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FATIGUE TEST TO THE BLADES AXLE OF ROTARY TILLER

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ABSTRACT

Taking a bledes axle of ratary tiller as a example, this paper discusses influences of four loading essential factors, which are strengthened amplitude, cycle times, loading sequence and loading frequency, on fatigue life. Determination principles of above four factors and monitoring methods of fatigue damage by local strain are dealt with.

Key words: rotary tiller, fatigue, test

That actual field testing check of farm mechinery is rapidly simulated by laboratory program fatigue test can shorten the period of development and improvement of a product. In the time of in-door simulation test, damage monitoring and four loading essential factors, which are strengthened amplitude, cycle times, loading sequence and loading frequeney, have to be dealt with. If these problems are solved successfully, it is possible to accelerate test speed , reduce costs andmanhours, and raise accuracy of test result.However strengthening method, loading pattern and influence of loading frequency on test result have not so far been discussed systematically,damage monitoring is even more a diffcult problem . Authors have studied above problems with the object of blades axle of rotary tiller.

STRENGTHENING AMPLITUDE

Strengthening coefficient K_1 = load amplitude after strengthening / load amplitude before strengthening = SA_2 / SA_1

Strengthening effect is greater and test time is shorter with K_1being bigger.But mechanical performances of material must also be considered in the choice of strengthening coefficient. Thus K_1 can not be too big .At the first , maximal value after load being strengthened should not exceed yield limit, otherwise fatigue test results will transfer into static strength; in addition, must be attention to that oringinal fatigue failure of long cycles ($N_f > N_t$) must not turn into fatigue failure of low cycles ($N_f < N_t$). As $N_f < N_t$,occurrence of fatigue is in the elastic and plastic range , material fatigue resistance is mainly determined by plasticity with action of plastic strain amplitude, As $N_f > N_t$, occurrence of fatigue is in the elastic range,material fatigue resistance is mainly determined by strength . So they are two different forms , should not mix them up.Generallly,N_t is about 10^4.

Example: Torque spetrum of blade axle of Dongfeng-12 rotary tiller is shown in Tab 1, design life is 2240 hours, testing subroutine blocksare 20. Material of axle is Steel 20, with stress at maximal level 79.647 MPa. Stress at maximal level after strengthening S'_1equals 119.56 MPa. Take strengthening coeffient as 1.5 . P-S-N curve data of Steel 20 binding fatigue: smooth sample $\tau_{-1} = 129.36$ MPa > S'_1, even if notched sample will not entre low cycles fatigue range($N_f = 8.34 \times 10^4$when $\sigma = 225.4$ MPa .S'_1equals 206.094 MPa when converted to the pull and press stresses.

LOADING SEQUENCE

In program loading fatigue experiment, there may usually be following four patterns:low-high,high-low,low-high-low and high-low-high.

Authors give out estimation of pipe's torque fatique crack propagation life in Article [2].Crack propagation has been caculated on four loading patterns and random sequence (sequence of each loading is random). Assuming that $a_0 = 2$mm,$a_c = 30.9$mm,the result can be seen in Tab.2.

From Tab.2, fatigue crack propagation life of five loading patterns are not the same. Especially the greater the dimension of program block, the more obvious the difference . Fatigue life oflow-high loading pattern is the longest , low-high-low and random loading are in the second (result of random loading pattern is a little smaller than that of low-high-low pattern), and the loading life of high-low and high-low-high loading pattern are the shortest.

With reduction of dimension of subroutine block (namely number of loading blocks increases) results of five loading pattern become identical .The more the subroutine blocks of experimental loading, the less the influence of loading sequence . But sometimes loading spectrum and loading system do not permit subroutine blocks to be too small (for example, cycle number of the first and second level on loading spectrum is some smaller) , then loading sequence may be of influence to fatigue life . Also real loading history is a ramdom spectrum , there must be some influence of loading seqence when dividing them into low–high–low , low–high , high–low and high–low–high loading spectra. To reflect randomness of loading , authors choose random sequence loading.

From Tab.2,with increase of loading blocks, error caused by random sequence become smaller rapidly. When number of loading blocks gets to 14 , error almost becomes to zero. some internal defects more or less exist in construction , so it is proper to divide subroutine blocks into more than 14 while programming of loading spectrum . When loading block number is 5, deviation is only 0.7816. This proves that the random sequence loading is relatively stable, and also better than other four patterns. When dimension of subroutine block is 1 / 2 and after loading five blocks , least deviation of damage of other four loading patterns is 2.4mm,the largest 9.7mm , because real loading history will be impossible to be any one kind of the four . Thus this will bring some damage error caused by loading sequence in choosing any one of four loading patterns.These deviations will be greater than that of damage cause by differerence of every loading sequence block in random patterns.

