PROCESS QUALITY ANALYSIS AND MONITORING METHODOLOGY FOR ROLLER BEARINGS CAGES STAMPING

Ripanu Marius-Ionut [1], Nagiţ Gheorghe [1], Merticaru Vasile [1], Huşanu Valerică [2], Iacob-Strugaru Sorin-Claudiu [1]

[1] "Gheorghe Asachi" Technical University of Iaşi; [2] SC RULMENTI SA, Bârlad
ripanumariusionut@yahoo.com; nagit@tuiasi.ro; v.husanu@urb.ro; v_merticaru_jr@yahoo.com; issc71@yahoo.com

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Abstract: The paper presents a methodology developed for process quality analysis and monitoring of the stamping technology for manufacturing steel roller bearings cages. The stamping technology subjected to the case study is part of the industrial process of manufacturing steel window-type cages for spherical roller bearings with two rows of symmetrical rollers. The research approach is based on a cause & effect analysis upon the qualitative and quantitative parameters involved in the quality and accuracy of the stamping process. An obtained hierarchy of the critical input parameters is also presented and discussed in the paper.

1. INTRODUCTION. PROBLEM STATEMENT

The paper presents a methodology developed and applied for process quality analysis and monitoring of the stamping technology for manufacturing steel roller bearings cages.

1.1. GENERAL OVERVIEW UPON ROLLER BEARINGS MANUFACTURING

Roller bearings manufacturing represents and will represent one of the most viable and profitable area within machine manufacturing industry, as long as roller bearings practically can be considered as essential parts of almost every product which has a rotating shaft.

Studies of engineering value analysis developed by specialists, [3], evidence some credible reasons for important concerning and preoccupation in maintaining and development of roller bearings industry, in their constructive and functional optimization, of course in relation with the optimization of the associated manufacturing processes. Such reasons are:

- market demand increasing for roller bearings as industrial products, in relation with the increasing of the number of machines and equipment including them as sub-assemblies;
- integration of roller bearings in industrial applications for realizing technical performances at strictly specified levels;
- significant contribution of roller bearings for the reliability and durability of the product or equipment where they are integrated.

Under the nowadays demands regarding sustainability for products and processes, roller bearings must provide performance in reliability, efficiency and ecology, even in the harshest conditions.

No matter the industrial application area, respectively the mining and extracting industry, metallurgy, energy production, construction industry, agricultural equipment, wood industry, celulose and paper industry, machine manufacturing, automotive or aircrafts industry etc., industrials [5] generally stipulate precise quality requirements for roller bearings, sometimes in relation also with the difficult operation environment.

For applications like measuring instruments, computer components, radar antennas or machine-tool spindles, accuracy requirements are the most important and tipically higher.

On the other hand, other general applications of roller bearings, like automotive applications, electric motors, agricultural and construction equipment, do not require the highest precision and tolerances control, [4]. In such conditions, roller bearings manufacturers provide their products at varying degrees of precision and tolerance.

The international standards for roller bearings industry stipulates control of size limit tolerances for all envelope dimensions [4] such as outer and inner rings widths, bearing bores, outside diameter, tapered bores, chamfer dimensions etc.

1.2. ASPECTS ABOUT SPHERICAL ROLLER BEARINGS WITH TWO ROWS OF SYMMETRICAL ROLLERS

Spherical roller bearings with two rows of symmetrical rollers are a particular type of roller bearings which cover the majority of the functional requirements in a large variety of standard or special industrial applications. Spherical roller bearings with two rows of symmetrical rollers are interchangeable and each configuration can be successfully replaced by another, in the conditions of providing similar performances in standard applications.

Industrial manufacturers produce different types of spherical roller bearings with two rows of symmetrical rollers, with brass cages or sheet metal cages, [7].

1.3. ASPECTS IN ROLLER BEARINGS CAGES MANUFACTURING

The main function of the roller bearing cage is to avoid direct contact between the rolling elements. At the roller bearings, the cage realizes also the guidance of rollers and at the roller bearings with separable rings the cage retains the rolling elements.

Because of the forces of inertia, friction and deformation, the cages are submitted to mechanical stress and to chemical action of lubricants and additives. For such reason, the design and material of cages represent key elements for roller bearings performance [7].

Industrial practice evidences the following variants of manufacturing for roller bearings cages [4]:

- Stamped cages, which allow the use of more and larger rolling elements;
- Machined cages, which have the property to reduce wear and unbalance in high speed exploiting;
- Riveted cages, which provide a strong connection for the cage assembly;
- Molded cages, recommended in high speed operating.

