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CALSPAN CORPORATION

Technical Note: DISCUSSION OF CONTINUED BICYCLE SYSTEM SIMULATION STUDIES - TASK 1

JUNE 6, 1975

CONTRACT CC-254: SCHWINN BICYCLE COMPANY

The work performed under Task 1, Bicycle System Simulation Studies, during the past year is described in this note. For convenience, a copy of the task description is attached. The work statement covers three items -

1) Development of a transient handling task for evaluating design parameters.

2) Development of a new subroutine to permit more efficient computation of rider physical characteristics.

3) Determination of the effects of bicycle design parameters on control using the maneuver developed in 1).

Efforts on the first item (and indirectly on the third item) are discussed in detail below. Briefly, problems associated with obtaining satisfactory values of coefficients in the rider model prevented completion of this phase of work. A method for computing the principal rider physical characteristics (moments of inertia, mass center locations, etc.) from basic inputs (weight, stature, and riding position) under item 2) has been successfully devised and was used in all studies performed in this phase of work.

Effort on Task 1 was initiated very soon after contract approval was received from Schwinn. These first efforts were applied to operating the simulation in a simple path following maneuver at a low speed (6 mph) condition. It was our intention to extrapolate the performance of the rider model from a condition of open-loop cornering at 10 mph to a condition of a precise 90 degree turn at 6 mph. Thus, rider model coefficients which has been proven to be quite satisfactory for maintaining roll stability in unrestricted cornering (see Figure 1) were evaluated in the path following mode.

The effort went through four phases -

1. A series of five runs aimed at selecting suitable rider coefficients for stabilized open-loop cornering

(at a command roll angle of approximately 20 degrees) at 6 mph. These culminated in a run which implied reasonable system stability characteristics. (Figure 2).

2. On the basis of these results, a series of about 20 runs were made in an effort to establish satisfactory rider guidance model coefficients. Although a wide range of values for many of these coefficients were examined, no single set could be demonstrated to be appropriate (i.e., stable and well-damped) and small-error responses were not achieved in this mode of operation. See Figure 3.

3. We then returned to investigating performance in the open-loop mode in an effort to establish better values for the stabilization coefficients in combined lean/steer torque control. Some 12 runs were made at this condition for various combinations of these coefficients. No substantial improvement was achieved (Figure 4), and a decision was made to halt work on this effort until a better approach could be devised.

4. Some three months later, a few additional runs were performed after modification of the rider physical model but the results were again negative (i.e., no improvement in path-following was achieved). See Figure 5.

Thus, we have not slighted this task but extremely knotty problems with the rider model have prevented us from making significant progress. We now believe that their solution lies in extending the simplified analyses (developed as part of Task 2) to transient motion conditions and utilizing the resulting expressions in closed loop (i.e., rider-bicycle) analyses to provide a firm basis for selecting rider model coefficients. Then we can return to the simulation to perform design parameter significance studies.

To summarize our work on Task 1, we have decided on an appropriate maneuver for use in the evaluation and we have improved the method for computing rider physical characteristics (Subtasks 1 and 2). We were unable to perform what we considered to be valid parameter evaluation runs (Subtask 3) and elected to stop work on this effort rather than waste funds. In turn, the remaining funds were allocated to supporting efforts on reviewing the proposed ISO bicycle standards, analysis of effects of adding reflectors to the wheels, additional frame stiffness tests, and advancing techniques for performing tire tests. A preliminary evaluation of adult three-wheelers was also initiated but no contract charges were applied to this effort.

