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Medůna, Ondřej:

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URN: urn:nbn:de:gbv:ilm1-2013100033-321-7

URL: http://nbn-resolving.de/urn:nbn:de:gbv:ilm1-2013100033-321-7

Erschienen in:

10. Kolloquium Getriebetechnik : Technische Universität Ilmenau, 11. - 13. September 2013. - Ilmenau : Univ.-Verl. Ilmenau, 2013. - S. 321-328. (Berichte der Ilmenauer Mechanismentechnik ; 2)

ISSN: 2194-9476

ISBN: 978-3-86360-065-5 [Druckausgabe]

URN: urn:nbn:de:gbv:ilm1-2013100033

URL: http://nbn-resolving.de/urn:nbn:de:gbv:ilm1-2013100033

Universitätsverlag Ilmenau, 2013
http://www.tu-ilmenau.de/universitaetsverlag/

EFFECT OF BOUNDARY CONDITIONS ON THE STRESS RESULTS OF FLEXIBLE PART OF THE MECHANISM

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Abstract

This paper presents a numerical simulation of a multi-body system with a flexible part. There is a needle bar mechanism of an industrial sewing machine driven by radial cam. As a flexible body the needle bar lever is considered in this mechanism. Stress distribution/peaks on this lever is one of the most important criterion for maximum mechanism speed determination. In conclusion of this paper, the quality of the results is compared due to using different boundary conditions.

1 Introduction

The main task of this work is to show options of creation of mechanism multi-body system with flexible part. It can be useful to determine critical working speed with respect to safety against failure of the main parts of this machine.

The analyzed object is the industrial sewing machine. The most problematic part of this machine is the needle bar lever. The whole machine consists of many complicated mechanisms. Their effect on the analyzed needle bar mechanism load is negligible therefore there is only a multi-body system of the needle bar mechanism created. The main problem can be stress peaks on needle bar lever during machine run, so this part is considered as a flexible body in multi-body system. There is shown comparison of results quality due to using different MBS excitation load.

2 Multi-body system of analyzed mechanism

Multi-body system (MBS) is created using an assembly of all the main parts of analyzed mechanism (see in Fig. 1). All the inertia properties are determined by geometry and material density of each part. The translational and revolute kinematic joints among adjacent parts are added to MBS.

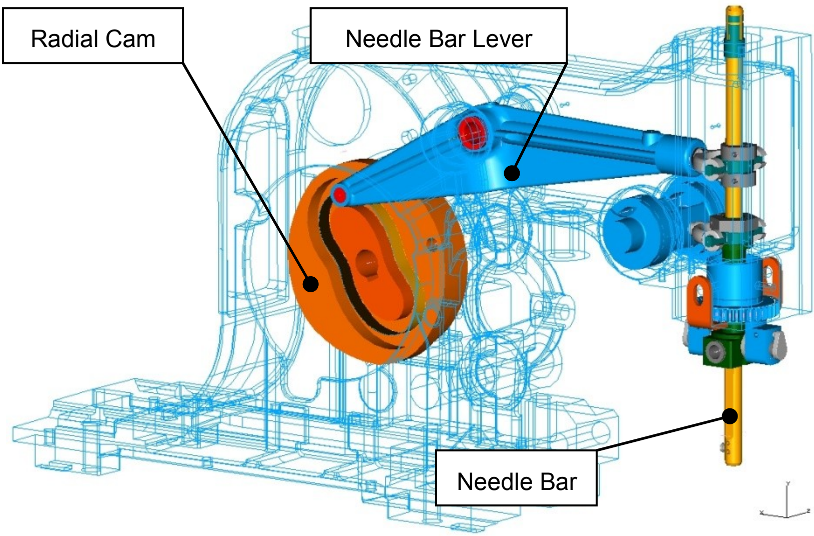

Fig. 1: Needle bar mechanism created in sw MSC.ADAMS

There are defined 2 contacts of curve-to-curve type to respect the cam-follower kinematic joint on the real mechanism. The first one is defined between the circle (follower) and the curve of inner cam-profile, the second one is defined between the circle (follower) and the curve of outer cam-profile. The radius of the circle representing the follower is set to R_{MBS} = 6.33 mm instead of the nominal follower radius $R_{NOMINAL}$ = 6.35 mm. This difference simulates the manufacturing tolerance of cam-follower parts.

