Review Paper on Design Optimization of Link Mechanism in Vertical Carousel Machine

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Abstract— This paper presents review of design optimization of link mechanism in vertical carousel machine. In this paper problem definition and problem solving methodology is presented in detail. This methodology suggests use of high end design analysis softwares like CATIA V5, Hypermesh, Nastran and ADAMS VIEW. Research papers are studied thoroughly for this review paper. For more practical study of the problems arising in the design and optimization of link mechanism, data required is accumulated from local manufacturing company. This paper focuses on study of mechanism of vertical carousel machine, its causes of failure of mechanism of vertical carousel machine.

Key words: Vertical Carousel Machine, Multi body Dynamics, Link Mechanism, FEA

I. Introduction

Industrial carousel is a type of “moving shelving unit” that brings a stored item to the order selector. The product stored on a carousel may be a retail product, manufacturing part, or a customer order.

A vertical carousel consists of trays that travel vertical in front of an access window; one or several chains drive the tray, which are arranged according to the nature, dimensions and weight of items to be stored. This type of storage is generally associated with stock management. It also consists of a control and management panel. Carriers (shelves) are connected to transport chains that rotate the entire stored inventory around inside a steel clad casing in either direction working on the shortest routing principle to deliver the requested items at an ergonomic height to the operator. The picking port working area is illuminated by directional low voltage LED lights. The carriers are presented at the access port in front of the operator at a picking / placing height, usually 900mm, depending on the pitch of the carriers.

Failure of vertical carousel machine is often caused by failure of guide ways and failure of pin in linkages. If the vertical carousel machine fails, material stored inside may get damaged and the valuable time is also wasted. Since many customers of Tech-mark are located overseas, the maintenance becomes a challenge. This damages the impression of company. As such in this project, to avoid frequent failure of machines it is proposed to carry out the design analysis of the linkage mechanism of carousel machine to make it reliable.

II. Operation

A vertical carousel consists of trays that travel vertically in front of an access window. One or several chains drive the trays, which are arranged according to the nature, dimensions, and weight of the items to be stored. This type of storage is generally associated with stock management.

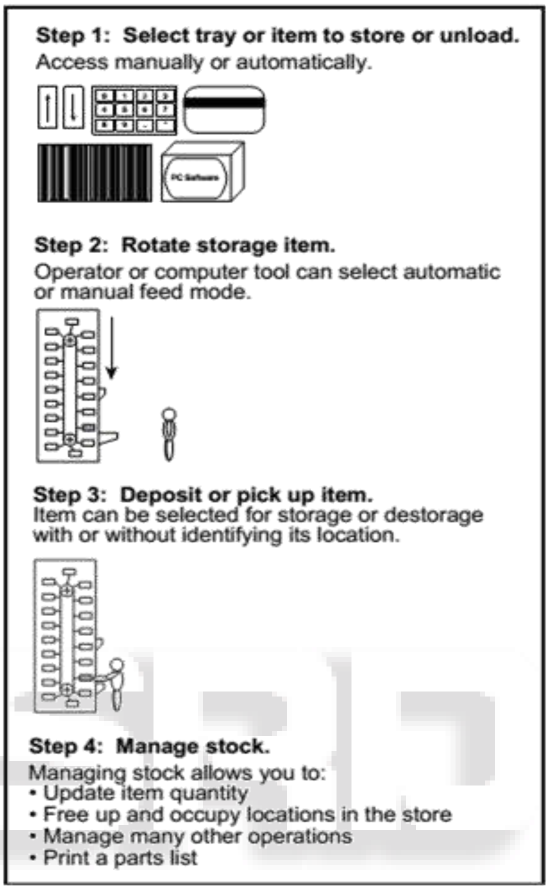

Fig. 1 Step Followed for Operation of Vertical Carousel Machine

III. Applications

There are many uses of vertical carousel machine. Key areas where vertical carousel machines are used are as follows.

