Design of Measurement System for Rotary Swaging Force Measurement

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Abstract: This article describes a design of the measurement system for rotary swaging force measurement. Rotary swaging in its present form is an up-to-date way of material forming. Rotary swaging is an incremental process of material forming for the purpose of reducing and forming raw material cross-sections and can be used, for example, in the production of various rotary and non-rotary forged iron products, rods, wires, sensor detectors or composite materials. However, force measurement is no standard part of this production technology. In this article, the first version of the measurement system design is introduced. The force measurement has been conducted in the case of two raw products in different deformation and reinforcement stages of materials. The obtained results and swaging force progress are also commented here.

Keywords: Rotary swaging; Force measurement; Force sensor; Signal transmission.

1 Introduction

Rotary swaging in its present form is an up-to-date way of material forming, which unlike other technologies of forming has the following advantages. The main advantages of rotary swaging are the high-quality surface, dimensional accuracy, and productivity of the production output of forged iron products. It is usually not necessary to perform subsequent machining or other surface treatment. In this sense, this technology can be applied in, for example, production of various rotary as well as non-rotary forged iron products, rods, wires, sensor detectors, or composite materials, e.g. copper-clad steel composite conductors used as conductors in automotive and aviation industry[1, 2, 3, 9]. However, force measurement is no standard part of this production technology. The determination of required material deformation stage and optimization of shapes and sets of metal liners is usually based on the existing acquired experience and lately also on MKP analyses based on tested load capacity of the forging machine [4]. In cooperation with the Department of Materials Forming, Faculty of Metallurgy and Materials Engineering, in finding new research solutions, the demand for a measurement system allowing real-time recording and demonstrating swaging force has arisen.

2 Rotary Swaging Description and Measurement System Design

In reality, there are several forging machine arrangements. They can roughly be divided on the basis of the number of the forging mechanism parts rotating inter se. For the purpose of our experiments, the forging machine arrangement (Fig. 1) has been used. Raw product (1) is deformed into the required final shape by forging segments (2), which perform a radial movement up and down, i.e. perpendicular to the axis of rotation, in rapid succession one after another. There can be two to six forging segments. The force required for the raw product deformation is induced by dynamic impacts occurring between a forging metal liner (3) and rollers (6), which are placed in the cage (5). The rollers roll against the supporting ring (7), which is static on the basis of the selected constructional arrangement, or it can also perform rotary movement along with the cage. The swaging segment and metal liner are placed in a carrier (4) and they rotate around the axis of rotation together. The respective planes of the metal liners are profiled into the required shape of the final forged piece. The raw product is let in the space between metal liners in the direction of the axis of rotation. Using this constructional arrangement with the induced radial forces, the raw product is deformed into the required shape. The longitudinal feed of the raw product can be either manual or smooth using a feeder. In the workplace of the authors, the prototype of the measurement system suitable for measuring rotary swaging force [5, 6] has been designed and further constructed. The system consists of a tensometric force sensor, which replaces a selected control member of the forging system [7]. The sensor is connected to the suitable apparatus, which is installed on the carrier (4), which it performs the rotary movement with. Using wireless transfer, the apparatus communicates with the computer installed out of the working area of the forging machine. A suitable graphic interface is installed in the computer and provides wireless communication with the selected apparatus and records the measured data and processes them. The graphic and communication interface has been developed in LabVIREW [8] program. The apparatus location on the forging machine is shown in Fig. 2.

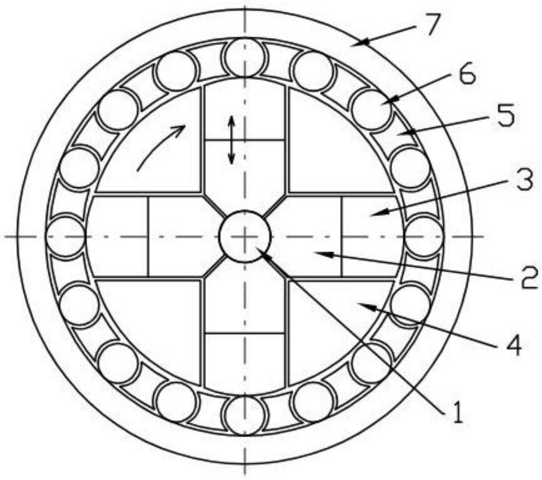

Fig. 1: Rotary swaging principle.