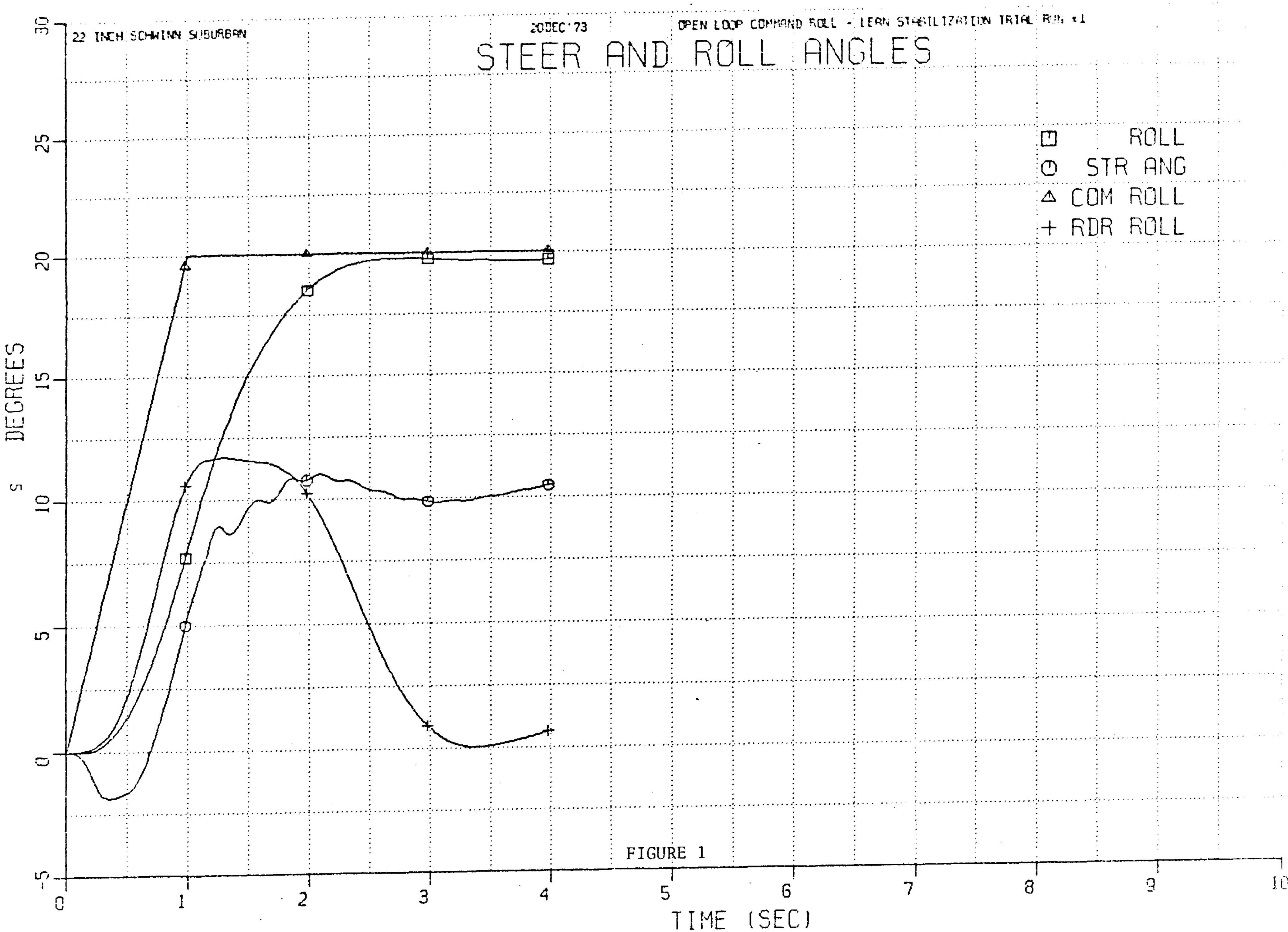

22 INCH SCHWINN SUBURBAN
20DEC'73
OPEN LOOP COMMAND ROLL - LEAN STABILIZATION TRIAL RUN
STEER AND ROLL ANGLES
ROLL
STR ANG
COM ROLL
RDR ROLL
DEGREES
TIME (SEC)
-5
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
8
9
10