1) Storing medicine in pharmacies
2) Storing components in the electronics industry
3) Storing tools in machine tool sector
4) Storing fabric samples
5) Preparing orders in electrical industry
6) Storing laundry and linen in a nursing home or hospital
7) Filing documents in an administrative setting
8) Storing parts among automobile manufacturers
9) Managing trays for postal sorting

IV. System Options

Vertical carousel machine can be used with efficiently and successfully with following accessories.

1) Air conditioning of rotary storage
2) Internal air purification
3) Modular shelving
4) Filing management software
5) PC

6) Electronic balance
7) Bar code reader
8) Badge reader
9) Label generator
10) Tray management conveyors
11) Schematic construction diagram typical vertical carousel machine is given below.

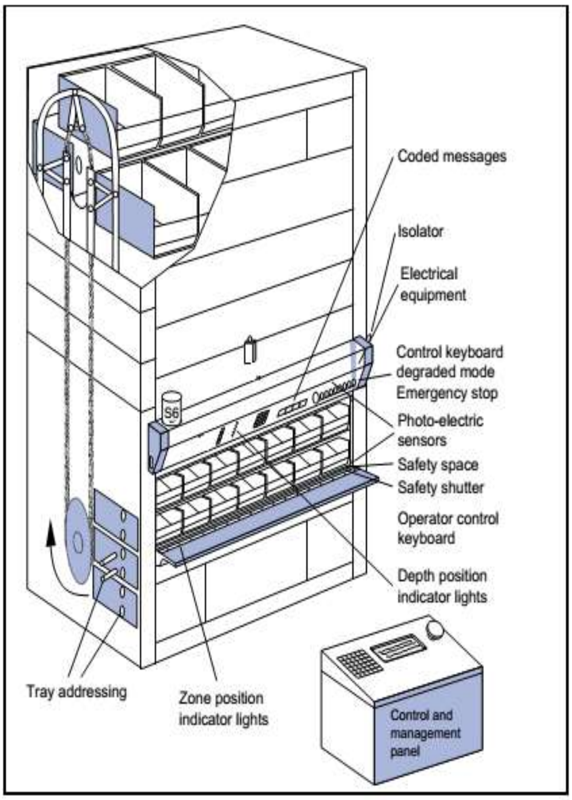

Fig. 2 Construction of Vertical Carousel Machine

V. FORMULATION OF PROBLEM

Failure of vertical carousel machine is often caused by failure of guide ways and failure of pin in linkages. If the vertical carousel machine fails, material stored inside may get damaged and the valuable time is also wasted. Since many customers of Tech-mark are located overseas, the maintenance becomes a challenge. This damages the impression of company. As such in this project, to avoid frequent failure of machines it is proposed to carry out the design analysis of the linkage mechanism of carousel machine to make it reliable.

VI. REVIEW OF LITERATURES

Saad Mukras et al. have predicted that wear on the components of a mechanical system without considering the system as a whole, in most cases, lead to inaccurate predictions. This is because the wear is directly affected by the system dynamics which evolves simultaneously with the wear. In addition, the contact condition (regions of contact for the wearing bodies) also depends on the system dynamics and can only be determined in a multibody dynamics framework.

In their work, a procedure to analyze planar multibody systems in which wear is present at one or more revolute joints is presented. The analysis involves modeling multibody systems with revolute joints that consist of clearance. Wear can then be incorporated into the system dynamic analysis by allowing the size and shape of the clearance to evolve as dictated by wear. An iterative wear prediction procedure based on Archard's wear model is used to compute the wear as a function of the evolving dynamics and tribological data. The procedure is then validated by comparing the wear prediction with wear on an experimental slider-crank mechanism. (11 February 2010) [1]

Imed Khemili et al. have done the studies of the dynamic behavior of a planar flexible slider–crank mechanism with clearance is done. Simulation and experimental tests were carried out for this goal. For the simulation tests, they have built the model under the software ADAMS. They used a contact model based on the so called Impact-function. An experimental set-up was designed and built to achieve some experimental validations. The presented results show that, in the presence of clearance, the mechanism responses were greatly influenced. The motion is characterized by the occurrence of three phases: a free motion, a continuous contact motion and an impact motion. In this paper, both the case of the mechanism with rigid link and the case with flexible link were studied. It is shown that in the presence of clearance, the coupler flexibility has a role of suspension for the mechanism. , (September–October 2008) [2]