Stamped cages can be manufactured after a technological process as the one presented in Fig. 1.

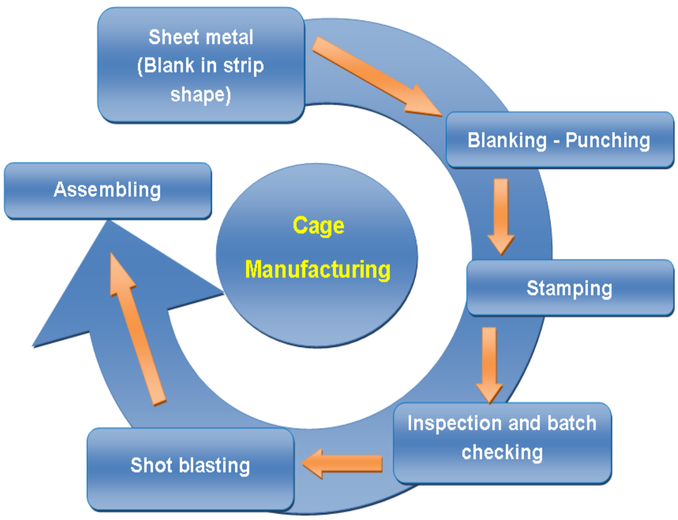

Fig. 1. Process chart for metal cages manufacturing *(after* [1]*)*

1.4. PROBLEM STATEMENT

One of the most important aspects concerning the roller bearings cages is related to the manufacturing accuracy and quality. On the other hand, roller bearings cages are usually made of materials with low hardness and, in such conditions, exploiting factors like external pressure and direct contact with other parts can determine damages like distortion or dents. Such manufacturing or exploiting defects can aggravate and determine chipping or cracking, which can affect the smooth movement of the rollers.

As a conclusion, process quality analysis and monitoring of the manufacturing processes for roller bearings cages become vital for industrials in the area.

Providing a predictable uniformity and repeatability for the roller bearing cage process will assure a consistent performance of the roller bearing. Variations in the manufacturing process may lead to products which overpass the admissible tolerances.

2. RESEARCH APPROACH IDENTIFICATION

The scientific research approach upon process quality analysis and monitoring of the stamping technology for manufacturing steel roller bearings cages, which makes the object of the present paper, represents a collaborative team work of specialists from "Gheorghe Asachi" Technical University of Iaşi and from SC RULMENTI SA Bârlad, the productive enterprise being interested in the optimization of their roller bearings manufacturing processes.

By the identification and the analysis of an existing technology for manufacturing steel roller bearings cages, there can be evidenced the main factors which can influence the accuracy and quality of such a part.

Regarding the process of cage stamping, the cage configuration and precision, material thickness and material quality are some of the most involved parameters. When establishing the configurations and dimensions of the cage, technological requirements imposed by the stamping process, such as providing a minimum number of operations, more simple and more reliable and durable stamping devices and not at last reduced process preparing times, are considered.

In this sense, further on in the paper, a Cause & Effect Analysis upon the qualitative and quantitative parameters involved in the quality and accuracy of the cage windows stamping process which is part of the industrial process of manufacturing steel window-type cages for spherical roller bearings with two rows of symmetrical rollers is presented.

3. CASE STUDY DESCRIPTION

The part which makes the object of the case study is a window-type steel cage for spherical roller bearings with two rows of symmetrical rollers as it is shown in Fig.2.

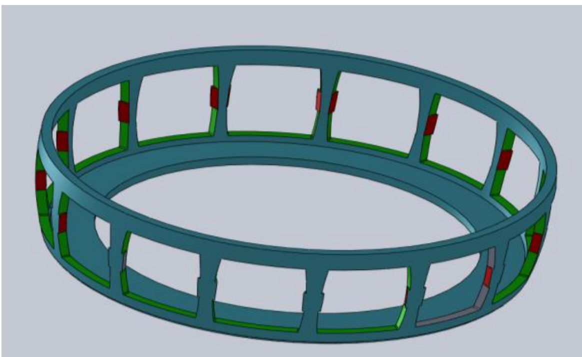

Fig.2. Steel window-type cage for spherical roller bearings with two rows of symmetrical rollers

The considered roller bearing cage is processed by stamping on a hydraulic press LVD 600 and the windows were the spherical rollers are positioned are executed by precision stamping.

