Dynamics of Mechanical Impact on a Quadrilateral Articulated Mechanism

Andra Constantin[1], Sorin Dumitru[1], Nicolae Dumitru[1], Ionut Geonea[1], Cristian Copilusi[1]

[1]Faculty of Mechanics
University of Craiova
Calea Bucuresti, nr. 107, Craiova, 200512, Romania
constantinralucaandra@yahoo.com, [sorin.dumitru, nicolae.dumitru, ionut.geonea, cristian.copilusi]@ edu.ucv.ro

EXTENDED ABSTRACT

1 Introduction

The dynamics of mechanical impact is studied for a planar kinematic chain consisting of a freely moving bar and a fixed plate. Through mathematical modelling and virtual prototyping, the dynamic components of the impact function are identified. The structure of the impact function thus determined is used to study the dynamic response of an articulated quadrilateral mechanism. This mechanism is part of the structure of an experimental stand used for fatigue testing of a torsion spring-bar. It was considered that due to errors in execution and assembly or due to wear, radial clearance occurs in the rotational joint between the rod pivot and the rocker arm bearing. This clearance will lead to the generation of a mechanical impact with considerable effects for fast moving mechanisms, thus the effect of the impact force on the kinematic and dynamic parameters of the mechanism will be studied. The evolution of the kinematic parameters before and after the impact is studied with the Finite Element Method and under the assumption that the contacting bodies are deformable.

2 Mathematical models

In a first step, impact dynamics is studied for a simple planar kinematic chain composed of a freely moving bar under the action of gravitational force and a fixed plate. On this stand the kinematic and dynamic components of the impact force structure are tested theoretically, by virtual prototyping and experimentally. The results obtained will be used for the analysis of the dynamic response of an articulated quadrilateral mechanism with fast motions.

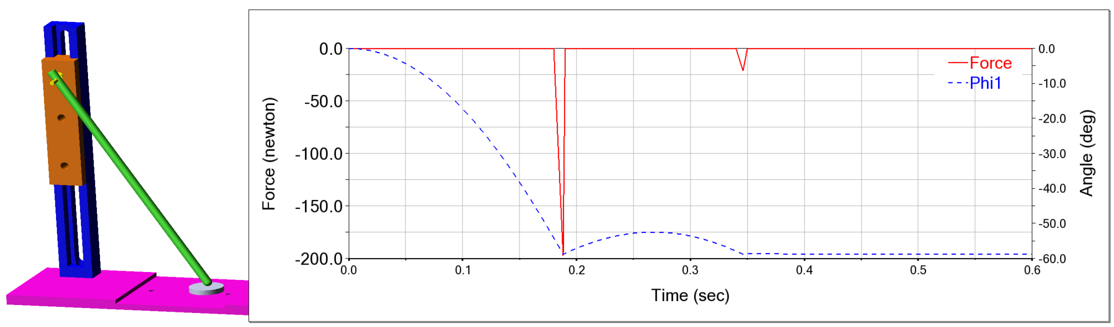

Figure 1: Variation diagrams for impact force and bar rotation angle

A dynamic impact force model of the form [1]:

$$F_{impact} = F\left(y, \dot{y}, y_1, k, e, c_{\max}, d\right) \tag{1}$$

where: y—distance depending on time, which is necessary for the impact function calculus, namely: yA = yA(t); $\dot{y}$ —the point speed at which it will consider that it will actuate the impact force, i.e., speed (point A speed); y_1—a positive real variable, which can be considered to be the free length of *y* component displacement; *k*—stiffness which corresponds to the interaction between the bar and the contact surface; *e*—is a positive real variable which specifies the deformation characteristics exponent of the applied force; c_{max}—is a non-negative, double-precision variable that specifies the maximum damping coefficient; *d*—is a positive double-precision variable that specifies the secondary penetration at which ADAMS/Solver applies full damping.
A dynamic impact force model of the type shown in relation (1) was constructed in the Adams program:
IMPACT (.MODEL_2.dz_25, .MODEL_2.vz_25, 1.0E-02, 307692, 3.2, 1, 0.01), where:
- dz_25 is the z-axis displacement of the marker 25;- vz_25 is the z-axis velocity of the marker 25;
-distance y_1=1.0E-02; -stiffness k=307692; -force exponent e=3.2; -damping factor c_{max}=1; penetration depth d=0.01.
Several experimental methods were used to determine the results of the indentation process, i.e. microscopic analysis, profilometer for determining the maximum indentation or 3D scanner. Measurements were made on several samples, following two directions longitudinal and transverse.