O. A. Bauchau et al. have described a multibody dynamics approach to the modeling of rotorcraft systems and reviews the key aspects of the simulation procedure. The multibody dynamics analysis is cast within the framework of nonlinear finite element methods, and the element library includes rigid and deformable bodies as well as joint elements. No modal reduction is performed for the modeling of flexible bodies. The structural and joint element library is briefly described. The algorithms used to integrate the resulting equations of motion with maximum efficiency and robustness is discussed. Various solution procedures, static, dynamic, stability, and trim analyses, are presented. Post-processing and visualization issues are also addressed. Finally, the paper concludes with selected rotorcraft applications. (Mathematical and Computer Modeling, 2001) [3]

J Ambrosio et al. have given computational methodology for dynamic analysis of multimode mechanical systems with joint clearance is presented in this work. Clearances always exist in real joints in order to ensure the correct relative motion between the connected bodies being the gap associated to them a result of machining tolerance, wear, and local deformations. Clearance at different joints is the source for impact forces, resulting in wear and tear of the joints, and consequently the degradation of the system performance. The model for planar revolute joints is based on a thorough geometric description of contact conditions and on a continuous contact force model, which represents the impact forces. It is shown that the model proposed here lead to realistic contact forces. These forces correlate well with the joint reaction forces of an ideal revolute joint, which correspond to a null joint clearance. The application to the analysis of a simple planar multibody system illustrates the use of the different models proposed. (July 2004) [4]

Jinn-Biau Sheu et al. have investigated the kinematic synthesis of a four-link mechanism with rolling contacts. This mechanism comprises a two-fingered gripper and a grasped object. The synthesis equations used for motion generation and function generation are established. The number of free choices in design variables for the kinematic synthesis is also discussed. Furthermore, the optimization-based numerical technique is applied to solve the design equations. The optimized solutions are illustrated to discuss the kinematic states of the mechanism. It is also shown that the optimization-based method is effective in finding the admissible synthesis solution of the mechanism. (Mathematical and Computer Modeling, 2008) [5]

Jeffery H. Yakey et al. extended randomized path planning algorithms to the case of articulated robots that have closed kinematic chains. This is an important class of problems, which includes applications such as manipulation planning using multiple open-chain manipulators that co-operatively grasp the object and planning for reconfigurable robots in which links might be arranged in a loop to ease manipulation or locomotion. Applications also exist in areas beyond robotics, including computer graphics, computational chemistry, and virtual prototyping. Such applications typically involve high degrees of freedom and a parameterization of the configurations that satisfy closure constraints is usually not available. It is shown how to implement key primitive operations of randomized path planners for general closed kinematics chains. These primitives include the generation of random free configurations and the generation of local paths. To demonstrate the feasibility of our primitives for general chains, it is shown their application to recently developed randomized planners and present computed results for high-dimensional problems. This paper presents a coordinate-invariant differential geometric analysis of kinematic singularities for closed kinematic chains containing both active and passive joints. Using the geometric frame work developed in Park and Kim (1996) for closed chain manipulability analysis, classify closed chain singularities into three basic types: (i) Those corresponding to singular points of the joint configuration space (configuration space singularities), (ii) Those induced by the choice of actuated joints (actuator singularities), and (iii) Those configurations in which the end effector loses one or more degrees of freedom of available motion (end effector singularities).The proposed geometric classification provides a high-level taxonomy for mechanism singularities that is independent of the choice of local coordinates used to describe the kinematics, and includes mechanisms that have more actuators than kinematic degrees of freedom. (December 2001) [6]

