DESIGN AND FABRICATION OF SLITHERING RAM BY USING QUICK ARRIVAL MECHANISM

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Abstract: Quick Return Mechanisms (QRMs) are one of the essential accessories used in machine tools which involve reciprocating cutting action with a quick return stroke and a constant angular velocity of driving crank. The aim of this work was to simulate, design and construct a prototype of a QRM that can be used for demonstration and instrumentation. The QRM was simulated using Solidworks and a prototype was developed from the simulated results. The experiment was conducted using the prototype. The kinematic simulation of the Solidworks model was compared with the kinematics of motion of the prototype. The result showed that the Percentage Stroke Length error was 0.36%. It was observed that, there was no significant difference in the simulated and experimental results, hence, the prototype can be used for demonstration and experimentation to assist students in understanding basic principles of the machine operation. Keywords: quick return mechanism, solid-work model, prototype, kinematic simulation, stroke length, machine operation.

1. INTRODUCTION

Fixed link for the purpose of motion transmission is known as Mechanism. Such mechanism known as Quick return mechanism are the essential part used in reciprocating cutting tool with a quick return stroke having constant angular velocity of driving crank. Ratio of cutting stroke time to the return stroke is called the time ratio which is greater than one. Confirmed that in QRM, [1] velocity of cutting stroke and return stroke change with change in length of slotter link while the total velocity ratio remained constant [2] calculated the time ratio and stroke length from the given dimension of links with a view of helping designers to design a quick return mechanism for desired stroke length. Forward stroke the velocity of slider reduced gradually to zero by the time the slider was at full stroke [3]. This evidently proved that the elliptical gears wear designed correctly and an alternate mechanism to that of QRM is designed successfully. This software package is used for rapid prototyping, distance learning and as a teaching aid. Presented an analysis showing the effects of link-length and link-angle tolerances on the shaper-ram stroke error, as well as sensitivity coefficients to link-length and link-angle tolerances [4, 5]. They observed that the output being most sensitive to the link-length tolerance near the limiting positions of this mechanism was the greatest mechanical error in the output. Developed software using programming language C# which was useful for synthesis and analysis of crank with sensitive link [6]. It was concluded that the Crank is the most sensitive link. Finite element analyses of machine parts in static and modal domains are carried out on machine parts and their sub-assemblies [7]. The research resulted in the creation of a dynamic simulation model of the machine structure. Although there is scope for the accuracy of the model to be improved, in its current form it provides a firm basis for predicting the behaviour of the machine. In addition, much can be learned from the simulation model in terms of how the structure is likely to react to different types of excitations. This mechanism was an excellent experience in tackling a design project where the majority of constraints were self-imposed [8]. The final design produced is an effective one; however errors in the model do lead to some doubts as well as areas for the project to progress into. Hopefully, with a little work, the mechanism will be operational and seen by future kinematics students for years to come. Reviews basic QR mechanisms; they presented a project problem and solution examples on drag link quick return mechanism in which the mechanism was simulated using GNLINK and Working Model [9]. From the project problems and solution examples specifically on drag link quick return mechanism, they got results that show the feasible time ratio for varying coupler link, the range of time ratio that would be possible by adjusting the length of the Coupler Link, feasible mechanism solutions that would exist for a given time ratio if both the base length and the coupler link length of the drag link quick return mechanism are changed. The paper arrangement and testing values of Quick return ratio one when presented on flywheel motor. They were able to present a proposed a Quick return ratio mechanism having ratio one. As well as the tabulated readings of kinetic energy developed for limited period, weight wise and age wise. The data is use for increasing kinetic energy gain and improvement in bicycle which gives the great future in human powered mechanisms [10, 11]. Objective of the project was to investigate the performance of a Crank and lever reciprocating mechanism and to verify that the motion does have a quick return stroke and a slow forward stoke with additionally attaching spraying pump. They determined the increase in efficiency of the system mechanism and also confirmed that the quick return motion may increase the efficiency of the machine [12, 13]. The paper also dealt with various literatures in the field of kinematic and dynamic analysis of six-bar quick return mechanism [14, 15]. Static and dynamic force behavior of mechanism was discussed with different types of terminologies and methodologies. They obtained results on how to find the joint forces of different mechanisms using different analytical, graphical, and computer aided programming techniques in which the results can be validated using various motion analysis coordinate systems. The objectives of this study are: (i) Use of SolidWorks to design and analyze a crank and slotted lever mechanism, (ii) Construction of the individual parts of the mechanism according to the results of the design and analysis, (iii) Production of a prototype from the model, and (iv) Comparison between the simulated results and the experimental results.