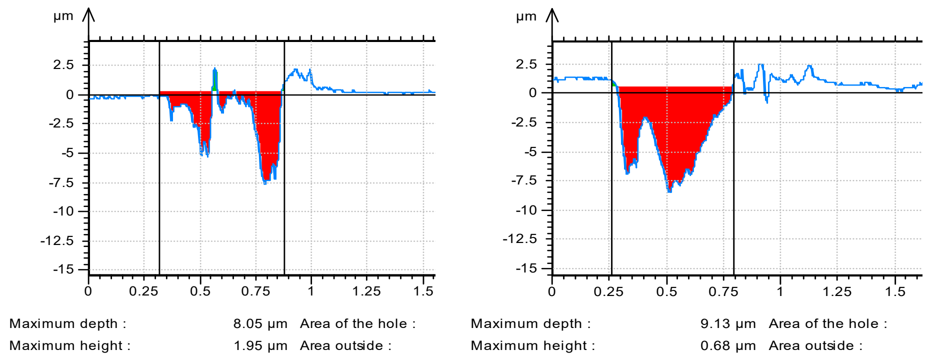

Figure 2: Profile variation after impact (longitudinal, cross section)

3 Dynamic analysis of the mechanical impact of an articulated quadrilateral mechanism

To determine the impact force at the contact between the bar and the fixed plate, we considered two phases leading to the indentation process: the elastic phase and the elastoplastic phase. The contact force in the elastic phase was determined based on Hertz theory [2]. For the elastoplastic phase several models were used [3, 4]. A mechanical impact analysis was carried out on an articulated quadrilateral mechanism, which is part of the structure of an experimental stand, used for fatigue testing of a torsion beam spring in an automobile structure. The components of the mechanism are: the flywheel (crank), the connecting rod, which is adjustable in length, and the rocker arm. We considered that between the centre of rotation of the connecting rod pivot (marker_75) and the centre of the rocker arm bore there is a radial clearance of 0.05 mm.

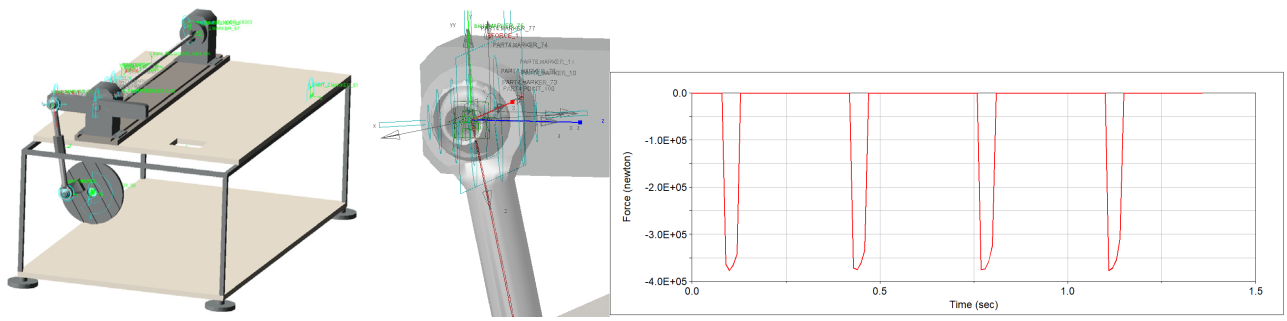

Figure 3: Test bench - articulated quadrilateral mechanism, location of MARKER_76 and obtained impact force

The dynamic impact force model is: IMPACT (.model_1.dy_76, .model_1.vy_76, 50, 486807.8459, 0.1, 100, 1.0E-03)

4 Conclusions

Through theoretical, virtual and experimental modelling, the dynamics of mechanical impact at the contact between a rotating bar and a fixed plate was studied. The dynamic impact force model was used for the analysis of the dynamic response of an articulated quadrilateral mechanism. The presence of mechanical impact, due to errors in design and assembly and due to wear in the joint, influences the kinematic parameters of the mechanism (velocities and accelerations), the driving moment and the linkage forces in the joints.

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