A Modal Analysis of New-type Coupling Discs of Generator Set

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Abstract: This paper has designed a new type of coupling disc structure for the diesel generator set, eliminating the "seams" in the section die. It also has focused on the modal analysis by using limited meta-simulation software, discussed the optimum stiffness structure, and analyzed the related causes of normal operation whereas over-vibration at the course of start or stop. Thus, it provide reference in theory for improving structure and design of coupling disc for diesel generator set

Introduction

Currently, metal-stacked couplings are widely used in diesel generator set at home, due to their compensation of misalignment errors as well as their other advantages of no lubrication in movement, resistance of 300ºC, high radical rigidity, high power mass ration and efficient restrict drift of generator magnetic center.

However, there is difficulty in processing the external round surface of the metal-stacked coupling discs with a diameter of more than 300mm, which are simply know as discs, in that metal-stacked coupling discs are generally heatproof stainless steel plates or spring steel plates, of which the tolerance of the external round size is of high standard with a grade of no less than IT9. Mass manufacturing with digital controlled punch process produces high cost; a good external circular plate with a die also produces high cost for its large size and high cost of manufacture and maintenance as well as its press tonnage. An external circular plate with die section technology, though with a smaller size, convenient process and maintenance, and smaller tonnage, causes "seams", for which the tolerance cannot satisfy the requirements of the design.

Currently, processing coupling disc of larger diameter requires lathe FT after section die. Special fixture needs to be designed and processed for lathe FT. Therefore, additional turning is used to eliminate the "seams".

Design improvement of the structure of the coupling discs

Fig.1 and Fig.2 demonstrate the diagrams of the design of the structure of the coupling discs before and after improvement respectively.

By comparing Fig.1 and Fig.2, it is clearly seen that after improvement, on the circumference surface in Fig.1, there are 20 evenly distributing semicircle grooves in Fig.2. Naturally, the number of semicircle grooves depends on the diameter of the disc accordingly. In the section die of the external circular plate, a diameter of 6 to 8mm can avoid "seams" and reduces a process of turning the outside circle. Disc processing routes can be changed as follows: cutting bed materials, punching center holes and key seat holes, punching section outside circles, punching 12 screw holes, punching 12 outer screw holes and deburring.

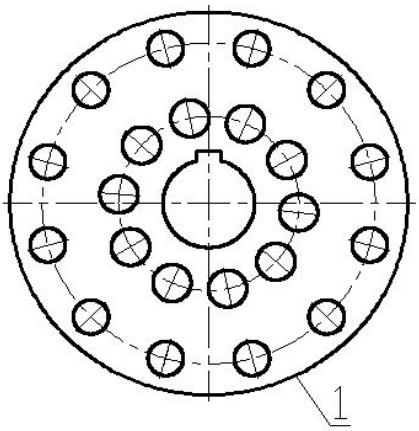

Fig.1 the original design of disc structure

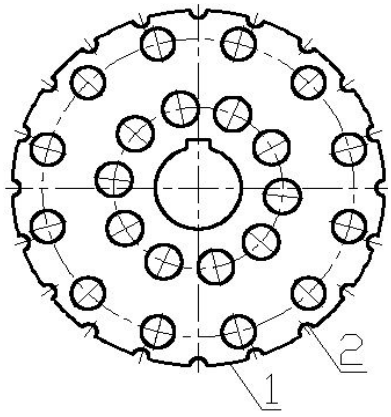

Fig.2 the improved design of the disc structure

Modal analysis of the new-type coupling disc

Does the new-type coupling discs' structure meet the operating requirements of diesel generator set?So it is necessary to make a modal analysis for it.

Except for transferring the nominal torque, the main index of the design for diesel generator sets' coupling discs is compensating misalignment errors of sets, which is related to its stiffness design. However, experience has proved that coupling disc sets with the high rigidity are unable to compensate misalignment errors as the traditional rigid coupling, which can cause other components of the low stiffness to be deformed and damaged excessively. Despite of being able to compensate misalignment errors, coupling disc sets with the low stiffness would have large deformation when diesel generator sets were operating, which could result in accidents because of rotor core's cylindrical surface colliding with stator core's bore surface. Therefore, appropriate rigidity design is of great significance to coupling disc sets.