James Brandon Allen has investigated the propagation of uncertainties in the input forces through a mechanical system. The system of interest was a wheel loader, but the methodology developed can be applied to any multibody systems. The modeling technique implemented focused on efficiently modeling stochastic systems for which the equations of motion are not available. The analysis targeted the reaction forces in joints of interest. The modeling approach developed in his thesis builds a foundation for determining the uncertainties in a Caterpillar 980G II wheel loader. The study begins with constructing a simple multibody deterministic system. This simple mechanism is modeled using differential algebraic equations in Matlab. Next, the model is compared with the CAD model constructed in ProMechanica. The stochastic model of the simple mechanism is then developed using a Monte Carlo approach and a Linear/Quadratic transformation method. The Collocation Method was developed for the simple case study for both Matlab and ProMechanica models. Thus, after the Collocation Method was validated on the simple case study, the method was applied to the full 980G II wheel loader in the CAD model in ProMechanica. This study developed and implemented an efficient computational method to propagate computational method to propagate uncertainties through “black-box” models of mechanical systems. The method was also proved to be reliable and easier to implement than traditional methods. (11May 2009) [7]

Selçuk Erkaya et al. have investigated an experimental study of the effects of balancing and link flexibility on the dynamics of a mechanism with imperfect revolute joints, that is, joints having radial clearance. A planar slider-crank mechanism, widely used in vehicle engines, is used in the experimental investigation. Bearing vibrations are considered to evaluate the reflection of balancing and link flexibility effects on a mechanism having two revolute joints with clearance. On the other hand, these vibrations are measured to clarify how the balancing and link flexibility feature can decrease the undesired effects of joint clearances. For this purpose, three accelerometers, an analyzer and a PC are used for measuring the related vibrations on the main frame. The experimental results show that joint clearance leads to sudden changes in motion characteristics of the mechanism. During small time intervals, these sudden changes cause forces to impact in the joints of the mechanism with clearance. This also leads to some vibration peaks, and increases the vibration amplitudes. Furthermore, the flexibility feature of the mechanism link has a crucial role in decreasing additional vibration arising from joint clearance. Also, the undesired effects of clearance are reduced to some degree by using the balancing. (Scientica Iranica, 2012) [8]

Assad Anis used ADAMS software to analyze slider-crank mechanism (IJET-IJENS August 2012) [9]

After referring these papers it is seen that, Saad Mukras et al. have presented a procedure to analyze planar multibody systems in which wear is present at one or more revolute joints are presented. The analysis involves modeling multibody systems with revolute joints that consist of clearance. Imed Khemili et al. have done the studies of the dynamic behavior of a planar flexible slider–crank mechanism with clearance is done. For the simulation tests, they have built the model under the software ADAMS. O. A. Bauchau et al. have presented multibody dynamics approach using finite element methods. J Ambrosio et al. have given computational methodology for dynamic analysis of multimode mechanical systems with joint clearance is presented in this work. The application to the analysis of a simple planar multibody system illustrates the use of the different models proposed. Jinn-Biau Sheu et al. have investigated the kinematic synthesis of a four-link mechanism with rolling contacts. Jeffery H. Yakey et al.

extended randomized path planning algorithms to the case of articulated robots that have closed kinematic chains. They have presented a coordinate-invariant differential geometric analysis of kinematic singularities for closed kinematic chains containing both active and passive joints. James Brandon Allen has investigated the propagation of uncertainties in the input forces through a mechanical system. The system of interest was a wheel loader, but the methodology developed can be applied to any multibody systems. He has used MATLAB and CAD models in ProMechanica. The experimental results from Selçuk Erkaya et al. show that joint clearance leads to sudden changes in motion characteristics of the mechanism. During small time intervals, these sudden changes cause forces to impact in the joints of the mechanism with clearance.

However no work is performed regarding kinematic analysis of vertical carousel mechanism. The kinematic analysis also can be used further for kinetic analysis. In order to do the kinematic analysis, this paper presents a combination of CAD (Computer Aided Design) software, MBD (multi-body dynamics) software and graphical method is used Hence, it may be concluded that, design and optimization of the linkage mechanism in vertical carousel machine can be done using analytical methods with the help of software packages, which has revolute joints with clearances and rolling contacts.