FIGURE 1

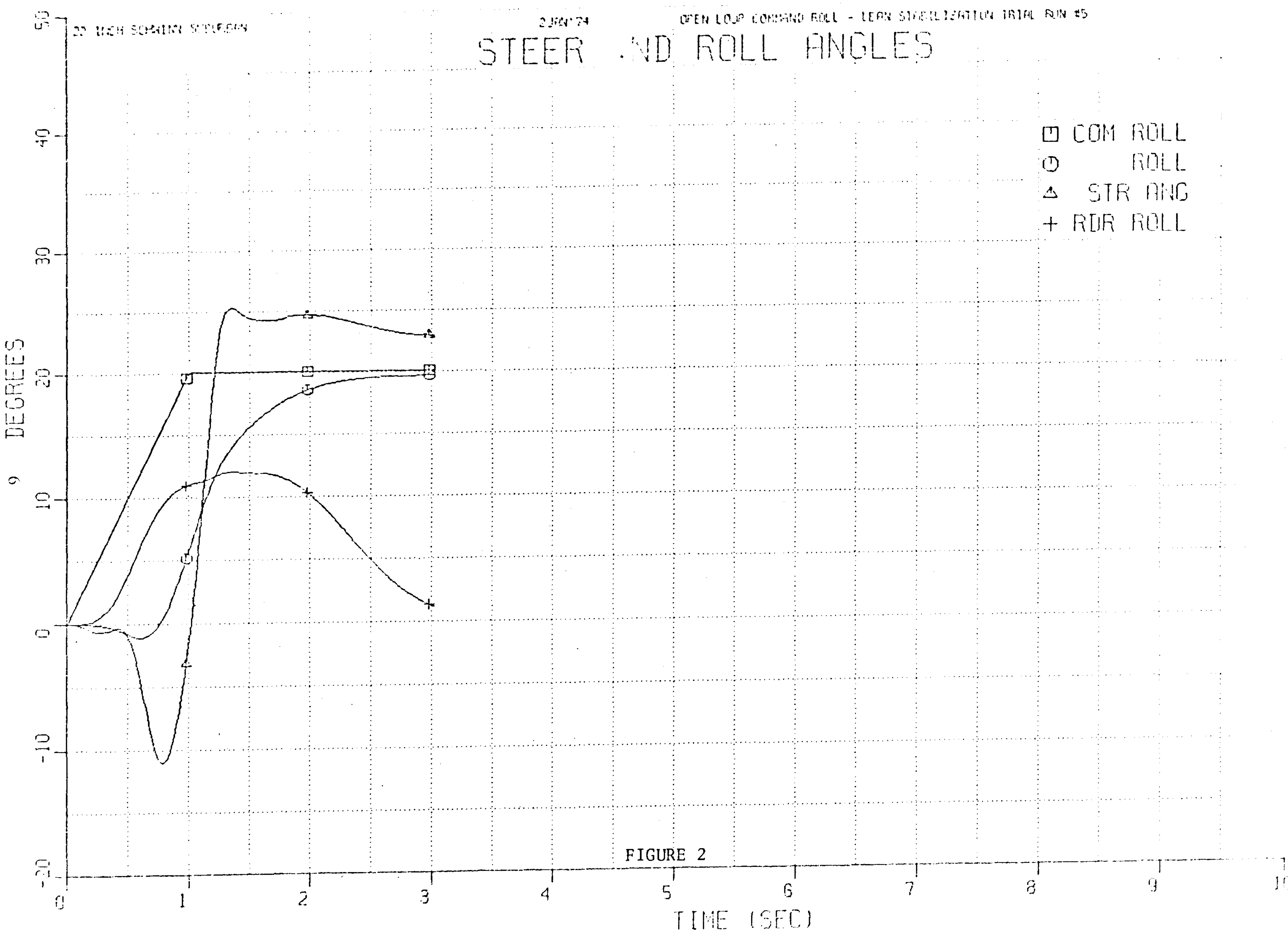