2. MATERIAL AND METHODS

Design Concept: the machine was designed in order to achieve simple technology for an easy operation and fabrication of a motorized device. This device must be capable of simulation design and construct of a prototype of a QRM that can be used for demonstration and instrumentation. Design data: link AC (link 3) which is the turning pair is fixed (Figure 1), which corresponds to the connecting rod of a reciprocating steam engine. Crank CB is the driving crank which revolves about the fixed centre C with uniform angular speed. A sliding block was attached to the crank pin at B slides along the slotted bar AP and make it to oscillate about the pivoting point A. the link PR transmits the motion from AP to the ram which reciprocates the tool along the line of stroke R1R2. The line of the stroke of the ram (R1R2) which is perpendicular to AC produced. When the crank rotates along CB1 and CB2 or through an angle β in the clockwise direction, the forward stroke occurs, and from CB2 to CB1 gives the return stroke in clockwise direction through angle α. The crank has uniform angular speed. The same routine occurs in the extreme position [16, 17]. In the extreme positions, AP1 and AP2 are tangential to the circle and the cutting tool is at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position CB1 and CB2 (or through an angle β) in the clockwise direction. The return stroke occurs when the crank rotates from the position CB2 to CB1 (or through angle α) in the clockwise direction. Since the crank has uniform angular speed.

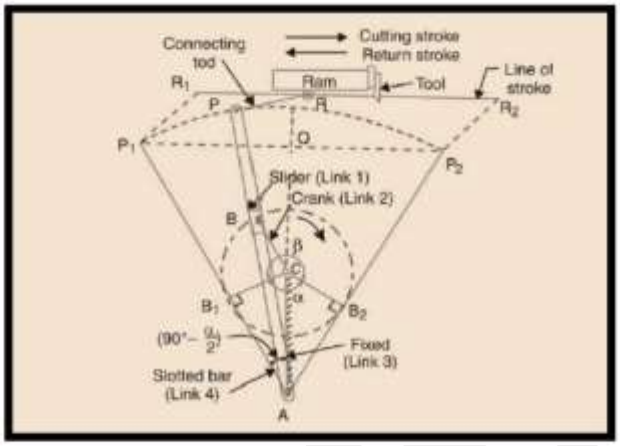

Fig. 1. Crank and Slotted lever Quick Return Mechanism [16]

Quick-return (QR) mechanisms feature different input durations for their working and return strokes. The time ratio (TR) of a QR mechanism is the ratio of the change in input displacement during the working stroke to its change during the return stroke. QR mechanisms are used in shapers, power-driven saws, and many other applications requiring a load-intensive working stroke in comparison to a low-load return stroke [1–3]. Several basic types of mechanism have a QR action. These include slider-crank mechanisms (e.g., see the offset slider-crank mechanism in Fig. 1a and the inverted slider-crank mechanisms, including the crank-shaper mechanism, in Fig. 1b and the Whitworth in Fig. 1c) and four-bar mechanisms (e.g., see the crank-rocker-driven piston in Fig. 2a and the drag-link-driven piston in Fig. 2b). Mechanism analysis techniques taught in a first course on the theory of mechanisms can be applied to evaluate the performance of QR mechanisms. Design of a mechanism, on the other hand, requires determining a mechanism to perform a desired task. For example, synthesis of a reciprocating QR device requires determination of a mechanism to produce a desired TR and a necessary stroke. Note that there is not necessarily a unique mechanism design for a particular task: many mechanism types (e.g., offset slider-crank, Whitworth, drag-link, etc.) may be capable of performing it. Even within one mechanism type, many different link-length combinations (perhaps an infinity of several dimensions [1]) may perform the required task mechanisms of various types and/or dimensions that satisfy the primary task exist, concerns such as mechanism size, minimum transmission angles, maximum accelerations, etc., can be considered to isolate a preferred design. The task of a QR mechanism is simple to understand. Several concepts of design and analysis can be illustrated by a QR mechanism project. For example, students can be exposed to concepts of kinematic analysis, of minimum transmission angles, of type and dimensional synthesis, and of computer-aided modelling programs. Several techniques can be considered and developed by students to achieve the required synthesis task; for example, physical modelling, graphical, iterative, and analytical techniques can all be used to synthesize a desired mechanism. Having a laboratory manual that briefly outlines different possible techniques, and leaves the student-applied technique open, requires a creative algorithm-design process. Over the past 10 years at the Department of Mechanical Engineering, University of Victoria, a variety of projects featuring different mechanism types have been used within a first course on the theory of mechanisms. The QR project, along with similar technique-open projects on inertia modelling and on cam design, has given the students a strong appreciation of mechanism analysis and design issues, and has allowed the assignment to the course of a significant percentage of accreditation units (AUs) for Engineering design [4].1 The project described in this work is assigned to and completed by the students within the first four weeks of a first course on mechanism analysis. This course occurs in the first term of third year, of a semestered four-year academic programme that leads to an accredited bachelor of engineering in mechanical engineering degree.

