REPLACEMENT OF A CAST STAND OF A RUBBER MACHINE WITH A WELDED STAND

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Abstract

The article deals with the simulation of the load of a rubber four-roll calender, focusing on the replacement of the existing casted stand with welded stand. The calender load is relatively complex, because it is necessary to maintain high accuracy of the rolled strip. The load consists of applying of a rolling force, the crossing of the rollers and the roller counter-bending. The previous cast stand is to be replaced by welded, which offers higher variability to different customer requirements. The welded stand can also be manufactured in shorter stand. Cast frame stiffness (which is sufficient) is used as reference. An example of weld part simulation is performed for console.

Keywords: Calender; rubber industry; weld joint; FEM

1. Introduction

1.1. Background

Calenders are rolling machines used in rubber industry for production of belts made from raw rubber applied on supporting fabric. Because it is about processing of raw rubber, of which composition is changing and current volume of it between the rollers as well, the acting forces in between the rollers are strongly variable. Load variability together with high requirements for dimension precision of rolled belt leads to significant requirements for stiffness of the stand in which the rollers are mounted. [1], [2], [3]

Historically these stands were produced as iron castings. Cast stands have some indisputable advantages. For example cast stands have the possibility of optimal distribution of material (with respect to stress). Next advantage is suitability for series production. Suitability for series production in current market environment becomes disadvantage because customers dictate own demands for final product. Thus a new task of changing current cast stand for a new welded stand has arisen.

1.2. Problem definition

Current cast stands of calenders are practically verified by plenty of years of operation. Its strength is sufficient and the stiffness is satisfactory but unknown. And it is just the stiffness that is crucial for the possibility of maintaining high production precision. Production precision of thickness of rolled material is continually measured. On the basis of measured value, the controlling system adaptively controls the acting force of main hydraulic cylinders. Decrease of stand stiffness would lead in stronger responses of adaptive controlling. Therefore the stiffness of newly designed stand has to be similar to the stiffness of original cast stands.

Cast stand is for FEM simulation considered as solid piece with homogenous material. Welded stand however is not of homogenous material. The problem for FEM simulation are added welds and their closest regions. Filler material of weld does not necessarily have to be of the same composition as welded metal plates. Welds and their regions are affected by heat and contain residual stress. The problem is how to simulate weld in frame design.

1.3. Used approaches

The aim of the thesis is a FEM simulation model that will be close to a real welded stand and will be able to indicate the stress values separately in welded plates and welds. Although in the construction of the stand only steel plates are considered, these will be modelled as 3D bodies, so even the welds will be modelled as 3D bodies. [4], [5], [6]

In this paper, two possible approaches to modelling the bonding of metal plates and welding volume are considered. The Siemens NX software is used for simulation. These approaches are:

- Direct connection of nodes of adjacent elements (Mesh Mating).
- Connection of adjacent faces by gluing (Gluing).

2. Calender, stand and its load

In this paper, a four-roll calender is considered. The calender consists of two stands, in which are placed four rolls. The working part of these rolls is located between the stands. The rolls can be independently driven and typically are mounted in S-shape.

Fig. 1. An example of four-roll calender (Dalian Huahan Rubber & Plastic Machinery CO.,LTD.) [7]

In order to achieve the desired thickness of the rolled rubber strip, the rollers are adjustable. The mechanism of the rolls positioning can be achieved mechanically (see Fig. 1.) or hydraulically (considered calender). From the point of view of the load of the stand, the type of used mechanism is not essential, it is always the main force load. The positioning force is orderly greater than other force loads (Fig. 2.).

In order to achieve a constant thickness across the width of the belt, the calender is provided with a mechanism for crossing and bending the rolls. The crossing of the rollers allows the roller bearing to move in a direction perpendicular to the main load. The bearing move is effected by pressing the bearing body on the adjustable stop. The pressing action is permanent (this is a preload). The second way to achieve a constant thickness is to counter-bend the rolls. This is exerted by the force acting on the overhanging end of the rollers through the consoles attached to the stand.

Fig. 2. Load groups (left: roll adjustment; middle: roll crossing; right: roll counter-bending)

The force load is transmitted between the rolls where the rubber is rolled. The force load is therefore also out of the plane of the stand. For the virtual simulation, therefore, a model consist of a stand, roller counter-bend console, bearing bodies, and one half of the rolls is built up (this is the reason why the plane of symmetry is used).

Fig. 3. 3D simplified 1/2 model of Four-roll calender with cast stand

3. Virtual simulation of calender

An existing calender with a cast stand was used as a benchmark for determining the stiffness of the calender stand. The simulation was prepared with a contact definition. The load was specified according to Fig. 2. The contact pairs were defined between the rollers. For connecting the rolls with bearing bodies, 1D elements were used, which were connected in a manner corresponding to the used bearing (the main bearings are non-tilting roller bearings, the rolls bearings are tilting). The simulation was performed for two load states, maximum and typical [8].

Fig. 4. Results of simulation of calenders' cast frame (left – stress distribution; right – total displacement)

It is clear from the results (Fig. 4.) that the stand is sufficiently dimensioned in terms of strength. Increased stress occurs only around and on counter-bending consoles. The stiffness of the stand was read for the main directions of the adjustment mechanisms. Stiffness is the default parameter for designing a new welded stand.