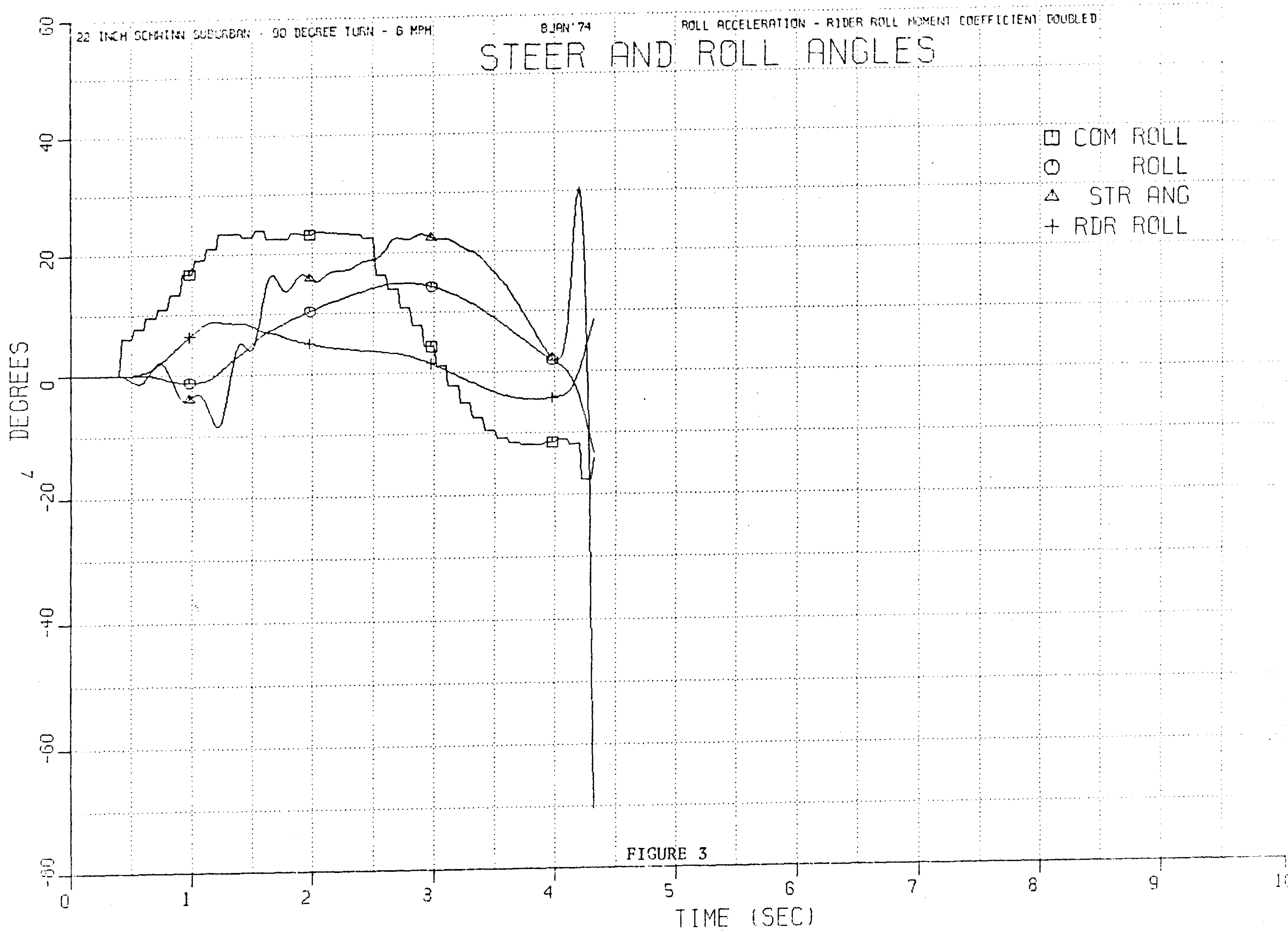

