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Friction Calibration Using Centre Intrude Specimens And Their Experimental Verification

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Abstract

This research aims to investigate the possibilities of alternative non-conventional specimens for friction calibration. From literature survey it is observed that researchers have made attempts to investigate alternate specimens for friction calibration. It is found that ring compression test is recommended as the standard test for determination of coefficient of friction, because it gives reliable results. There is need to search other friction of friction calibration specimens, which are in same conformity as ring compression test. Six different solid geometry specimens are tried for friction prediction using computer simulation techniques. Out of these six geometry specimens two solid geometries with centre intrude of different dimensions give the reliable results. FE simulation of these specimens has been done using MSC.MARC software.

Keywords: Ring compression test, Friction calibration curve, co-efficient of friction, Centre intrude specimens.

Introduction

Ring compression test has gained wide acceptance particularly for bulk deformation processes. In this flat ring is upset plastically between two flat patterns. As the height is reduced, the ring expands radically outwards. If friction at the interface is zero, both the inner and outer diameter of the ring expands as if it were a solid disk. With increasing friction, however the internal diameter becomes smaller. This is due to the fact that an incremental decrease in the internal diameter involves a smaller contact area (hence less friction energy) than an incremental increase of the same magnitude on the outer diameter. For a particular reduction in height, there is a critical friction value at which the internal diameter increases from the original if μ is lower and decreases if μ is higher.

By measuring the change in the specimen's internal diameter and using the curves, which are obtained through theoretical analysis, we can determine the coefficient of friction. Each ring geometry has its own specific set of curves. The most common geometry of a specimen has outer: inner diameter: height proportions of 6:3:2. The actual size of the specimen is usually not relevant in these tests. Thus we know the percentage of reduction in internal diameter and height; we can determine using the appropriate chart.

The major advantage of the ring compression test is that it does not require any force measurement and that it involves large-scale deformation of the work piece material, as in case in actual practice. This test can also be used to rate different metal working fluids.

Fig. 1

In Fig.1 different ring compression specimens are shown, Fig.2 show deformed ring specimens under low and high condition & Fig.3 shows the relationship between decrease in internal diameter &decrease in thickness of the ring specimen, with respect to friction. Using these curves, friction can be determined between platens.

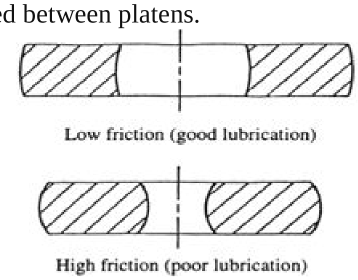


Fig. 2

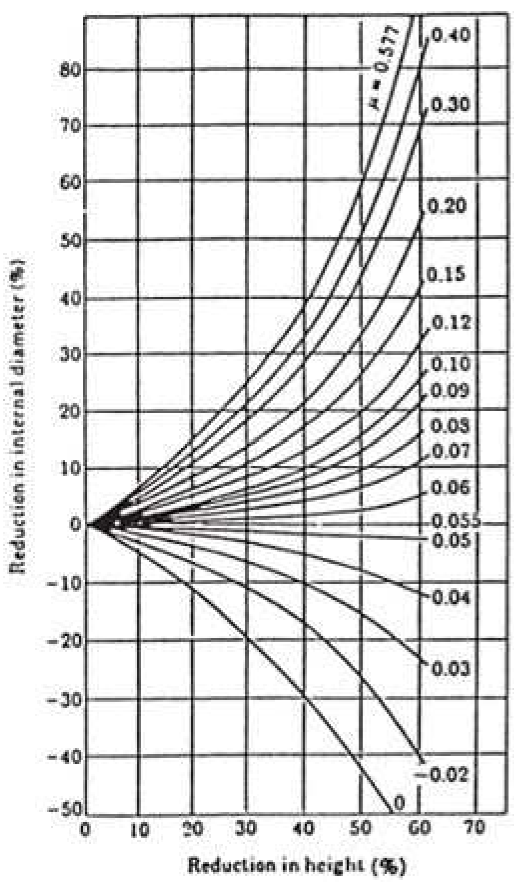


Fig. 3

This study is related to the investigation of non-conventional specimens for friction calibration curve. Following are major objectives of this thesis:

1. Selection of alternate specimens for friction calibration.
2. Finite Element simulation of upsetting using selected specimens.
3. Generation of friction calibration curve for suitable specimen.