First, types of QR mechanisms and potential techniques for their synthesis are reviewed. The subsequent section presents a typical set of requirements for the QR project. Note that the project requires application of analysis techniques taught very early within a first course on the theory of mechanisms, requires the development of relevant synthesis techniques, and exposes students to the application of computer-based algorithms for the analysis of mechanisms. Examples of solution techniques that have been used to solve portions of the QR project are then presented. The paper closes with further considerations and conclusions.

A crank-shaper is comprised of a tool driven by an inverted slider-crank. The crank length of a crank-shaper is less than the base length (O2 to O4) of the mechanism. Fig. 1b illustrates a typical configuration. Notice that the crank (member 2) is rotating counter-clock wise in this case and that the follower (member 4) of the driving mechanism (the inverted slider-crank) oscillates between two extremes. The crank displacements at these extremes define the values of a and b for the device's TR. A Whitworth mechanism (Fig. 1c) is formed when the crank of the slider-crank inversion is greater than the base distance. Fig. 1c illustrates a Whitworth QR mechanism, where again the crank (member 2) is rotating counter-clockwise. Notice that the follower (member 4) of the Whitworth is dragged through a full rotation during a revolution of the crank. The crank displacements when the follower is parallel to the sliding direction (horizontal in Fig. 1c) define the values of a and b. Fig. 2a shows a piston being driven by the follower of a crank-rocker four-bar linkage. From the oscillation extremes of the follower, the crank positions B¢ to B≤ are defined. Fig. 2b depicts a QR mechanism driven by a drag-link (also known as a crank-crank) linkage. The extreme positions of the piston occur when the follower direction is parallel to the sliding direction (horizontal in Fig. 2b). Design of QR mechanisms After choosing a mechanism type, appropriate dimensions for the desired task must be selected. Several techniques can be applied. The most basic techniques are physical modelling and graphical. In physical modelling, a scale model (e.g. a 'cardboard and pin' model) is made and the output for a given input is directly measured. The graphical technique involves drawing the mechanism in its various positions.

Physical modelling and graphical solutions are time consuming and can be inaccurate. An alternative is to derive analytical expressions for the mechanism lengths required for a desired TR. Note, however, that it is not always possible to derive a closed-form solution for link lengths as a function of a desired TR, due to the nonlinear from of the TR solution. However, if a closed-form solution for the displacements of the driving mechanism can be found, a solution of the TR for given link lengths can be found iteratively. Searching over the feasible link lengths allows mechanisms having desired TRs to be resolved.

The idea of this project is to expose students to concepts of mechanism synthesis and to provide a practical problem where analytical, graphical, and computer-aided analysis techniques can be applied. An example project problem, for designing a drag-link-based QR mechanism, is given below. Available for this project are two mechanism analysis programs: GNLINK [5], a program developed at the University of Manitoba and the University of Toronto, and the commercial program Working Model® [6]. It should be noted that any QR mechanism type can be substituted for the presented drag-link-based one. Substituting different mechanism types allows the teaching objectives of the project to remain the same, but allows for modification of the project from year to year. Example problem background An application requires a QR mechanism with TR = 1.500 and a stroke of 0.300 m. Currently a drag-link-based QR mechanism exists, as illustrated in Fig. 3. The current lengths of the drag-link mechanism are: distance between fixed centres O2 and O4 = r1 = 0.1000 m, length of crank O2A = r2 = 0.2250 m, length of coupler AB = r3 = 0.3000 m, and length of follower O4B = r4 = 0.2750 m. The length of the slider's coupler is CD = r6 = 0.3000 m and it is connected a distance O4C = r5 = 0.1000 m from O4. The current drag-link crank and follower are made of cast iron and would be expensive to modify. It is proposed to design a new coupler, AB (length r3), for the four-bar and to relocate pin C (length r5) on the follower to create a mechanism capable of performing the task requirements. Furthermore, it is suggested that the coupler should be adjustable in length for future modification of the drag-link-based QR for other TRs.