Fig. 2: Forging machine with the installed measurement system.

3 Experimental Results

In order to test the designed measurement system, the raw product with a circular section of 50mm in diameter and 100 mm of length has been selected.

The final forged piece will also have the circular section of 40 mm in diameter. The selected material reduction comes from used forging segments supplied by their producer and these were then fit on the forging machine before installing the measurement system. The raw product was made of spring steel. The record of the forging force progress in time during the whole length of operation of the forging machine is shown in Fig. 3.

The longitudinal feed of the raw product into the space between the forging segments was manual, and thus not smooth. Therefore, the forging force progress shown in Figure 3 also corresponds to that. The forging force progress has several characteristic intervals. The time record in the interval of 0 – 32s corresponds to the rest mode of the machine. The time record in the interval of 32 – 80s shows the forging force at the moment of the carrier approaching with forging parts in selected revolutions and in idle run without the raw product. The forging force value here is around 100kN. From the interval of 80s, the raw product starts to be pressed into the working space of the rotating forging segments. There is an apparent rapid increase in forging force up to the value of about 645kN. A slight decrease of this force corresponds to lower speed of the longitudinal feed of the raw product into the working space of the forging machine. In the interval of 280s, the process of swaging the raw product was finished and the forged piece left the working space of the forging machine. The record of the interval of 280 – 400s corresponds to the idle run of the machine without the forging process and coasting of the machine as a result of momentum at the time of turning the machine off. From the interval of 400s until the end of recording, the machine is in the rest mode.

The force curve in Figure 3 shows the resulting envelopes of force, which burns maximum values of the measured force in each cycle of the machine. The recording of the force in time has been conducted at the frequency of 2000 kicks of the forging segment per minute. In Fig. 4, the real progress or curve of the forging force is shown in time during swaging, which provides foundation for generating the envelope of the forging force curve shown in Fig. 3.

