material

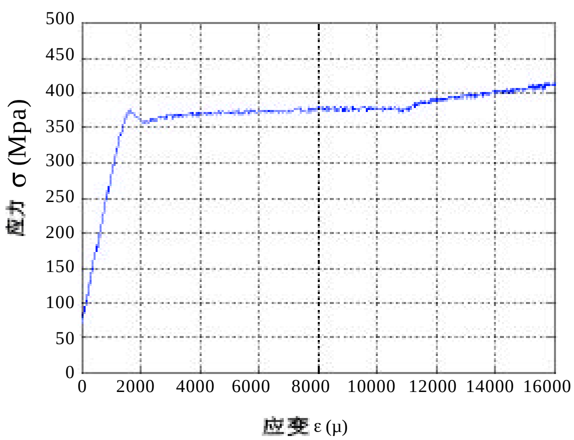

Fig. 8: Tensible test s-e curve

There are 6 groups of test samples.After clamped, give the sample a slow uniform loading. The tensible test curve of the sample shows in Fig. 8. which does not have an obvious yielding procedure, the yield limit data is just over the yield limit the highest index σ_S = 345 Mpa of the bridge material 16 Mn steel (the number calculated from field hardness test is 305.48 Mpa). The max yield strength of 16Mn according to materials engineering menual is above σ_S = 274 Mpa which indicates that the material still satisfies the international standard in spite of long-term exposure. In this report, we use the national standard limit yield of 16 Mn steel as the basis of computation and judgment for easy computation.

Metallographic phase and inclusion test of the skew bridge material: The impurity and inclusion interior the sample are guaranteed by melting and casting, especially melting, any change in the condition of melting and casting will change the constituent. The guarantee of the constituent is more than that, besides melting and teeming, in some cases, the subsequent processes such as casting, forging, machining, welding rib plate and thermal treatment and so on, will sometimes change the surface constituent more or less.

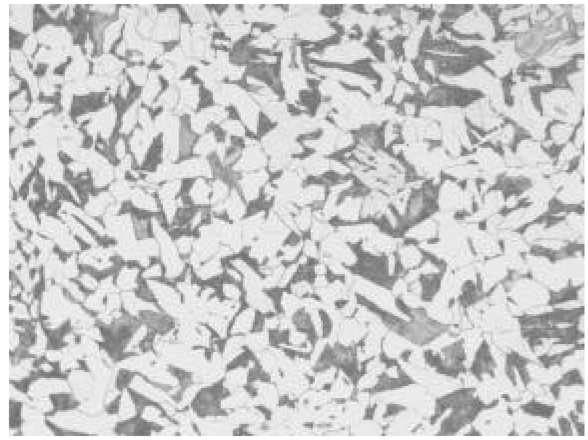

Fig. 9: Analysis of metallographic structure

The test result of skew bridge sample metallographic structure is in Fig. 9. In the picture, the metallographic structure of the sample is magnified 200 times to be observed, respectively. The heating temperature is a little high so there is a little widmanstatten structure; the cooling is not uniform so the crystalline grain is not uniform. The metallographic structure of the sample is mainly polygon ferrite.

The reason of forming polygon ferrite is that the cooling speed is not very high and the intensity of the polygon ferrite is not very high. Besides, the crystalline grain is big, texture is not uniform and exist a lot of big and thick sheets of ferrite which has a big effection to the property of the material.

MECHANICAL PERFORMANCE EXPERIMENT ON SKEW BRIDGE STRUCTURE SAFETY

Vibration testing of skew bridge: In order to ensure the maximum deformation, stress distribution and vibration condition, the most advanced modern telemetering system to make field test is utilized in the skew bridge working condition and provide the measured data with theory study and simulation study.

According to the preliminary calculation results, combined with the actual working condition and the

Fig. 10: Arrangement of the acceleration test transducers

Fig. 12: Wireless strain sensor

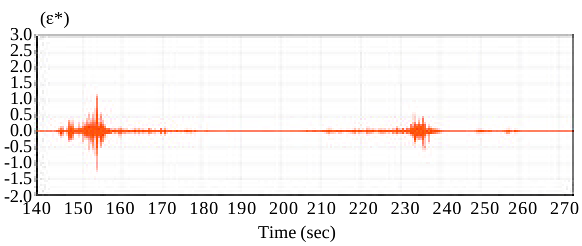

Fig. 11: Maximum vibration amplitude test curve

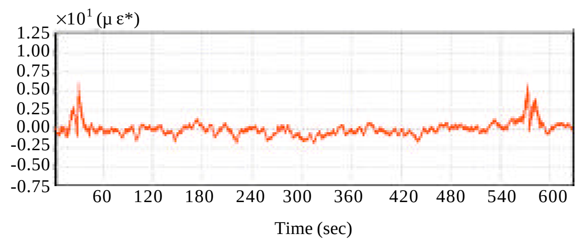

Fig. 13: Stress test curve

feasibility of field operation of the blast furnace skew bridge, these vibration and strain test points are located at bridge.

In the test, the acceleration transducers arranged at test points are triaxial transducers. Triaxial telemetering acceleration transducer is applied in the vibration test, magnet steel helps the transducer stick to the test point. The carrier wave of transmitter is modulated by vibration acceleration signal before spreading in space, using 2.4 G wave band frequency network, after receiving the signal the receiver send it to the computer acquisition system. It is defined that X direction goes uphill the gradient of skew bridge, Z direction goes vertically downhill the gradient of skew bridge, Y and X, Z direction make up a right-handed system. The acceleration transducers are arranged in the test as Fig. 10 shows.

The vibration acceleration of skew bridge at working condition is tested, skew bridge has up and down (Z direction), left and right (Y direction), front and back (X direction) vibration modals. The vibration of Z direction of each test point is the most violent, Y direction ranks second and X direction ranks last, the max vibration amplitudes are beyond 1 g, the maximum vibration amplitude of test is beyond 1.5 g as Fig. 11 shows, it is because that there is no beam at this point of the skew bridge body which leads a rigid impact when skip car passes by, we should install the lost beam timely to diminish the impact effection to the bridge body caused by skip car.

Strain testing of skew bridge: All the strain transducers arranged at the test points are whole bridge strain gauges, using wireless remote sensor, as Fig. 12 shows. Signal from stress-strain sensor is sent to the signal emission device, it is bonded to the point closest to test point. Strain signal is sent to the receiver and receiver send it to the computer after countermodulation, stress-strain signal is gathered, displayed, saved and analyzed by computer acquisition system.

Stress data of skew bridge in working conditions, the results show in Fig. 13, the entire stress-strain level is very low, compared with the allowed intensity of the skew bridge material, the safety allowance is over 10 which is completely enough. But the stress-strain level of test point is a little high, the stress arrives 20 Mpa, this is because that the inclined support and the skew bridge supporting points are badly corroded and there is obvious gaps at the supporting points which results in the big local stress. But this stress number is far smaller than the allowed stress limit of the bridge material 16 Mn steel.

CONCLUSION

The study methods and result in the study can be extended to use in large iron or steel structures which is important to the bridge safety issues in theory and engineering.

On the basis of the conclusions above, considering the basic demand of increasing production and efficiency, decreasing engineering cost, we can make reinforcement to the key parts and anticorrosion to the whole bridge to satisfy the safety standard.

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