3 Stress determination on a needle bar lever

At this moment, all the parts of this MBS are rigid. To allow stress peaks determination on needle bar lever during simulation of machine run we need its FEM model to creation of “modal neutral file” (MNF). It allows this part to consider as flexible in MBS.

The needle bar lever FEM model consists of 27024 tetrahedron-type elements representing its geometry. The RBE2 elements are used for connection of flexible part to the other components of assembly (Fig. 2).

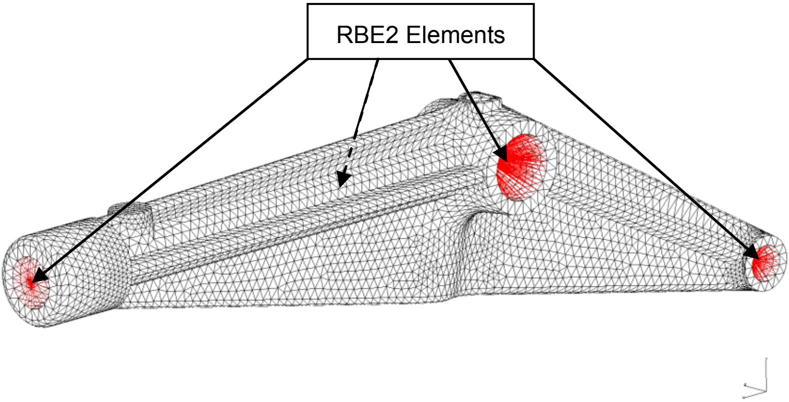

Fig. 2: FEM model of needle bar lever created in sw I-DEAS

This part is made from AL 2014-T4 alloy with mechanical properties shown in Tab. 1.

Tab. 1: Mechanical properties of AL 2014-T4 alloy

Young’s modulus [MPa]	72 400
Poisson’s ratio [1]	0.33
Mass density [kg/m^3]	2 800
Fatigue strength [MPa]	262
Tensile yield strength [MPa]	290
Ultimate tensile strength [MPa]	427

4 Versions of kinematic excitation of mechanism

Now, a MBS with respect to all main parts of needle bar mechanism is created. On the real machine, there is only one kinematic excitation of this mechanism – the radial cam is driven by an electric motor in nominal rotational speed $n_{NOMINAL}$ = 900.8 rpm. Because of complexity of real machine it is very difficult to include all the forces with effect to the mechanism behavior.

For example, there is an effect of needle penetrating through the sewed textiles or effect of manufacturing tolerance in kinematic joints. We can show effect on stress results of three versions of kinematic excitation applied to MBS in the next subchapters. All the records used as kinematic excitation are shown in Fig. 3.

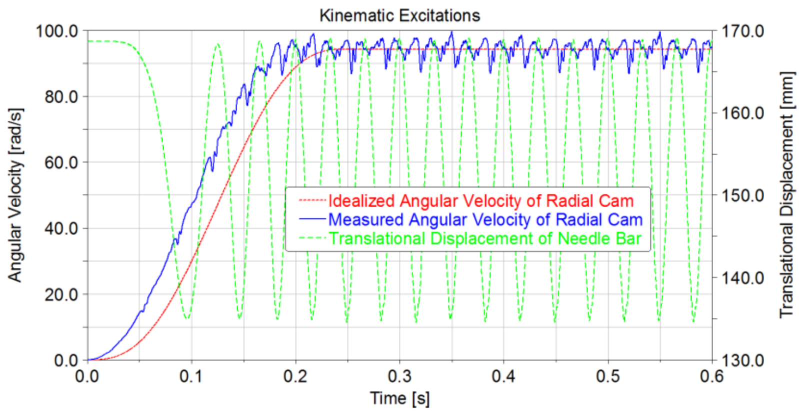

Fig. 3: Kinematic excitations used in simulations

4.1 Kinematic excitation only on the radial cam – n = const

The first version of the kinematic excitation is to drive only radial cam using the constant nominal rotational speed $n_{NOMINAL}$ = 900.8 rpm. This value is usual working speed therefore we could expect that the simulation load of the flexible needle bar lever is similar to the real load. Maximum von Mises stress value on the needle bar lever $\sigma \approx 30$ MPa is determined during 17 steady-state run cycles. Stress peak areas are shown in Fig. 4 and Fig. 5.