Solidworks Model and Prototype Component Parts: the component parts from the Solidworks model (Figure 2): slotted lever, guide, crank, coupler link, slider, flange and base. Prototype Component Parts (Figure 3): these components are what make up the frame work for the construction of the prototype: (1) Slotted Lever, (2) Guides, (3) Crank, (4) Coupler Link and Slider, (5) Speed Regulator and Switch, (6) Electric Motor, and (7) Base Box.

Fig. 2. Modelled Quick Return Mechanism using Solid work.

Materials used for Prototype: wood, Bolt and nut of size 10 were used, Glue, Nails, the electric motor. Screws, Switch, Speed Regulator Ruler: the Guiders, Printable Protractor. Equipment:saw, Hammer, Drilling machine, Planer and Chisel.Various procedures were used in the construction of the prototype, these include: woodwork operations: cutting of the plank with a saw into desired shapes, cutting of the coupler link, slider, crank and guards, cutting of the base and planning of the wooden surfaces. Mechanical workshop operations: drilling of holes with the use of the drilling machine based on the dimensions in the design drawing, making of the flange, fixing of the flange to the crank, and fixing of the electric motor to the base. Electrical operations: connection of the switch and regulator to the electric motor.

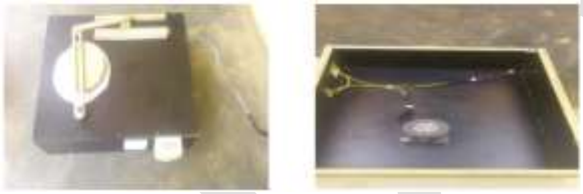

Fig. 3. Prototype Quick Return Mechanism constructed.

Method of Data Collection and Analysis The following methods of data collection and analysis were applied during the course of the project: - Measurements were taken directly from the Prototype, in which the angular displacement of the crank and their corresponding linear displacement values were taken and recorded. - The SolidWorks model was simulated to get the results. This was done once the assembly of the model was concluded. The simulation showed how the slider will move in real life experience.

3. RESULTS AND DISCUSION

The relationship between the slider displacement from the crank center measured in meters and the crank angular displacement measured in degrees are shown in as plotted with the use of EXCEL are shown in Figure 4, significant points have been labeled and explained as Return/forward stroke and Working/Backwards Stroke:

- Return/Forward Stroke: it can be seen that there was an increase in the positioning of the Slider even as the angular displacement of the crank increase. The Return Stroke started from 0 degrees at 0.001 m Slider displacement to 120 degrees at 0.275 m Slider displacement. - Working/Backwards Stroke: it can be seen that there was a decrease in the positioning of the Slider even as the angular displacement of the crank increase. The Working Stroke started from 120 degrees at 0.275 m Slider displacement to 360 degrees at 0.001 m Slider displacement.

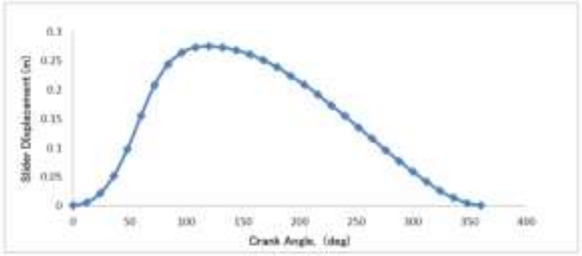

Fig. 4. Slider Displacement against Crank Angle of Solidworks Model.

The relationship between the velocity of the Slider and the time elapsed during the motion simulation performed on the SolidWorks are shown in Figure 5. Significant points have been labeled and explained as: - 1 - 2: this is referred to as the return/forward stroke and it involves a change in crank angle from 0 degrees to 84 degrees with a corresponding sharp increase in velocity from 0 m to 0.523 m/s; - 2 - 3: this is referred to as the working/backwards stroke and it involves a change in crank angle from 84 degrees to 360 degrees with a corresponding gradual decrease in velocity from 0.523 m/s to 0.0005 m. The slider velocity at point 1 is 0 m/s and the slider velocity at point 2 is 0.523 m/s while the slider velocity at point 3 is 0.001 m/s. It is seen that, as against the conventional motion of the crank and slotted lever mechanism which have the forward stoke first with the return stroke following, this crank and slotted lever mechanism has the return stroke first and the forward or cutting stroke following.