2 JAN 74
OPEN LOOP COMMAND ROLL - LEAN STABILIZATION TRIAL RUN #5
STEER .ND ROLL ANGLES
COM ROLL
ROLL
STR ANG
RDR ROLL
DEGREES
TIME (SEC)
50
40
30
20
10
0
-10
-20
0
1
2
3
4
5
6
7
8
9
10

FIGURE 2



22 INCH SCHWINN SUBURBAN - 90 DEGREE TURN - 6 MPH
8JAN'74
ROLL ACCELERATION - RIDER ROLL MOMENT COEFFICIENT DOUBLED
STEER AND ROLL ANGLES
COM ROLL
ROLL
STR ANG
RDR ROLL
DEGREES
TIME (SEC)
60
40
20
0
-20
-40
-60
-80
0
1
2
3
4
5
6
7
8
9
10

FIGURE 3

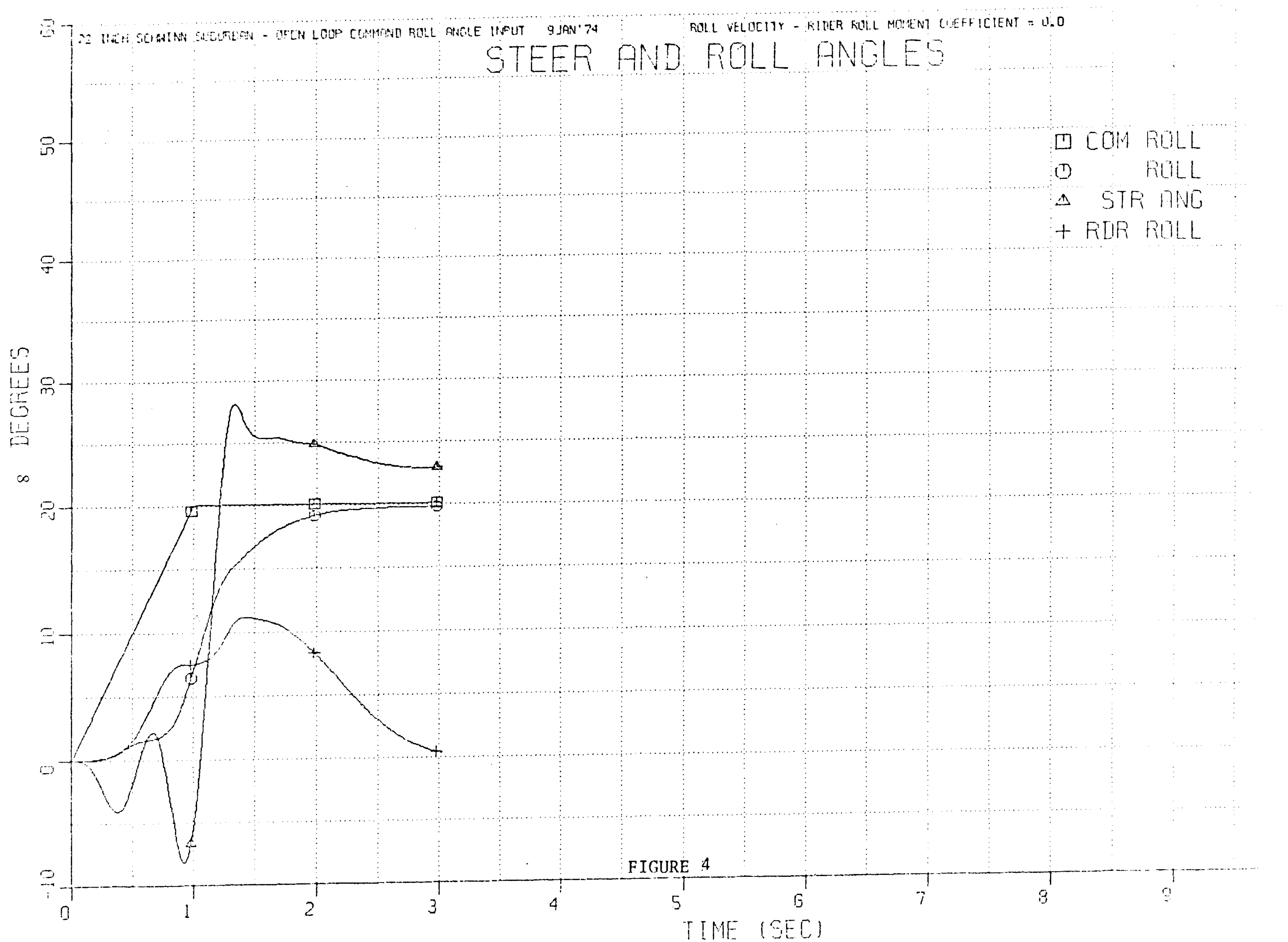

22 INCH SCHWINN SUBURBAN - OPEN LOOP COMMAND ROLL ANGLE INPUT 9JAN'74
ROLL VELOCITY - RIDER ROLL MOMENT COEFFICIENT = 0.0
STEER AND ROLL ANGLES
COM ROLL
ROLL
STR ANG
RDR ROLL
DEGREES
TIME (SEC)
-10
0
10
20
30
40
50
60
0
1
2
3
4
5
6
7
8
9

FIGURE 4


22 INCH SCHWINN SUBURBAN - 90 DEGREE TURN - 6 MPH
30APR'74
SAME COEFFICIENTS AS RUN NUMBER 15 (WITH NEW RIDER MODEL)
STEER AND RØLL ANGLES
COM ROLL
ROLL
STR ANG
RDR ROLL
DEGREES
250
200
150
100
50
0
-50
-100
0
1
2
3
4
5
6
7
8
9
10
TIME (SEC)

FIGURE 5

BICYCLE SYSTEM SIMULATION STUDIES
TASK NUMBER 1

DISCUSSION:

The bicycle simulation has been recently applied to the evaluation of the new Sprint design where it was demonstrated to be a useful tool (in conjunction with other techniques) for comparing new design concepts with proven configurations. Its continuing application for such purposes (for example, to the new LeTour design) can be enhanced by refinements and extensions to the computer program. Therefore, we have recommended further work (as represented by subtasks a and b) which is aimed at improving the simulation in its treatment of the important controllability aspect of performance. But, in a broader sense, the purpose of this task is the development of a rank ordering of the effects of various bicycle design parameters on stability and control characteristics. In this way, it should become possible to identify interactions of design and operational variables over the whole performance range of the bicycle.

WORK STATEMENT:

Continuing studies aimed at the exercise and further improvement of the bicycle-rider simulation previously developed will be performed. The subtasks to be accomplished on this effort will include -

a. Development of a simulated transient handling task (tentatively, a path-following exercise through a ninety degree turn) to be used in conjunction with the disturbance response task previously developed for evaluating bicycle design parameters. Checkout and validation of the procedure.

b. Improvement and refinement of the simulation computer program to increase its utility and operational efficiency by development of a subroutine requiring only rider weight, stature, and riding position as input. Collect essential data and devise subroutine.

c. Determination of relative quantitative effects of the more significant bicycle design parameters on stability and control. Develop rank ordering of these effects on the basis of response runs.

A letter report covering all aspects of the work will be prepared.

PERIOD OF PERFORMANCE:

Six months