CYCLE TIMES

Above analysis has shown that it is much better to run more than 14 subroutines in fatigue test . If only few subroutines are run , error of result in fatigue test will be much great . But now, ordinary step of strengthening loading spectrum is to enlarge every stress amplitude according to strengthening coefficient, and to keep every cycle times of each subroutine unchangeable . Influence of loading sequence on fatigue life has not been considered in the method. Since oringinal life is 10 times more than result after strengthening , strengthening spectrum using this method will make the period of experimental failure to be only a few, or not more than one.At this time, loading sequence will greatly influence experiment result. The authors think that while determining loading spectrum, not only every load of program block should be strengthened according to the strengthening coefficient, but also every cycling times should be divided by accelerating time multiple to get each real cycling times. Only by this way can the number of program blocks be kept unchangeable basically.

LOADING FREQUENCY

In Article[4], authors have got the formula of crack growth rate $(da/dN)_d$ as involving dynamic stress. $(da/dN)_d$ equals to β times of crack growth rate da/dN that is presently calculated accorgding to norminal stress

$$(da/dN)_d = \beta da/dN$$

where β is functions of construction paramrters,crack locations and dynamic parameters, it is defined as dynamic amplification coefficent.

Because most loading frequencies are less than the first step natural frequency or near this natural frequency in in-door simulated test of farm mechinery, authors study mainly influence of loading frequency below the second step natural frequency on fatique life. The numerical imitated result of the reletions between β and $\{p/\omega, \xi\}$ is shown in Fig.1. Here p/ω is loading frequency / natural frequency, and ξ is damp ratio. The follow conclusions is obtained from Fig 1:

(1) As frequency ratio $p/\omega < 0.4$, β near to 1, it means that crack propagation rate is not affected by loading frequency,

(2). As frequency ratio $p/\omega > 1.75$, β tends to a constant value which less than 1. it means that da/dN decrease at high frequency load.

(3). As $0.4 < p/\omega < 1.75$, crack propogation rate is affected by loading frequencey. The maximum value apears near $p/\omega = 1$. The less the damp, the greater the inflnence.

According to above conclusions, effect of test result would be understood if frequence ratio varies in testing, and result would be modified.

Example: Torque frequency of blades axle of rotary tiller is the range less than 26Hz. Loading frequency is 1 Hz since it is limited to dynamic characteristics of loading system which is devoloped by authors. Loading frequency is lower than field frequency. Furthermore, natural frequency of blades axle is higher than field condition since blades are not mounted in blades axle while fatigue test. One decrease, one increase, variation of frequency ratio is greater. So it must be considered whether test life is affected with varying frequency ratio. Results are obtained in calculation of twist vibration according to arrangement of blades on the blades axle: the first nataral frequency equals to 83.87Hz. As mounting blades, otherwise frequency equels to 226.3. Therefore, frequency ratio of field condition is 0.31, frequency ratio of testing axle is 0.0044. They all less than 0.4. Dependence on conclustion (1): crack propagation rate is not affected by loading frequency as frequency ratio < 0.4. Influence of test result variying with frequency ratio may be neglected.

DAMAGE MONITORING

In fatigue test ,it's still necessary to solve testing technical problem about how to monitor the temprory fatigue damage degree. Two methods are provided: one is that crack is diagnosed by rate of nature frequency variation , the another is to monitor local stress–strain of blades axle . The first method has been introduced in Article[3] . The second will be maily introduced in this paper.

Before fatigue test of blades axle , strain gages should be set up at locations of strength weakness , stress concentration and weld defect to monitor local stress–strain of rotor in fatigue test. In test, temprory strain is shown by a digital intrument. After a certain test time (some subroutine blocks), identical uniformamplitude torque is acted by a single computer to measure variations of stress–strain.According to the measuring result, stress variation curve $\tau(t)$ can be got by using least squares.

According to linear damage accumulation theory , considering that stress of real damage part is k_0 times as that of mesured part, and that influence of comprehensive influence coefficient K about dimension, surface procssing quality etc , and average stress. We may assume that local shear stress $\tau(t)$ is constant in a subroutine block . So long the period of subroutine block is rather short, this assumption is permitted. So $\tau(t)$ is the function of time, it can also be looked as function of number of subroutine blocks, written as τ_j, the following formula may be used to estimate fatigue damage[2]

$$\frac{[k_0 K\tau_b / S(\tau_b - \tau_m)]^m}{N_{-1}\tau_{-1}^m} \sum_{j=1}^{k} \sum_{i=1}^{6} n_i(\tau_i S_i)^m = 1 \qquad (1)$$

where S_i--the ith level load amplitude in loading spectrum; S-- applied uniform amplitude while measuring stress; n_i-- acting times of S_i; N_{-1}--cycles corresponding with τ_{-1}; τ_b--static shear strength limit; τ_m--average stress in loading spectrum; k--the subroutine number till damage

The subroutine number of test k may be obtained with solving Formula (1). k means fatigue life.

CONCLUSION

1. Determination of strengthening coefficient shouldensure that maximal stress amplitude will not go into low cycles fatigue range. Strengthening loading spectrum still ensure that there will be more 14 cycling blocks.

2. Random sequence loading is more suited to load characteristics of rotary tiller ,influence on fatigue life is minimum

3. As frequency ratio < 0.4, crack propagation rate is not affected by loading frequency. Otherwise, it is affected by loading frequency.

4.Fatigue life may be monitored and estimated from the variation of local stress–strain.

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