Within the considered case study,

the steel window-type cages for spherical roller bearings with two rows of symmetrical rollers are obtained by getting through 4 cold forming technological operations:

- Sheet metal cutting in strips having the dimensions of 1000x312.5x4 mm;
- Steel cage primarily shape obtaining by one blanking-drawing operation, as it is shown in Fig. 3 – left;
- Punching of the cage bottom and calibration, in the same operation, as it is shown in Fig. 3 – right;
- Simultaneous punching and calibrating of cage windows.

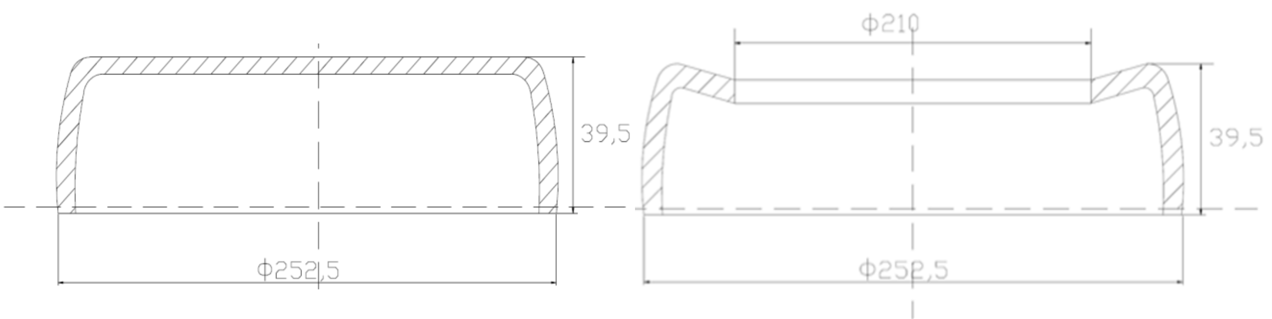

Fig.3. Steel cage after blanking-drawing and punching-calibrating operations

After the stamping process, the cage is machined by frontal lathing, internal lathing and blasting operations.

Measurements of the accuracy and quality parameters of the processed steel cages for spherical roller bearings with two rows of symmetrical rollers have been performed in the Quality Measurements Laboratory of SC RULMENTI SA Bârlad.

Accordingly to the technical documentation and to the procedures existing at the industrial partner, the accuracy and quality parameters which are controled after the stamping processes are the following:

- Burrs occurrences;
- Fissures, Breaks occurrences;
- Deformations;
- Cage windows dimensions (Cage window height, H; window width; retaining shoulder);
- Cage window compass;
- Other defects visually detected (Slippages; partial course).

For identifying the technological factors with possible influence upon the quality and accuracy of the stamped cages, the industrial experience of the specialists and experts involved in monitoring the process of roller bearing cages manufacturing has been integrated within the research approach.

Within the Cause & Effect Analysis approach, an Ishikawa (Fishbone) Diagram has been built for the considered process. Such a diagram helps to identify the multiple possible causes for effects or for a problem, in our case for the quality and accuracy of stamped parts.

The mentioned Cause & Effect Diagram has been developed as result of a brainstorming process with specialists of the process owner and with other experts from the area of the problem to be solved. The ideas of the brainstorming process have been in this way classified in useful categories.

The obtained diagram is shown in Fig. 4. Such a diagram realizes only the identification of the possible causes of the studied problem.