Fig. 5. Results of simulation of calenders' welded frame (left – stress distribution; right – total displacement)

In the next step, new stands welded from sheet metal were designed. Because of time savings, welds are not considered in the simulations, and the entire weldment is considered homogeneous (Fig. 5.). The simulation with included welds is only counted with for the final design of the stand.

4. Virtual simulation of counter-bend console

The results of the stress simulation of the calender stands revealed increased stress of counter-bend console, therefore it was decided to devote more attention to these consoles. The consoles are attached to the stand with screws and a circular key. Consoles are newly designed as a weldment. Because the consoles themselves are simpler than the entire stand, they were used for the first weldment simulation experiments.

Fig. 6. Simplified model of counter-bend console (left – homogeneous material; right - weldment)

The first created model was a console model without separate welds (see Fig. 6). The model consists of the console model fastened by the simplified screws to the metal plate part of the stand. Similarly, but with welds as separate volumes, a second model was also prepared. For bonding the volumes of the base and filler material, the connecting of the adjacent surfaces was used (Gluing).

Fig. 7. Results of stress distribution (von Mises) in model of counter-bend console (left – homogeneous material; right - weldment)

The results of the stress distribution in the console are shown in Fig. 7. It is clear that the values and the distribution are not practically different between the models at all (that is correct; in the weldment model the material assigned to weld bodies is the same as the rest of bodies). The advantage of the weldment model is the possibility of displaying the stress distribution just in the welds (Fig. 8.)

Fig. 8. Results of stress distribution (von Mises) in welds of model of counter-bend console

5. Conclusion

This work is focused on how to solve the new design of the four-roll calender stand. New calender stand will be produced as metal-plates weldment in contradiction to original cast stand. New stand should be designed to have similar properties as the old one, virtual simulation of the cast stand have been performed. Result of simulation is stiffness to which the welded stand should come as close as possible. Next results is discovering that the most stressed component is counter-bend console. That is reason why this console has been newly designed as weldment of metal plates and rolled semi-finished products and then subjected to two virtual simulations (once as a homogenous material without single welds and once with single weld bodies).

The intention for this console simulation was to verify the possibility of counting with the welds volumes as single bodies. For its subsequent evaluation it is important to consider the welds material (and his close regions) as a worse material than the connected one when it comes to the matter of strength. Simulation has proven that connecting welding material with welded material is possible and is functioning. It is proven by identical results of stress distribution on both models. Material of the welds is different from the connected one only in its lower mechanical properties (thus in the environment of virtual simulation, where linear material is used, these do not differ).

5.1. Future steps

Next logical step is to use a simulation with a single welds volume for the stand itself. Because of the number of welds it is certain that model preparation will be challenging, so this approach will only be used for an optimized stand.

In future work, it is appropriate to verify the effect of the direct connection of the adjacent elements (Mesh Mating). Because this is a more demanding method for model preparation, it might be a more accurate description of the actual model. It will be advantageous to compare these methods (Gluing vs Mesh Mating) with each other and determine their main properties.

6. Acknowledgments

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7. References

- [1] <https://en.wikipedia.org/wiki/Calender>, 2018. Wikipedia.org, Accessed on: 2018-07-13
- [2] https://www.tut.fi/ms/muo/vert/8_processing/4.3.b.htm, Tampere University of Technology, Processing methods for rubber materials - Calendering – Machinery, Accessed on: 2018-07-14
- [3] Abry, J., Mittelhaeuser, C., Wolf, S., Turlier, D. (2018). Enhanced fatigue structural stress analysis of a heavy vehicle seam welded steel chassis frame: FEA model preparation, weld model description, fatigue stress calculation and

- correlation with 10 year operating experience, *Procedia Engineering*, Volume 213, Pages 539-548, ISSN 1877-7058, <https://doi.org/10.1016/j.proeng.2018.02.050>.
- [4] Mitsoulis, E. (2008). Numerical simulation of calendering viscoplastic fluids, *Journal of Non-Newtonian Fluid Mechanics*, Volume 154, Issues 2–3, Pages 77-88, ISSN 0377-0257, <https://doi.org/10.1016/j.jnnfm.2008.03.001>.
- [5] Krejsa, M., Brozovsky, J., Mikolasek, D., Parenica, P., Koubova, L., Materna, A., (2017). Numerical Modeling of Fillet and Butt Welds in Steel Structural Elements with Verification Using Experiment, *Procedia Engineering*, Volume 190, Pages 318-325, ISSN 1877-7058, <https://doi.org/10.1016/j.proeng.2017.05.344>.
- [6] Barsoum, Z., Barsoum, I. (2009). Residual stress effects on fatigue life of welded structures using LEFM, *Engineering Failure Analysis*, Volume 16, Issue 1, Pages 449-467, ISSN 1350-6307, <https://doi.org/10.1016/j.engfailanal.2008.06.017>.
- [7] <http://www.huahandl.com/products/calender-equipments/>. Dalian Huahan Rubber & Plastic Machinery CO.,LTD., Four-Roll Calender, Accessed on: 2018-07-13
- [8] Čechura, M.; Dekastello, J.; Hlaváč, J.; Jirásko, J.; Keckstein, T.; Kubec Krónerová, E. & Zahálková, M. (2017). TH02010708 Interim report (TH02010708 Průběžná zpráva), Technology Agency of the Czech Republic, Report, unpublished