Literature Survey

Some of the important papers related to ring compression test have been reviewed and discussed here.

Sofuoglu et al. (2001) developed an alternative method to the ring compression test in order to quantitatively evaluate the coefficient of friction, m; at the die/work piece interface. This technique relates the percentage deformation in height of the specimen to the percentage increase in extruded height of the specimen.

Hayhurst et al (2004) proposed a new technique to calibrate the model, which utilizes two test piece geometries, namely the solid cylindrical compression test piece and the ring compression test piece. In addition, a mathematical model is required of the true stress–true strain behavior of the material, so that finite deformation/finite element techniques can be used to accurately predict the compression behavior of both test pieces.

Sahin et al. (2005) proposed a new approach to investigate the effect of the surface roughness on the frictional properties for different materials and conditions. Three types of steel, commercially pure aluminum and annealed CuZn40Pb2 brass were used as the test materials in the experimental part of the study. Experimental results were placed into ring compression calibration curves for each of the material type and surface conditions.

Rudkins et al (1996) performed experimental investigation into friction under hot forming conditions using the ring compression test. The experiments show how variations in temperature at the interface affected the frictional behavior.

Sofuoglu et al. (2000) investigated the effects of material properties, strain-rate sensitivity, and barreling on the behavior of friction calibration curves. A series of ring compression tests were conducted in order to determine the magnitude of the friction coefficient, m.

Kakkeri et al (2007) analysized the metal forming processes and found that a realistic frictional condition must be specified at the die/work piece interface in order to obtain accurate metal flow. Evaluated the coefficient of friction for Al 6061 and Al 6063.

From literature survey it is observed that the present attempts are to investigate alternate specimens for friction calibration. In this study two non-conventional specimens of different solid geometries are tried for friction prediction between the platen and billet. Based on the deformation studies, correlations have been made between diameter ratios and friction in the form of friction calibration curves. Friction predictions through these curves are validated using experimental studies.

Methodology

The methodology of this numerical study of investigation of non-conventional friction specimen incorporates following steps:

1. First step is the selection geometrical and frictional parameters of non-conventional specimens.
2. FE simulation of all the specimens to study material deformation for all friction conditions.
3. Selection of specimens giving consistent deformation with respect to friction.
4. Generation of friction calibration curve for eligible specimens.

In this study six non-conventional specimens have been used for friction calibration. The nomenclatures of these specimens are given in Table 4.1. The dimensions of the specimens are shown in Fig. 4.1-4.15.

Power law, which is given by the following relationship, has been used for material modeling.

$$\sigma = k\varepsilon n$$

Following values of material parameters are (Al 2024) taken for FE simulation purpose:

1. Strength coefficient k = 690 MPa
2. Hardening Exponent n = 0.16
3. Young's modulus = 7.8x104 N/mm^2
4. Poisson's ratio, ν = 0.3

The coefficient of friction (coulomb) values are taken as 0.1, 0.15, 0.2, 0.25 and 0.3.

FE Simulation

Finite element analyses of the compression test are carried out in order to study the deformation behaviour with respect to friction. Due to symmetric condition only a quarter specimens is modeled. Four nodded quadrilateral elements are used for FE modeling. The number of elements and nodes in each model are given in Table 1. FE simulations are carried out using MSC.MARC software (Ref.11). The interaction of platen and specimen are accounted using CONTACT command, in built in the software.

