RATIONAL CRITERIA FOR QUANTIFYING THE PERFORMANCE
OF MECHANICAL PRESSES

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SOMMARIO: Nel campo della ingegneria meccanica, un grande interesse rivestono le questioni concernenti la corretta definizione delle prestazioni di una pressa e i metodi teorici e pratici per determinare i corrispondenti limiti ammissibili di esercizio.

Dopo uno studio preliminare sui parametri realmente significativi, viene esposto un metodo analitico per ottenere la soluzione in forma quantitativa di problemi concernenti con la determinazione delle condizioni di esercizio compatibili con il regolare funzionamento della pressa.

Come conclusione, si propongono alcune generali relazioni per la formulazione quantitativa delle prestazioni delle pressa meccaniche e per descrivere in forma razionale le caratteristiche operative e di impiego di detta macchina.

SUMMARY: In the practical mechanics a great interest have for the mechanical engineers the questions concerning a correct definition of the performance of a mechanical press and the theoretical and practical methods to determine its allowable limit in service.

After a preliminary study on the parameters really significant, this paper shows an analytic method to get, in quantitative form, the solution of the problems concerning the determination of the duty conditions compatible with the regular operation of a mechanical press.

As a conclusion, some general relations are proposed in order to describe quantitatively the performance of a mechanical press and to give a rational form to the set of mechanical quantities characterising it.

PART I

I.1. Terms of the problem.

Let us consider an eccentric mechanical press having a set rhythm of working and suppose — to keep within sufficiently general terms — that this press has a variable stroke and a connecting rod of variable length.

The problem is to give quantitative expression to the performance that can be obtained from the machine, that is to define the range within which the machine may be used without appreciable risk of damage by a generic user.

An attempt will be made, on the basis of the results obtained from handling the above problem, to establish some rational criteria for defining the commercial performance of the press.

I.2.1. Operating conditions of the press.

An eccentric mechanical press consists essentially of:
— a frame;
— a power unit (including conceptually the flywheel);
— a mechanical drive that transforms the rotary motion of the power unit into the reciprocating motion of the ram, to which the tool punch is generally rigidly connected;
— accessory devices that take part only indirectly in the operations performed by the press.

The parameters defining the operation of a machine of this kind are generally constant and will be dealt with as such. Only 2 parameters will be considered as variable quantities: they describe respectively:
— the trim of the pin of the main crank mechanism of the press (with its eccentric bush);
— the position of the ram with respect to the connecting rod pin of the crank mechanism.

The former may be satisfactorily (even though not biuniformly) expressed by the stroke of the machine and the latter by the length of the connecting rod.

The operating conditions of an assigned press will be defined by the parameters:

\[ C \] (stroke) — length of the segment of straight line constituting the trajectory of the ram; in other words, \( C \) is the distance between the top dead center \((TDC)\) and the bottom dead center \((BDC)\) of the stroke of this machine member.

\[ L \] length of the connecting rod.

I.2.2. Operations performed by the press.

By operation performed by the press we mean the modifications that the tool applied to the machine produces in the workpiece in the course of a to-and-fro reciprocating motion of the ram along its power stroke.

From a purely technologic standpoint, an operation may be generically defined by a conventional name describing the principal features of the modifications produced in the workpiece: it can be assimilated to one of the types described in mechanical technologies (die-stamping, shearing extrusion, drawing, coining, etc.) whose meaning is presumed known.

For our purposes a criterion of this kind is insufficient
and must be completed by the quantitative expression of some essential aspects of the operation.

In the first place, it is necessary to define the working stroke of the operation, i.e. the location of the starting and finishing points of the stroke when the modifications of the workpiece begin and end. To simplify the treatment of the problem and allowing for the fact that the convention assumed here corresponds (sometimes, admittedly, only approximately) to the facts in the majority of cases, it will be assumed that the finishing point of the working stroke coincides with the \( BDC \). In this way, the geometric aspects of the operation are completely defined when the length \( c \) of the working stroke is assigned.

In the second place, it is necessary to describe the forces that develop in the press when the operation under consideration is executed: these generally depend upon the resistance set up by the workpiece to the motion of the ram. This means that we have to know in quantitative terms the function representing the amount of this resistance to the motion of the ram versus time. This presents considerable difficulties both practical and theoretical, such that the general tendency is to get round them by adopting for this function the following simplified scheme:

- during the part of the operating cycle in which the tool is not in contact with the workpiece (i.e. is outside the working stroke), the resistance to the motion of the ram is assumed to be zero;
- during the working stroke the resistance to the motion of the ram is defined by its maximum value \( P_0 \) (here called "the load required by the operation") and by the factor \( e \) defined by the relation

\[
\varepsilon = \frac{E}{P_0 \cdot \varepsilon}
\]

\( E \) being the work absorbed in the course of the operation.

Generally, since \( \varepsilon \leq 1.0 \), it is argued that the resistance to the motion of the ram must be regarded as expressed by a function variable through time whose maximum value \( P_0 \) occurs at one or more unknown instants of the working stroke.

Any ambiguity arising out of the assumed scheme can be removed if we admit that — to be on the safe side — load \( P_0 \) occurs in the press at the instants in which it makes heaviest the working conditions of the various machine members.

Factor \( \varepsilon \) depends mainly on phenomena extraneous to the structure of the machine and relating to accessory features of the operations (lubrication of the dies, geometry and assembly of the tools and so on), and on the mechanical properties of the materials. They may therefore be regarded in the remarks that follow — be regarded as defined by the range of the remarks that follow — be regarded as defined by the following parameters:

- working stroke \( c \);
- required load \( P_0 \);
- factor \( \varepsilon \).


On the basis of the foregoing remarks, any operating condition of an assigned press is defined — within the range of the restrictions described in I.2.1. — by a pair of values \((C, L)\) that describe the movement of the ram in a sufficiently complete form, provided that the constructional and operating characteristics are given.

Hence if we consider a plane \( H \) and in it a cartesian coordinate system, orthogonal for example, having the variable \( L \) on the abscissae and the variable \( C \) on the ordinates, there is a biunivoc correspondence between points \( Q(H) \) of plane \( H \) and the operating conditions of the press in question.

Since in general

\[
C > 0 \quad L > 0
\]

hence all the physically meaningful points \( Q(H) \) lie in the first quadrant.

In general, the operating conditions available to the machine are defined by the set \( Q(H) \) of points that in the representation described are compatible with the constructional characteristics of the machine.

This set may be continuous with respect to both variables (which occurs unless there are other restrictions apart from maximum and minimum), continuous with respect to one of the two variables (if the other can assume only a discrete number of values, or if there is a constraint of the type \( f(C, L) = a_n \), \( a_n \) being the generic element of a discrete set of parameters), or discrete (when, for instance, only a given number of values \( C \) and \( L \) is available).

Because of the foregoing, mention should be made in the machine characteristics (this usually happens anyway) of the quantities that make it possible to define the available operating conditions.

With regard to the operations that can be carried out on the press, these, within the range of the restrictions imposed in para. I.2.2., can be satisfactorily defined by cartesian axes of values \( c, P_0, \varepsilon \); thus if we consider a three-dimensional space \( O \) and in it a cartesian coordinate system \((c, P_0, \varepsilon)\) (for example, orthogonal), there is a biunivoc correspondence between the points of this space and the operations that can be carried out on the press. Since, according to the conventions assumed:

\[
\varepsilon > 0 \quad P_0 > 0 \quad \varepsilon > 0
\]

it follows that of the space in question only points \( Q(O) \) belonging to the first octant are of interest.

Let us now suppose that the press is set to work according to an operating condition \( Q(H) \) belonging to a field