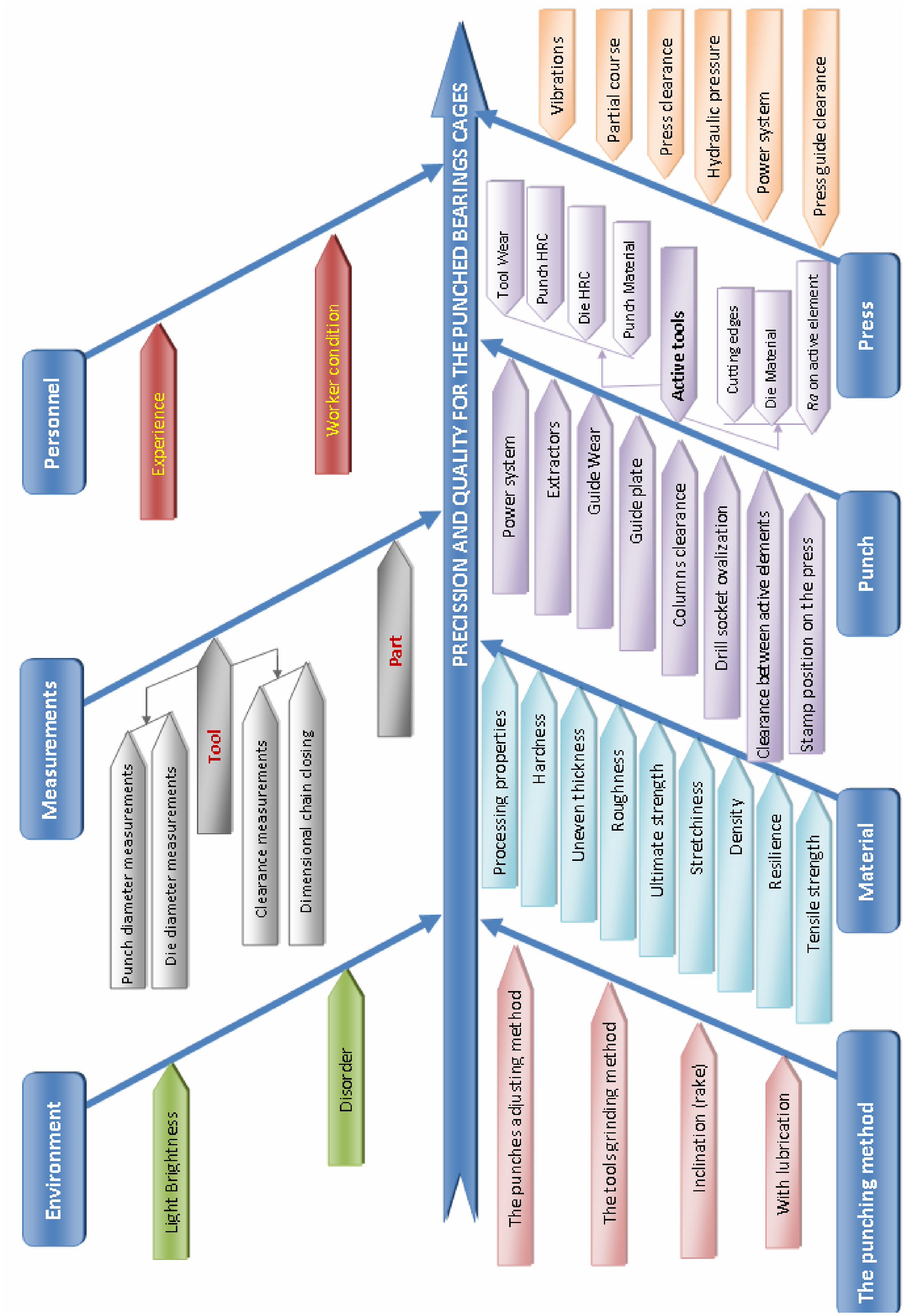

Fig. 4. Cause & Effect Diagram

In the process of creation of the Ishikawa (Fishbone) diagram, the following steps have been practically got through:

- ✓ Expert team forming ;
- ✓ Problem identification and clearly defining of effects;
- ✓ Fishbone diagram drawing;
- ✓ Brainstorming upon the main categories of problems causes;
- ✓ 7 significant categories of causes have been identified for the considered stamping process;
- ✓ Potential causes identification.

The technical and scientific knowledge of the work team made possible to quantify each cause's influence upon the accuracy and quality parameters for the stamped parts. In this sense a Cause & Effect Matrix built within a brainstorming session was used, in relation with the above presented Fishbone Diagram.

This matrix allows numerical quantification of the relation between process inputs and outputs. The considered outputs were the defects controlled accordingly to the procedures of the industrial partner in the research. The corresponding quantification was made by the team process experts and illustrates the team knowledge upon the process in the current stage.

The Cause & Effect Matrix allows to the research team to identify and agree upon the most critical inputs, in the sense of further optimizing investigations.

The Cause & Effect Matrix obtained with an especially built Excel worksheet is shown in Table 1.