[1] MSC stands for Mac Neal–Schwendler Corporation. Founded by Dr. Richard Macneal. The Marc system contains a series of integrated programs that facilitate analysis-engineering problems in the fields of structural mechanics, heat transfer, and electromagnetism. The marc system consists of the following programs:

- Marc
- Mentat

[2] Marc enables to assess the structural integrity and performance of parts undergoing large permanent deformations as a result of thermal or structural load. The types of deformations the program can study include geometric nonlinearities (metals bending) and material nonlinearities (elastomers and metals that yield under structural or thermal loading). Marc can also use to simulate deformable, part-to-part or part-to-self contact under varying conditions that include the effects of friction—critical for analyzing nonlinear behavior in tool-and-die set-up, spring coil clash, or a windshield wiper system. Mentat is the pre and post process for Marc software.

RESULTS AND DISCUSSION:

Fifteen non-conventional specimens have been taken for FE simulation. A brief summary of the deformation studies of each specimen is given below:

Sr. No.	**Nomenclature**	**No. Of Elements**	**No. Of Nodes**
1	Dumble	200	231
2	I-Section I	300	341
3	I-Section II	300	341
4	I-Section III	300	341
5	Center intrude I	800	861
6	Center intrude II	800	861

Table 1

1) Dumble: The deformed radii at various locations for different friction conditions are recorded. It can be observed, there is not much variation in deformed radii with respect to friction. Hence this specimen is not suitable for generation of friction calibration curve.

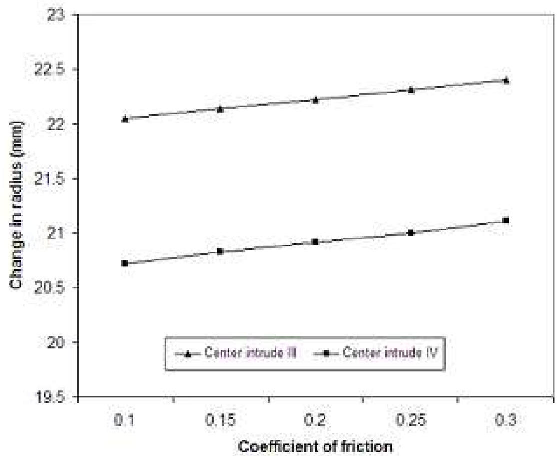
2) I-Section I: The deformed radii at various locations for different friction conditions are recorded. It can be observed, there is not much variation in deformed radii with respect to friction. Hence this specimen is not suitable for generation of friction calibration curve.

3) I-Section II: The deformed radii at various locations for different frictional conditions are recorded .It can be observed, there is not much variation in deformed radii with respect to friction. Hence this specimen is not suitable for generation of friction calibration curve.

4) I-Section III: The deformed radii at various locations for different frictional conditions are recorded. It can be observed, there is not much variation in deformed radii with respect to friction. Hence this specimen is not suitable for generation of friction calibration curve.

5) Center intrudes III: The deformed radii at various locations for different friction conditions are recorded. It can be observed, there is not much variation in deformed radii with respect to friction. A calibration curve for 5 mm reduction in height. It can be observed that calibration curve is of linear in nature as shown in fig.4.

6) Center intrudes IV: The deformed radiuses at various locations for different friction conditions are recorded. It can be observed, there is continuous increase in left end radius with respect to friction. A calibration curve for 5 mm reduction in height. It can be observed that calibration curve is of linear in nature as shown in fig.4.



Conclusion

In this study a search has been made to find alternative specimens for friction calibration using FEM. Total six non-conventional specimens were tried for this purpose. Out of these six specimens only two could undergo consistent deformation with respect to varying friction. Friction calibration curve, for these two eligible specimens are generated and found to be of linear in nature. These non standard specimens can be used as a substitute to ring compression test for friction determination. Friction calibration curves obtained using eligible specimens are found to be linear in nature. Hence, friction prediction becomes quite simple using such specimens.

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