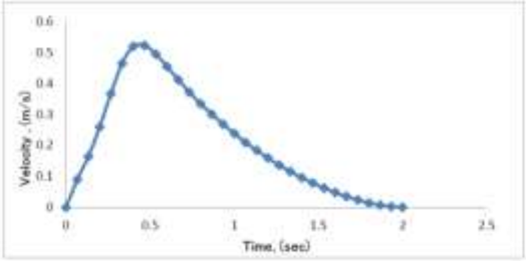

Fig. 5. Velocity Profile of Solidworks Model.

The relationship between the acceleration of the Slider and the time elapsed during the simulation performed on the SolidWorks are shown in Figure 6 below. Significant points have been labeled and explained.The acceleration of the Slider rise rapidly to 1.35 m/s 2 of (2) within 0.067seconds through an angular displacement of 12 degrees for the crank. After this, there was a slight fall in acceleration for the next 0.13 seconds which is followed by a sinusoidal increase in acceleration of the Slider to a maximum value of 1.395 m/s 2 at 60 degrees. Then, followed by gradual decline in acceleration of the Slider to 0.00025 m/s 2 at 360 degrees.

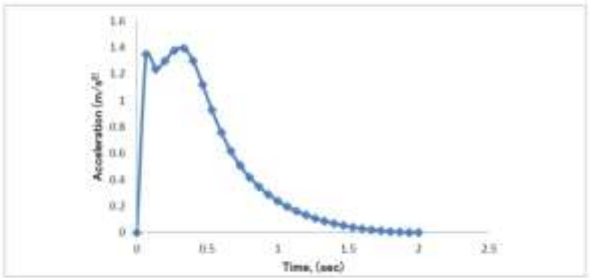

Fig. 6. Acceleration Profile of SolidWorks Model.

This shows the comparison between the experimental results of the prototype and analytical results of the SolidWorks model from MS EXCEL. The analytical results of the SolidWorks model from MS EXCEL were made the standard by which the comparison was done. X (m) = Prototype Slider displacement, x(m) = SolidWorks Slider displacement.The graph in Figure 8 shows the relationship between the measured slider displacement from the prototype and the analytic values of Solidworks obtained from MS EXCEL, it can be seen from the Figure 8 that both curves follow the same sinusoidal path and the maximum and minimum values of both curves coincide at the same angular displacements.

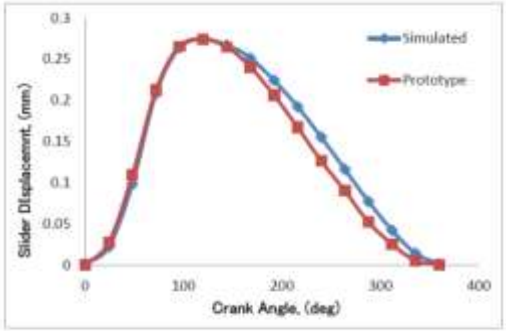

Fig. 7. Analytical Slider Displacement of SolidWorks model and Experimental Slider Displacement Prototype

4. CONCLUSIONS

The following are the deductions and explanations from the results obtained: - The maximum slider displacement for both SolidWorks model and Prototype was 0.275 m, while the minimum slider displacement for both SolidWorks model and Prototype were at 0.001 and 0.000 respectively. - The wave front of the Solid works Model (crank angle and slider displacement graph) in Figure 4 gives the same sinusoidal curve. - The velocity profile and Acceleration profile of the solid works model are shown in Figures 5 and 6. - It can be seen from the prototype that the maximum slider velocity and maximum slider acceleration were 0.520 m/s at 72 degrees and 0.928 m/s 2 at 96 degrees respectively. - The wave front of the prototype against the solid work model as seen in Figure 8, gives the same and very close curvilinear pattern with a positive correlation of 0.992. - The Stroke Length of the Solidworks Model was found to be 0.274m which is not equal to the calculated Stroke Length of 0.275 m; this is due to some technicalities within the SolidWorks design model and that the Stroke Length was gotten from the z plane of the SolidWorks design environment. - The Percentage Stroke Error = $Expected\ value – Actual\ Value\ Expected\ Value$ × 100%= 0.275−0.274 0.275 × 100% = 0.36% (percentage error can be ignored because it was very minute). It could be concluded that similar results were obtained for the Solidworks model and the prototype which confirmed the kinematics of motion of a crank and slotted lever quick return mechanism.The constructed prototype provides a framework for both experimentation and demonstration.The gives a leverage to which international standards can be achieved as regards the availability of Crank and Slotted Lever Quick Return Mechanism in Nigerian Universities.

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