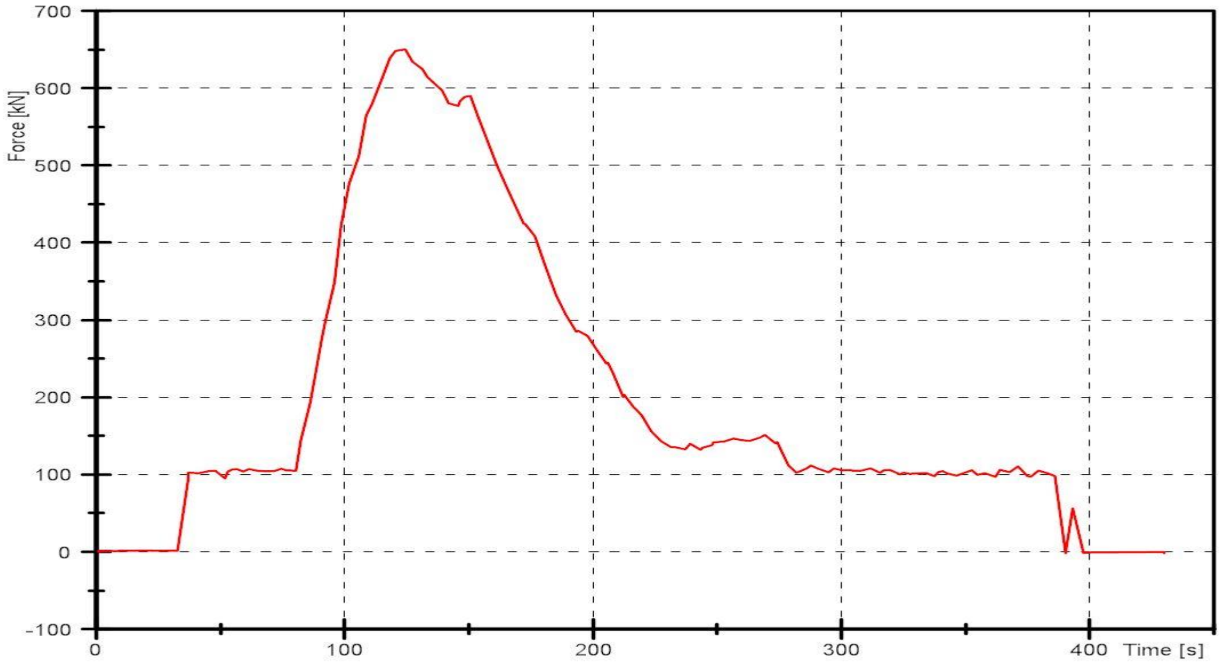

Fig. 3: Record of the forging force progress in time during the whole length of operation of the forging machine.

The resulting forged piece with the diameter of 40mm was significantly reinforced by the deformation during swaging. Thus treated, the forged piece was again put into the feeder of the forging machine. In the forging machine, the forging segments were replaced so as the resulting forged piece also had circular section with the diameter of 30mm. The record of the forging force curve in time during the whole length of operation of the forging machine is shown in Fig. 5.

Maximum force measured during this swaging was 735kN. The curve of the forging force has similar character as in the previous case including the machine operation stage without applying swaging load.

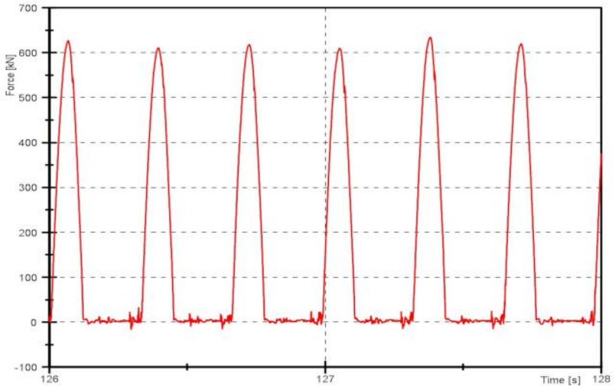

Fig. 4: Cut of the real forging force curve in time during forging (swaging).

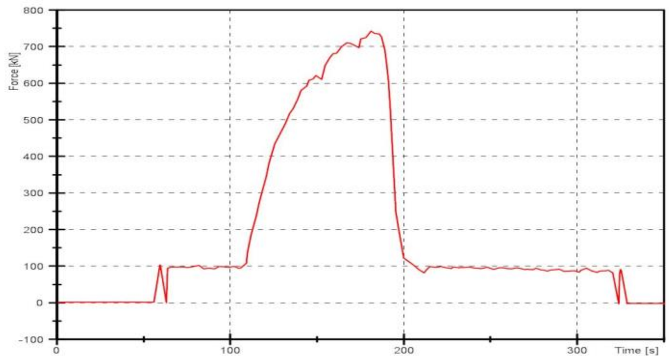

Fig. 5: Record of the forging force curve of the second raw product.

4 Conclusion

The presented article shows Design of Measurement System for Rotary Swaging Force, which is the up-to-date way of very accurate raw products forming. The prototype of the measurement system was designed and installed onto the forging machine. The measurement system consists of a special force sensor, measuring apparatus, and a computer with tailor-made graphic and communication interface. This interface is further used for setting up the measurement system in order to record and evaluate obtained results from the forging force measurement. Communication between the computer and the measuring apparatus has been performed using wireless data transfer.

For verification of the measurement, two experiments have been conducted. The progress of the forging force is demonstrated in Figures 3 and 5. The measurement results in the envelope of the forging force curve and its shape. The maximum value of the forging force is dependent on the speed and size of the conducted deformation during the rotary swaging and also on the inner stress of the raw product. In the first case, the measurement result was compared to the results obtained from MKP simulation. The maximum force here is in compliance in the order of units. The measurement results and acquired experience will lead to upgrading the constructional version of the measurement system applied. The measurement system is protected by a patent with the registration number: 305725.

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