According to conservation of energy and Lagrangian dynamical equation, dynamical equation of the rotor in matrix is as follows:

$$M\ddot{y} + K\dot{y} = F$$

In the equation, M is mass matrix while K is rigidity matrix, and F stands for the function of the runtime t for the force vector; y is coordinate axis that is perpendicular to spin axis in a three-dimensional Cartesian coordinate system.

Referring to the specific diesel generator sets such as 500KW sets, M and K are constant matrix. In other words, when designing the structure of disc sets first we should design the structure and then test the appropriate and optimal rigidity.

The modern FEM software has programmed complicated calculations of rigidity check that is using classical mechanics method. As long as users know component's structure, material, proportion and location, namely degree-of-freedom restrictive way, they can calculate the rigidity, finite elements analysis and check the rigidity by adopting SI unit, namely International System of Units. Heat-resistance stainless steel 0Cr18Ni10Ti is selected as the material of discs. Characteristics are as follows: the thickness is 0.002m, the allowable yield point in the mechanical parts design manual is 160MPa, the Poisson ratio v is 0.3, the elastic modulus E is 210GPa, and the proportion is 8000kg/m3 .Because of disc sets assembled in the flywheel of diesel engine by 12 holes in the outer side and in the half-coupling of electric generator by 12 holes in the inner side,its element type chooses construction solid geometry SOLID186.The global 0.008m is selected for grid cell dividing by using the mapping division. When loaded, freedom is restricted for the 12 holes of the outer end of disc, while for the inner end 12 holes, 0.0001m displacement is set in the directions of Ux, Uy, Uz respectively, which is preset for a compensation of misalignment.After loading the finite element model,natural frequency of discs from one order to ten order can be obtained. Table 1 and Table2 are analysis results

of the FEM software.Table 1 shows the natural frequency from one order to ten order for the disc whose thickness is 2mm while Table 2 displays the natural frequency from one order to ten order for four overlapping discs whose thickness are 2mm.

Diesel generator sets with four-pole rotor core are most widely used with a rated speed of 1500RPM, namely 25 revolutions per second. As is shown in Table 1 and Table 2, each order frequency in its ten-order frequency is more than 25, instead of 25-time frequency doubling. However, from the perspective of disc's stress-strain, on condition of 6200MPa from the dead load of rotor core, centrifugal force and unilateral magnetic pull, when a disc of 2mm is transmitting a power of 500KW, its maximum stress can reach 5600MPa and its maximum strain can reach 0.5mm. When four discs are overlapped, its maximum stress can reach 132MPa and its maximum strain can reach 0.2mm. Apparently, when using four overlapped discs, the stress is less than the yield point of 160MPa while the strain is just close to misalignment degree of the sets.

***** INDEX OF DATA SETS ON RESULTS FILE *****

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	285.81	1	1	1
2	288.72	1	2	2
3	288.79	1	3	3
4	297.82	1	4	4
5	297.97	1	5	5
6	314.61	1	6	6
7	314.66	1	7	7
8	326.68	1	8	8
9	340.60	1	9	9
10	340.62	1	10	10

Table 1 A list of 1-10 rank inherent frequency for a disc of 2mm

***** INDEX OF DATA SETS ON RESULTS FILE *****

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	2189.8	1	1	1
2	2213.1	1	2	2
3	2213.7	1	3	3
4	2283.8	1	4	4
5	2284.9	1	5	5
6	2414.3	1	6	6
7	2414.7	1	7	7
8	2497.3	1	8	8
9	2617.4	1	9	9
10	2617.8	1	10	10

Table 2 A list of 1-10 rank inherent frequency for 4 overlapped discs of 2mm

Diesel generator’s qualified vibration in running while excessive vibration at start or stop results in a multiple of the rotational speed of the disc in agreement with a natural frequency of a disc. Excessive vibration can be eliminate by mean of short running, accelerating or decelerating.

Summary

This paper has designed a new type of coupling disc structure for the diesel generator set, eliminating the “seams” in the section die. It also has focused on the modal analysis by using limited meta-simulation software, discussed the optimum stiffness structure, and analyzed the related causes of normal operation whereas over-vibration at the course of start or stop. Thus, it provide reference in theory for improving structure and design of coupling disc for diesel generator set.

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