This maximum value is very low compared with fatigue strength of used material of needle bar lever (262 MPa).

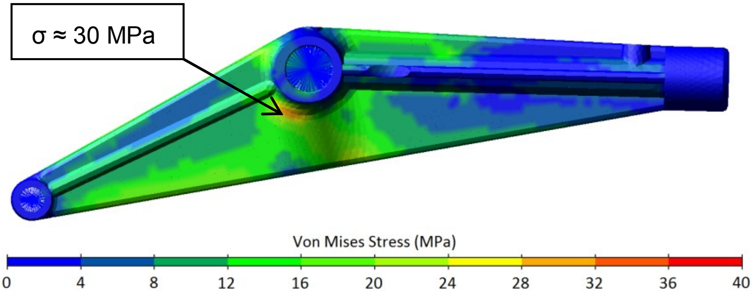

Fig. 4: Stress distribution on the needle bar lever – kin. excitation version 1

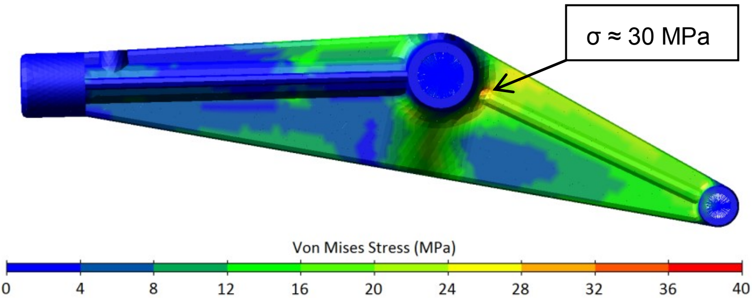

Fig. 5: Stress distribution on the needle bar lever – kin. excitation version 1

4.2 Kinematic excitation only on the radial cam – n ≠ const

The second version of the kinematic excitation is to drive only radial cam using the measured record of its rotational speed. This time-variable record consists of start-up and 17 run cycles on the real machine. The average value is the same as the constant value in the first version: $n_{NOMINAL}$ = 900.8 rpm.

The effect of unsteady rotational speed of the radial cam is not very significant - maximum von Mises stress value on the needle bar lever is now σ ≈ 35 MPa. Stress peak areas are shown in Fig. 6 and Fig. 7. These stress extremes are still very low compared with fatigue strength of used material (262 MPa).

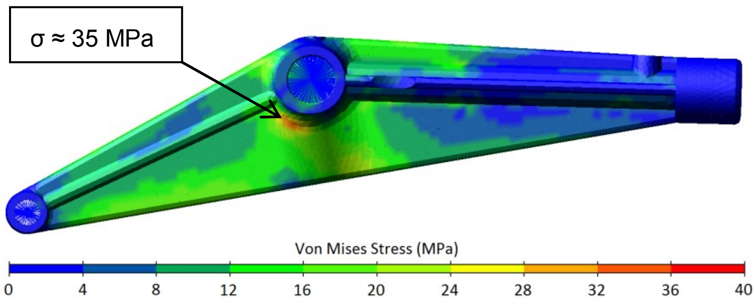

Fig. 6: Stress distribution on the needle bar lever – kin. excitation version 2

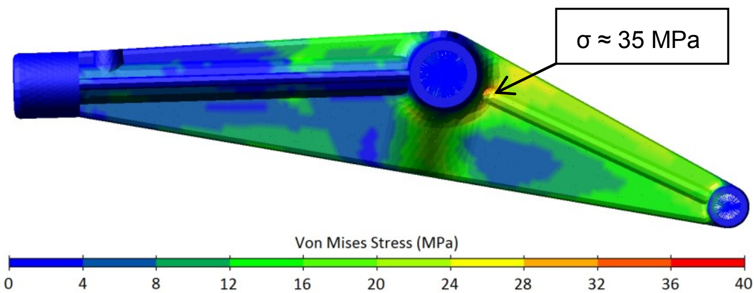

Fig. 7: Stress distribution on the needle bar lever – kin. excitation version 2

We can now compare translational acceleration of needle bar on MBS simulation model for this version of kinematic excitation with the measured record of acceleration on the real machine (Fig. 8). It's clear that these records are different, especially acceleration peaks. We can suppose that it is the effect of needle penetrating through the sewed textiles and the effect of manufacturing tolerance in kinematic. We can include these extra loads by adding measured translational displacement of needle bar as its excitation too. This version is described in the next chapter.