Table 1. Cause & Effect Matrix

Cause & Effect Matrix no.1										
Accuracy and quality for the punched bearing cages (Process outputs)										
			1	2	3	4	5	6	7	
			Burr	Fissure, Break	Deformation, Slippage	Cage window height, *H*	Retaining shoulder	Window compass	Partial course	
Rigor			7	9	5	8	9	4	9	
Process Stage	Process inputs									Total
Cage Punching	1	Columns clearance	8	8	7	6	6	5	2	303
	2	Clearance between active elements	9	9	8	5	8	4	2	303
	3	Guide plate	4	4	2	2	2	2	4	152
	4	Extractors	2	2	2	2	2	2	2	102
	5	Drill socket ovalization	7	7	7	8	8	4	2	317
	6	Guide wear	7	4	4	4	4	2	6	235
	7	Stretchiness	2	2	2	2	2	2	2	102
	8	Power system	2	2	2	2	2	2	2	102
	9	Press clearance	4	4	3	2	2	2	8	193
	10	Hydraulic pressure	7	7	5	2	2	2	8	251
	11	Press guide clearance	7	7	4	2	2	2	8	246

	12	Partial course	7	7	7	6	8	5	8	359
	13	Vibrations	1	1	1	1	1	1	1	51
	14	Experience	3	3	3	2	2	2	2	123
	15	Worker condition	4	5	2	2	2	1	1	130
	16	Adjustment	8	8	8	8	8	2	8	384
	17	Measuring caliber	1	1	1	1	1	1	1	51
	18	Clearance measurement	7	7	7	7	7	1	7	333
	19	Die diameter measurement	8	8	5	8	8	7	7	380
	20	Punch diameter measurement	8	8	5	8	8	7	7	380
	21	Stamp position on the press	2	2	2	2	2	2	6	138
	22	Light brightness	1	1	1	1	1	1	1	51
	23	Disorder	1	1	1	1	1	1	1	51
	24	The tools grinding method	9	9	9	5	5	6	7	361
	25	The punch adjusting method	9	9	9	9	9	7	3	397
	26	Punch Inclination (rake)	9	9	9	3	5	1	6	316
	27	With lubrication	2	2	2	2	2	2	1	93
	28	Processing properties	9	9	9	6	7	6	3	351
	29	Hardness	6	7	7	2	2	1	2	196
	30	Uneven thickness	8	8	9	5	5	4	6	328
	31	Roughness (Sheet metal)	9	9	9	6	7	6	3	351
	32	Ultimate strength	5	8	7	2	2	2	1	193
	33	Tensile strength	5	8	7	2	2	2	1	193
	34	Stretchiness	5	8	7	2	2	2	1	193
	35	Density	4	4	3	1	1	1	1	109
	36	Resilience	5	8	7	2	2	2	1	193
	37	Punch HRC	3	3	5	3	3	3	6	190
	38	Die HRC	3	3	5	3	3	3	6	190
	39	Punch material	3	3	5	3	3	3	6	190
	40	Die material	3	3	5	3	3	3	6	190
	41	R_a on active element	7	6	9	2	2	2	1	195
	42	Tool Wear	8	8	8	8	8	8	8	408
	43	Cutting edge	8	8	8	8	8	8	8	408
	44	Dimensional chain closing	9	8	7	5	5	3	9	348
Total			1673	2232	1175	1328	1548	536	1638	

In column *Total* from the Cause & Effect Matrix, the score obtained for each input can be found. There have been considered as critical inputs for the considered process, all the inputs having scores bigger than 300. The obtained hierarchy of the critical input parameters involved in the quality and accuracy of the cage windows stamping process is shown in Table 2.

Table 2. Hierarchy of the critical input parameters upon stamping process

No.	Process input	Value	Hierarchy
1.	Cutting edge	408	1
2.	Wear	408	1
3.	Punch diameter measurement	380	2
4.	Die diameter measurement	380	2
5.	The punch adjusting method	397	3
6.	The tools grinding method	361	4
7.	Partial course	359	5
8.	Processing properties	351	6
9.	Roughness (Sheet metal)	351	6
10.	Dimensional chain closing	348	7
11.	Uneven thickness	328	8
12.	Columns clearance	303	9
13.	Clearance between active elements	303	9
14.	Drill socket ovalization	317	10
15.	Punch Inclination (rake)	316	11

4. Conclusions

For specific applications of roller bearings, the selection of a particular and appropriate configuration of cage is essential. In the situation of standard roller bearings applications, each cage configuration is interchangeable with any other, providing similar performances. Regarding the material type of cages, the performance differences between the steel cages and the brass cages are insignificant, but often the steel ones are the cheaper solution.

The above presented research approach refers to a cause & effect analysis upon the qualitative and quantitative parameters involved in the quality and accuracy of the cage windows stamping process which is part of the industrial process of manufacturing steel window-type cages for spherical roller bearings with two rows of symmetrical rollers. The obtained results evidence the hierarchy of the critical input parameters. Based on experimental researches, an improved methodology for process quality analysis and monitoring of the presented stamping technology, which will consider also other important quality parameters, is intended to be further on developed and industrially applied.

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