VII. SUMMERY

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VIII. PROPOSED WORK:

It is proposed to carry out “Design optimization of link mechanism in vertical carousel machine”. For this dissertation work, the work is divided into following phases.

A. Phase I –

Analytical calculations of link mechanism will be done by using adequate failure criterions and graphical methods. Calculations are done using design formulae, design data book, CAD software and data provided by company for given load.

B. Phase II -

To see the effects of clearance, Flexible Body Dynamics using MSC NASTRAN will be done in the following steps.

- Step1: Creating 3D Geometric Model of the link and pin which is of analysis importance.
- Step2: Geometry import in Hypermesh (a Finite Element Modeling Software)
- Step3: Descritisation of the Part.
- Step4: Calculations for the load coming on the link
- Step5: Assigning material properties, boundary conditions, loads etc
- Step6: Analysis of the problem using MSC Nastran (a Finite Element Analysis Software)
- Step7: Exporting the analysis file as .MNF file for further MBD analysis in MSC ADAMS

C. Phase III -

Rigid Body Dynamics using MSC ADAMS will be done in following steps.

- Step1: Creating 3D Geometric Model of the System (Specifically the parts which are important for Analysis)
- Step2: Geometry Import in MSC ADAMS VIEW (a MBD Software)
- Step3: Assigning Model properties to the other system parts like Mass Properties, Boundary Conditions etc
- Step4: Assigning .MNF file to target link part. (Replace it as flexible body from rigid body)
- Step5: Defining the Kinematic Joints between the parts to define the pairs.
- Step6: Defining the Input parameters like Velocity, Accelerations etc
- Step7: Simulating using MSC ADAMS View.
- Step8: Reviewing the analysis results.
- Step9: Results Interpretation.

D. Phase IV -

Design optimizations & re-analysis as per step 1 to 8 at adequate angles, sizes, and material property.

E. Phase V -

From Finite Element Analysis results obtained from analysis, output parameters will be presented. Using these parameters and company requirements,

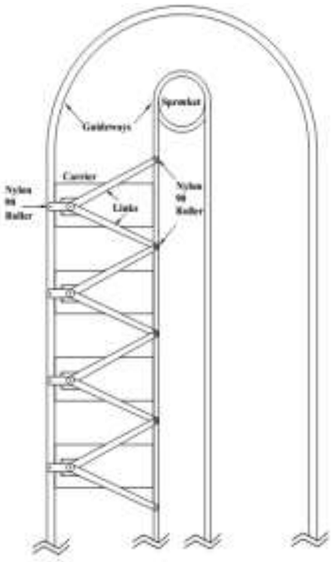

Fig. 3: Linkage mechanism in vertical carousel machine

IX. METHODOLOGY

For the constraints and load specified by company, design calculations of link mechanism using design formulae, design data book, CAD software and company data will be done at adequate positions in guide ways. This configuration will be simulated in available CAD/CAE software packages. With the help of this, optimum results will be obtained, which will be suggested to company. This configuration can be then tested at company premises. Based on these results, at company specified loads various sizes, shapes and properties, optimum results are obtained using software packages. These results are suggested to company.

X. SCOPE

Well definition of problem.

Study of input parameters required for analysis of link mechanism.

Evaluation of various components used to build carousel mechanism like chain, sprocket, guide ways, carriers, driveshaft motor etc. and for whole vertical carousel machine.

Analytical calculations of link mechanism which include, using failure criterions for link cross section and pin, contact stress analysis for roller. These calculations are done at adequate positions of link mechanism in guide ways.

Simulation of above case in available software packages.

Comparison & Interpretation of results (stresses & strains) obtained from numerical and analytical methods. Software is also used, for kinematic analysis to see effect of change in angle between links and for flexibility analysis to see the effects on clearance.

Solution & Design Optimisation to get better alternative material of different grade suggested and design dimensions are modified.

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