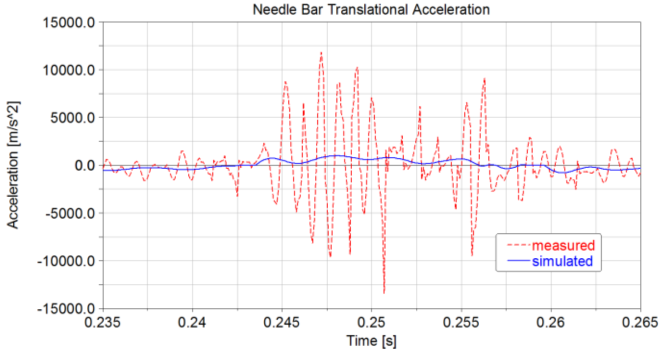

Fig. 8: Comparison of translation acceleration of the needle bar

4.3 Kinematic excitation on the radial cam & on the needle bar

The third version of the kinematic excitation is to drive radial cam using the measured record of rotational speed (same as in the second version) and to drive needle bar using the measured record of its translational displacement. The reason for using the measured displacement of needle bar is to include forces acting on the needle during penetration through the sewed textiles and any other effect we cannot exactly simulate. Maximum von Mises stress value on needle bar lever $\sigma \approx 160$ MPa is very different to stress peaks of the first two versions of kinematic excitation. This value is relatively close to fatigue strength of used material and therefore it is not recommended to increase working speed to required value $n_{INCREASED}$ = 1500 rpm.

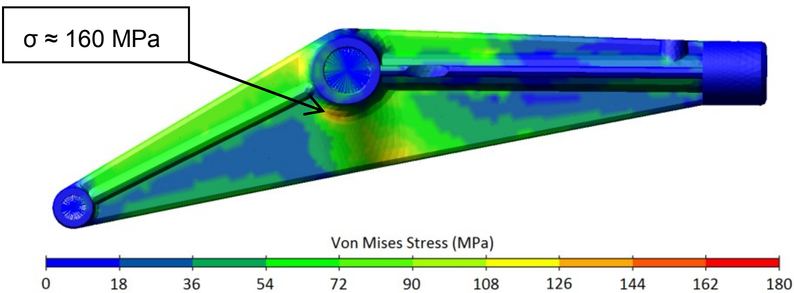

Fig. 9: Stress distribution on the needle bar lever – kin. excitation version 3

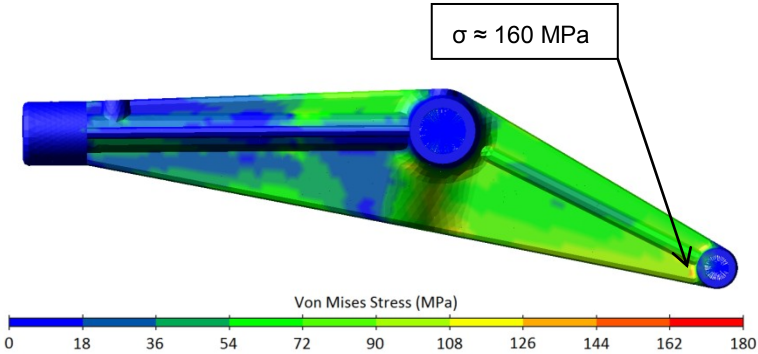

Fig. 10: Stress distribution on the needle bar lever – kin. excitation version 3

5 Conclusion

This work discusses modeling options of needle bar mechanism of industrial sewing machine. The simulation model of this mechanism is created as multi-body system including geometry of all movable parts and kinematic joints between them. The needle bar lever is desired as a flexible part to determine possible unsafe stress peaks during machine run.

The multi-body system uses 3 different versions of kinematic excitation for simulation of run machine. The stress result differences of each one show that it is necessary to use simultaneously two kinematic excitations in multi-body system for accuracy of results. The first one is drive of the radial cam using the measured record of rotational speed; the second one is drive of the needle bar using the measured record of its translational displacement.

On the base of the stress results for commonly used rotational speed of the radial cam $n_{NOMINAL}$ = 900.8 rpm it is not recommended to increase it to the required value $n_{INCREASED}$ = 1500 rpm. For this increasing it is necessary to modify design of needle bar lever.